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Forest Rehabilitation under Current Landuse Conditions in Northern Shaanxi, P.R. China
Ecological and Socioeconomic Perspectives

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The wonderful loess lands, which cover much of Kansu, Shensi, Ninghsia, and Shansi provinces, account for the marvelous fertility of these regions (when there is rainfall), for the loess furnishes an inexhaustible porous topsoil tens of feet deep. Geologists think the loess is organic matter blown down in centuries past from Mongolia and from the west by the great winds that rise in Central Asia. Scenically the result is an infinite variety of queer, embattled shapes—hills like great castles, like rows of mammoth, nicely rounded scones, like ranges torn by some giant hand, leaving behind the imprint of angry fingers. Fantastic, incredible, and sometimes frightening shapes, a world configurated by a mad god—and sometimes a world also of strange surrealist beauty.

—Edgar Snow*, Red Star Over China*

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This study is dedicated to the farmers in Yan'an.

Freising, 2003

1. Introduction and Research Objectives

Restoration of natural vegetation has long been recognized as an important option for reducing soil erosion and preventing further land degradation on the *Central China Loess Plateau* (WU et al., 1995; YU et al., 2002). Recently, the Chinese Government has called for increased efforts to improve the ecological environment in China's northwestern regions (including the *Loess Plateau*) and to integrate reforestation measures into the overall strategies of poverty reduction and sustainable economic development (LIU & LU, 1999). Detailed proposals for rapid implementation of plantings have been made for all provinces of Western China including Shaanxi Province (CAE, 2002). However, in many cases, reforestation programs have only insufficiently considered underlying environmental site-conditions and disproportionately focused on mono-species plantations and the introduction of exotic (non-native) species—both possibly limiting the effectiveness and potential benefits of ecological landscape rehabilitation.

In order to address general issues associated with the selection of species and sites for forest rehabilitation in an environmentally and ecologically appropriate way, the overall goal of this study is to develop an outline of naturally adapted forest communities for *Yan'an Prefecture* in *Shaanxi Province*. The outline includes an overview of major native tree and shrub species, a perspective on the floristic-sociological relationships between species and communities, and a description of their relative positioning in the ecological space along environmental gradients. It is focused on a specific area in the center of the *Loess Plateau* and designed to elaborate on a better understanding of ecological conditions that provide the basis for restoration activities and forest rehabilitation.

This study follows a pragmatic approach and focuses on deriving a flexible guide to natural vegetation rehabilitation. It is based on the belief that dynamics and structures of vegetation are the results of habitat conditions in the first place and—at least temporarily—can be captured and described syn-taxonomically in the form of distinct plant communities. These communities are interpreted as a blueprint for vegetation restoration. However, the study also recognizes that vegetation is a continuous phenomenon. Its classification is arbitrary as ecological conditions, disturbance history, current land management practices and other factors are all important in determining its distribution and development but are also changing over time.

The proposed results, i.e. *secondary naturally adapted plant communities*, are thus provisional in the sense that they will change as underlying conditions change. Therefore, they might also be interpreted as a baseline against which vegetation changes in response to environmental changes can be monitored in the future.

Specifically, this study aims at:

(1) Documenting the floristic composition of today's secondary natural forest and degraded secondary grassland communities in selected sites;
(2) Relating floristic differences within secondary natural forests as well as degraded secondary grasslandes to prevailing site conditions and environmental gradients;
(3) Analyzing the ecological suitability of today's degraded areas for forest vegetation under current climate conditions over the respective area.

In a separate analytical step, this study is also concerned with the present socioeconomic conditions and landuse trends of the rural population in Yan'an region. These conditions provide the framework in which vegetation rehabilitation takes place and determine the potential interaction between local people and the environment. By approaching the socioeconomic situation from a primarily observational perspective, the study describes current landuse and economic conditions across different sub-regions. It raises some of the potential implications of current landuse developments and aims to arrive at a realistic judgement of the integration of economic and ecological development options in this region.

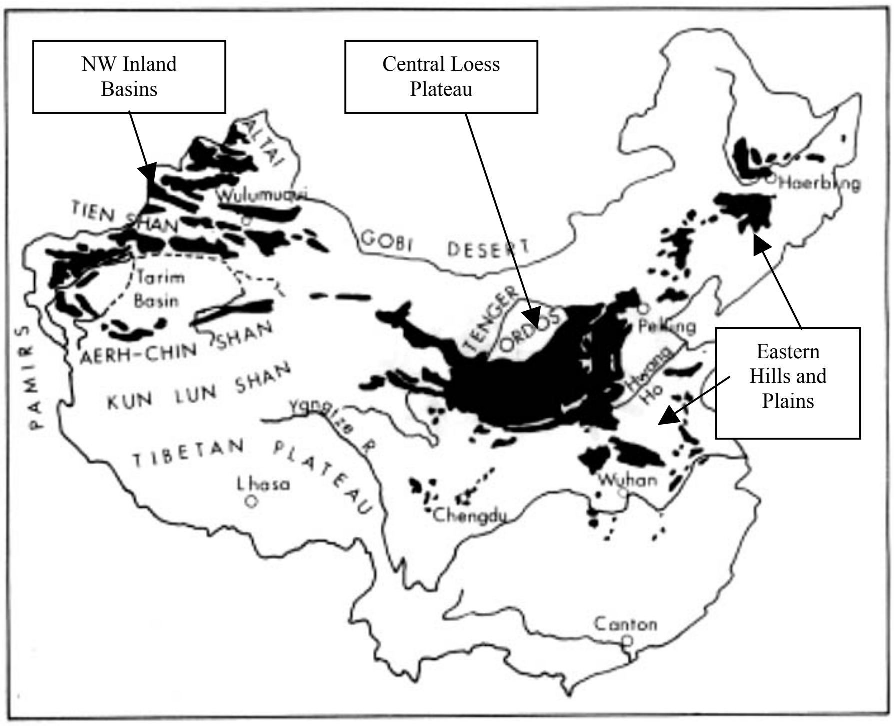
This thesis is structured as follows: Chapter 2 provides a broad overview of the *Central Loess Plateau* in which the research project was implemented. The overview includes a description of the location, geological, climate and vegetation characteristics of this macro-region that historically has been one of the most prominent cultural and economic centers of China. Chapter 3 briefly surveys recent environmental and ecological research in the *Loess Plateau* and summarizes current research findings as they are relevant to this study. Chapter 4 introduces *Shaanxi Province* and *Yan'an Prefecture*, the administrative framework of the project, and their characteristic landscape types. Chapter 5 includes the research approaches of the ecological and socioeconomic analyses. Chapters 6 and 7 present and discuss overall research results of the ecological and socioeconomic analyses, respectively. Chapter 8, finally, concludes with a critical discussion of the relevance of the research findings and possible implications for large-scale ecological rehabilitation.

2. The Central China Loess Plateau

2.1 Geographical Location

Loess in China is widespread and—depending on different concepts and definitions of loess and loess-like depositions in various studies—covers an area of 273 000 to 630 000 sq. kilometers (LIU, 1985, PÉCSI & RICHTER, 1996; ZOU et al., 1997; CHENG & WAN, 2002). In this study, we adopt the classification presented by LIU (1985), which divides loess deposition areas in China into three sub-regions, namely, the *Northwestern Inland Basins* (Xinjiang, Qinghai, Gansu), the *Central Loess Plateau* (middle reaches of the Yellow River basin), and the *Eastern Hills and Plains* (North China Plain) (fig 2-1).

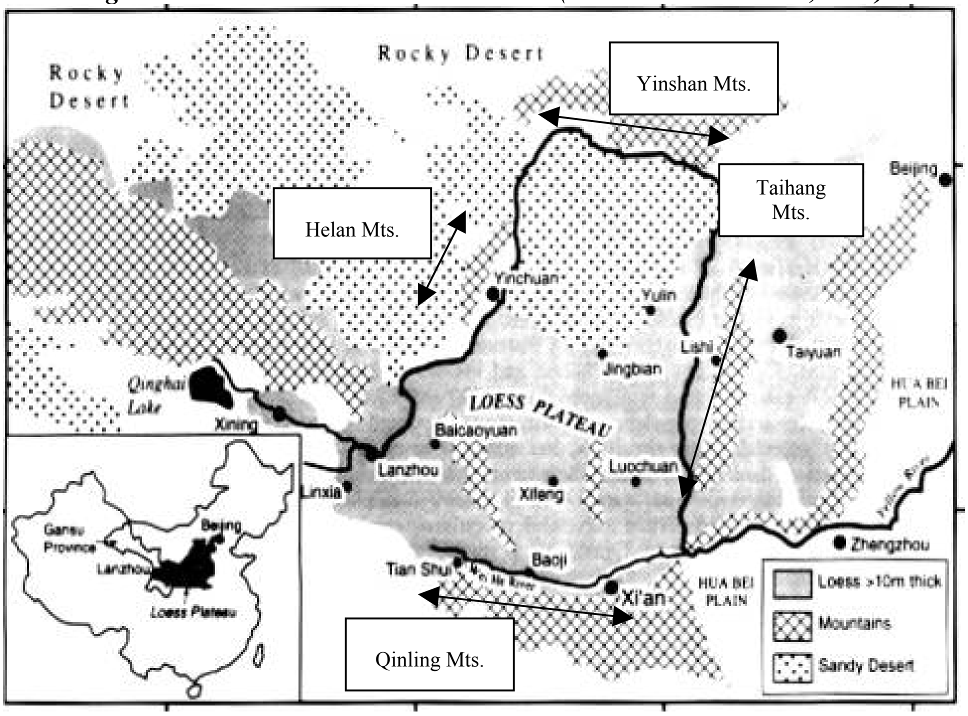
Fig. 2-1: Regions of Loess Distribution in China (SMALLEY, 1975)



Of these sub-regions, the *Loess Plateau* comprises the world's largest continuous deposits of wind-blown loess and represents about 70% of the total loess area of China. It extends over an area of roughly 300 000 sq. kilometers from 33°43' to 41°16' northern latitude to 100°54' to 114°33' eastern longitude. It is surrounded by the *Helan Mountains* in the west, the *Yinshan Mountains* in the north, the *Taihang Mountains* in the west, and the *Qinling Mountains* in the south (fig. 2-2). Administratively, the *Loess Plateau* includes parts of *Qinghai, Gansu, Shaanxi, Shanxi*, and *Henan* provinces as well as the *Autonomous Regions of Inner Mongolia* and *Ningxia*. Its largest extension from south to north is about 600 kilometers, and from west to east about 1500 kilometers.

The *Loess Plateau* is located between China's coastal regions in the east and the continental high mountain areas of the *Qinghai-Tibet Plateau* and describes the middle section of the country's overall three-step topography. Average elevation in the plateau ranges from 1000 meters in the eastern and southeastern parts to 2000 meters in the west and northwest. The lowlands and plains of the southern end of the plateau are at about 400 meters.

Fig. 2-2: The Central China Loess Plateau (Meng & Derbyshire, 1998)



Loess layers over the *Loess Plateau* gradually thin out from southeast to northwest. There are manifold small-scale variations in composition and thickness of loess layers as determined by topography, deposition patterns and history. Because of the prevailing atmospheric dynamic—mostly winds from northern, northwestern, and western directions—thickest loess layers are often found on western slopes of the major mountain ranges embedded in the plateau, while on eastern slopes loess layers are often less pronounced.

The rocky parts of the major mountain ranges such as *Liupan, Lüliang, Zhongtiao*, and *Huanglong Mountains* penetrate the loess layers in many locations. Especially in western *Shanxi*, northern *Shaanxi*, and central *Gansu*, loess layers can reach up to 150 to 250 meters height. Together with the regional climatic, geological, and geo-morphological conditions, the *Loess Plateau* represents a complex natural macro-region with several ecologically distinct subregions and characteristic landscape types.

2.2 Geological Characteristics

2.2.1 Sources and Formation Process of Loess

Loess (chin.: *huang tu* - yellow earth) is the source material of soil development, dominates the landscape, shapes the natural vegetation development as well as determines landuse and agricultural development. From historic times until today, loess has been closely related to the cultural and economic development of China (Liu, 1985).

Loess is composed of mainly silt-sized particles (2 to 63 μm) and carbonate-enriched. Silt-sized particles predominantly include quartz, feldspar, and mica, which together make up 80 to 90% of the mineral composition. Besides, there are a number of other minerals, such as vermiculite, montmorillonite, kaolinite, augite, and epidote, which determine the generally favorable soil nutrient properties of loessial soils. Loess is an excellent substratum for plants and well suited for agriculture.

For loess deposition areas in China, the main source of silt-sized quartz and other clastic materials are Cenozoic and Mesozoic detrital sediments of the large desert areas (about 1.5 million sq. kilometers) of western China. Here, weathering processes such as huge variations in daily and annual temperatures—particularly under the influence of soluble salts (Na_2SO_4)—produce fine particles from coarse quartz grains (LIU, 1985).[1] Carbonate, the second characteristic component, mainly originates from the source areas together with silicates often in form of proto-calcite (silt-sized calcite) (PÉCSI & RICHTER, 1996).

The formation of huge loess layers in the *Yellow River Basin* is due to the characteristic atmospheric dynamics in the central-northern part of the *East-Asian* sub-continent. Continued transportation of silt-sized materials from western desert areas and accumulation in the middle reaches of the *Yellow River* are mainly driven by strong winds from the *Siberian-Mongolian* plains prevailing during the winter half-year. Deposition and accumulation of silt continue until today (ZOU et al., 1997).

Following the sedimentation of the dust, rainwater begins to dilute the upper layers of the undisturbed silt sediments. Calcite ($CaCO_3$) is then partly hydrolytically solved and transported downward until leakage water evaporates or is used up by plants. With the disappearance of soil water, carbonate is formed again coating silt particles to a coherent but porous structure, a process known as *secondary carbonization (loessification)*.

Only after the solution of the original carbonate, its downward transportation as well as the emergence of secondary carbonate [$Ca^{2+} + 2HCO^{-}_3 \Leftrightarrow CaCO_3$ (solid) $+ H_2O + CO_2$], the originally deposited silt is transformed into loess. Secondary carbonization, thus, is closely related to semi-arid and arid conditions and low biological activity, which prevent a complete dissolution and wash-out of carbonate and foster the secondary cohesion of quartz particles and other minerals.

2.2.2 General Properties of Loess

Loess is of light gray, yellow, light brown or red color depending on mineral composition and organic content. In general, loess is characterized by a high content of silt (~ 50 to more than 60%), a low content of sand (~ 2%), and a varying clay content (~15 to 25%). Loessial soils are of silty to silty-loamy texture. Carbonate makes up 8 to 16%, while oxides of silicon, aluminum, and iron can amount up to 50 to 60%, 7 to 15%, and 2 to 6%, respectively. Average pH-values range between 6.2 to 8.6.

Although loess contains more than 60 different minerals, the overall mineral composition of loess layers formed in different geological times are quite similar indicating that deposited silt and resulting loess layers originate from the same geological source. Similarly, no significant differences in chemical features exist for the different types of loess deposits over the *Loess Plateau* (ZOU et al., 1997).

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[1] In contrast, glacial grinding during glacial periods is seen as the main mechanism for producing large amounts of silt-sized quartz grains in Central Europe.

Because of their light and porous structure, loessial soils are of good water permeability, are well ventilated, and can easily be penetrated by roots. While vertical water permeability is excellent (up to 40 meters deep), horizontal permeability of loess is limited—a fact that has important consequences in planning of erosion protection measures and irrigation systems. During dry periods, upper strata of loessial soils often dry up.

Because of the comparatively strong cohesion of silt particles through secondary carbonate, undisturbed loess is of rock-like solidity; and vertical loess walls are very stable. However, the carbonate cohesion is easily broken through mechanical disturbances, e.g. cultivation and terracing; and loessial soils become prone to erosion, especially on steep slopes and under climate conditions with intense rainfall events. Furthermore, when loessial soils are wetted, lime concretions often move downward in the strata slowly forming holes and vertical cleavages that trigger increased erosion as such holes serve as erosion gullies for rainwater and runoff (ZOU et al., 1997).

2.2.3 Loess Deposition History

Silt deposition rates varied with climate conditions over geological periods. Periods of intensive deposition during cold and arid periods alternated with periods of lower deposition rates during warm and humid climate where silt layers were gradually de-carbonated and transformed into loamy brown soils. Also, during humid climate conditions, rich vegetation cover developed and led to the accumulation of organic material in the upper soil strata. Magnetostratigraphic studies document several layers of paleosols (fossil soils of loess origin), which are related to historic changes in overall climate conditions, loess deposition rates, as well as vegetation and soil development. Vegetation composition is well documented by pollen analysis for warm and humid as well as cold and dry periods (LIU, 1985, ZOU et al., 1997). Today, paleosols and organic layers are often visible at construction sites where the different loess layers and soil strata are exposed.

Silt (loess) deposits on the Loess Plateau are divided into 4 major types:

1. *Wucheng Loess/Red Clay*: begin of silt (loess) deposition during the early Pleistocene when—at the beginning of the Quaternary (approx. 2.0 million years ago)—climate conditions deteriorated from warm-humid to dry cold periods;
2. *Lishi Loess*: silt depositions during the Medio-Pleistocene;
3. *Malan Loess*: silt deposition during the late Pleistocene;
4. *Holocene Loess*: silt deposition during the Holocene (10 000 years to today).

Malan and Holocene Loess form the most recent loess layers and are often summarized as *New Loss* because of their similar mineral composition, structures and colors. *New Loess* reaches up to 50 meters depth in Gansu province; in Shaanxi province, about 20 meters in Yan'an area and 15 meters in Luochuan county (ZOU et al., 1997).

2.2.4 New Loess and Agricultural Production

New Loess is of great importance for agricultural development and forestry. It is of light gray or yellow color and homogenous texture, and develops into loamy-silty soils with a high volume of pores and vertical cleavages. *New Loess* is rich in carbonate but upper layers are generally without accumulations of lime concretions.

However, lower strata with intensive concretion building are often transformed into solid rock-like horizons. In these layers, carbonate content can make up to 40% of the mineral composition. Under long-term intensive cultivation and with continued erosion of upper loess layers, such rock-like strata often appear at the surface where agricultural productivity then is significantly reduced.

In terms of particle composition of *New Loess*, there is clear north-south trend with a higher proportion of sandy particles in the northern areas and silty particles in the southern areas of the plateau. Fertile loessial soils with large proportions of clay are mostly distributed in valleys and lowlands plains, where soil development continued undisturbed over long periods or where secondary fluvial loess accumulation and sedimentation took place, e.g. *Wei River Plain*. Particle composition in different sub-regions, thus, are often taken into consideration, when soil and water conservation measures are planned. For example, terrace banks in northern sandy areas need to be lower and with less steep slopes than in southern areas where there is a higher clay content in the soil strata that more effectively stabilizes terraces (LIU, 1985).

Organic content of *New Loess*, in general, is low (0.3 to 2%) but also follows a regional trend with higher content in southern areas of warm-humid climate than in northern cold-dry areas. Reserves of potassium and phosphorus are comparatively large but are often not easily available for plant use because of the alkaline conditions. Nitrogen, in general, is sufficiently available whereas some trace element such as Zinc, Manganese, Copper, Boron, Molybdenum and partly Iron are of limited availability. *Northern Shaanxi*, for example, exhibits high rates of *Keshan Disease* because of low Copper and Zinc contents in local drinking water (LIU, 1985). For *Yan'an*, Selenium shortage is documented, which results in frequent occurrences of deficiency diseases among the population (ANONYMOUS, 2000a).

2.3 Climate

2.3.1 General Conditions

The *Loess Plateau* is part of a transition zone between the *Southeast-Asian* monsoon climate and the *Siberian-Mongolian* continental climate, which are characteristic climate patterns of most parts of northern and northwestern China. Distinct features of the regional climate are warm and rainy periods during the summer months from June to September; and cold, windy and dry periods during the wintertime. Especially in the western border regions of the *Loess Plateau* in *Gansu* and *Qinhgai*, the high mountains of the *Tibet-Qinghai Plateau* with an average elevation of about 4000 meters are an additional element influencing the regional climate. The mountains act as a topographic barrier for the southern and southeastern winds and foster increased precipitation at the eastern foothills of the *Tibet-Qinghai Plateau*.

Spring and autumn are short transition periods. In spring, temperatures rise quickly but frequently sudden cold spells have negative impacts on plant development and agricultural production. Autumn is characterized by rapidly decreasing temperatures that mark a sharp end of the vegetation period. In general, the regional climate is shaped by large variations in daily and annual temperatures (ZOU et al., 1997; CHENG & WAN, 2002).

2.3.2 Temperature

The regional climate of the *Loess Plateau* exhibits a clear distinction between cold winter and hot summer seasons.

Temperatures reach a maximum in July in nearly all areas (mean temperature in July > 22°C) whereas temperatures are the lowest in January (mean temperature in January < 0°C). The fertile and intensively cultivated basins of the lower reaches of the *Fen* and *Wei Rivers* constitute high temperature areas with mean annual temperatures (MAT) of 13°C and 16°C, respectively. For areas outside these two major agricultural centers, MAT of 7.2 to 11.8°C are recorded depending on specific location and elevation. In general, lower MAT are found in the central and northern parts of the plateau and in mountain areas at higher elevation. (fig. 2-3).

Variations in average temperature per month are more pronounced in northern and western parts of the plateau than in the southern and eastern parts. Depending on the geographic location, these variations can amount to 26 to 36 K between the coldest and warmest month. In northwest *Shanxi* and north *Shaanxi*, variations in average temperatures per month exceed 30 K. The daily temperature range varies from 10 to 16 K in the south of the plateau to 15 to 25 K in the north and northwest. Greatest variations in daily temperatures occur in spring (CAS, 1995; Zou et al., 1997).

Fig. 2-3: Iso-Thermals-Central Loess Plateau (Cheng & Wan, 2002)

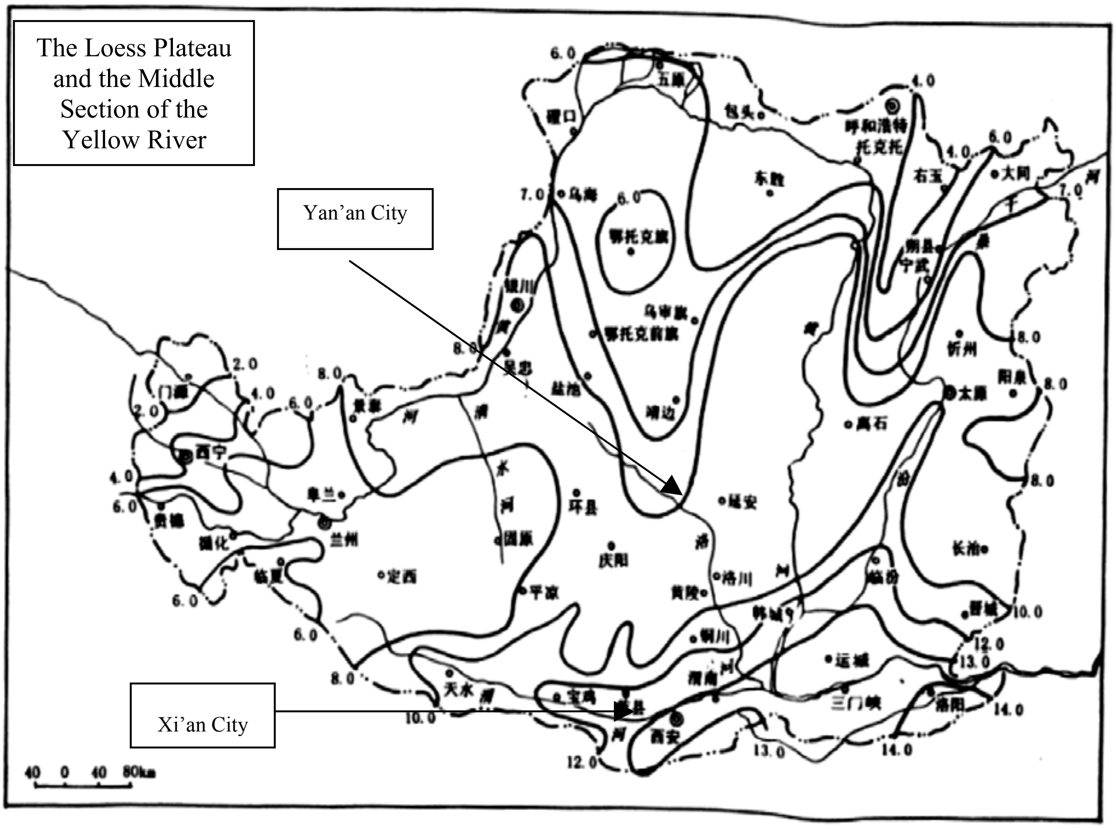

图1-3 黄土高原地区年平均气温分布图

Tab. 2-1 illustrates the regional temperature gradient over the *Loess Plateau* as measured at different climate stations (locations arranged in south-north direction).

Tab. 2-1: Mean Annual Temperature in the Central Loess Plateau

Province	Shaanxi	Gansu	Shaanxi	Ningxia	Shanxi	Shanxi
Location	Xi'an	Tianshui	Yan'an	Wuzhong	Taiyuan	Datong
MAT (^{o}C)	13.3	11.8	9.3	> 10	9.3	7.2
Elevation (m)	200	1000	900	1000	500	500

(Source: Shaanxi Provincial Climate Map, 1985)

2.3.3 Vegetation Period

In general, vegetation and agricultural production periods are shorter in the *Loess Plateau* than in other agricultural areas of China. Compared to the *North China Plain*, which comprises another major agricultural region of China, average temperatures in the *Loess Plateau* are 4 to 10 K lower in January and about 3 K lower in July. The temperature range between the coldest and warmest month is 2 to 4 K larger in the *Loess Plateau* indicating more extreme climate conditions and less favorable conditions for agriculture.

Average day temperatures increase to above 0°C around March. In the south of the *Loess Plateau*, i.e. *Wei River Plain*, average day temperatures permanently exceed 0°C already around early February while in the north, day temperatures exceed this point permanently as late as mid April. In autumn, day temperatures decrease to below 0°C as early as October in the north and around late December in the south. The vegetation period with average day temperatures exceeding 5°C starts in the south of the plateau around early March (southern areas) to early April (northern areas). The vegetation period—depending on geographical location—ends around late October to mid November.

The time period when average day temperatures exceed 10°C is defined as active vegetation period or period of agricultural productivity. Agricultural production begins around end of March in the southern areas and around early to mid May in the northern parts of the *Loess Plateau*. The length of the frost-free period in the plateau amounts to about 150 days, with the longest frost-free period recorded in the *Wei River Plain* and the shortest in the mountainous areas of the north of the plateau.

2.3.4 Precipitation and Evaporation

Annual precipitation in the *Loess Plateau* is comparatively low and unevenly distributed over the region. It also displays strong seasonal patterns with warm-humid periods during the summer months (July to September), cold and dry periods during the winter (November to February), and drought periods during springtime. An additional characteristic feature are large fluctuations in rainfall from year to year.

On average, annual precipitation varies between 250 to 600 mm. Similarly to temperature, a distinct precipitation gradient exists from southeast to northwest of the plateau. With annual precipitation rates of more than 650 mm in the southeast as well as about 600 mm in areas around *Xi'an* and *Luochuan*, these places experience rather high precipitation rates, while toward northern and northwestern areas, annual rainfall decreases significantly (fig. 2-4).

For example, *Yan'an* in the central-north of *Shaanxi* receives about 550 mm; *Yulin* in the north of the province about 440 mm; and in *Yinchuan (Ningxia Autonomous Region*) at the northwestern border of the plateau, annual precipitation is less than 300 mm (LIN, 1986). In addition, rainfall distribution shows a general vertical trend with mountain areas receiving higher precipitation than lowlands and plateaus (ZOU et al., 1997).

The strong seasonal patterns of the precipitation regime are determined by the changing air circulation dynamics between the summer and winter months. Many areas of the plateau receive only 5 to 10% of annual rainfall during the winter months due to the then prevailing Siberian-Mongolian high air pressure weather conditions.

Spring (from late March to May) is, in general, the driest period of the year. However, in early May, with increasing influence of the *South-East Asian* summer monsoon, precipitation begins to slightly increase in the plateau. Beginning around end of June, finally, significant rainfall occurs throughout the region. July, August, and September with a maximum in precipitation amounting up to 60% or more of the total annual rainfall can be characterized as the typical rainy season of the plateau.

Fig. 2-4: Iso-Hyetes-Central Loess Plateau (CHENG & WAN, 2002)

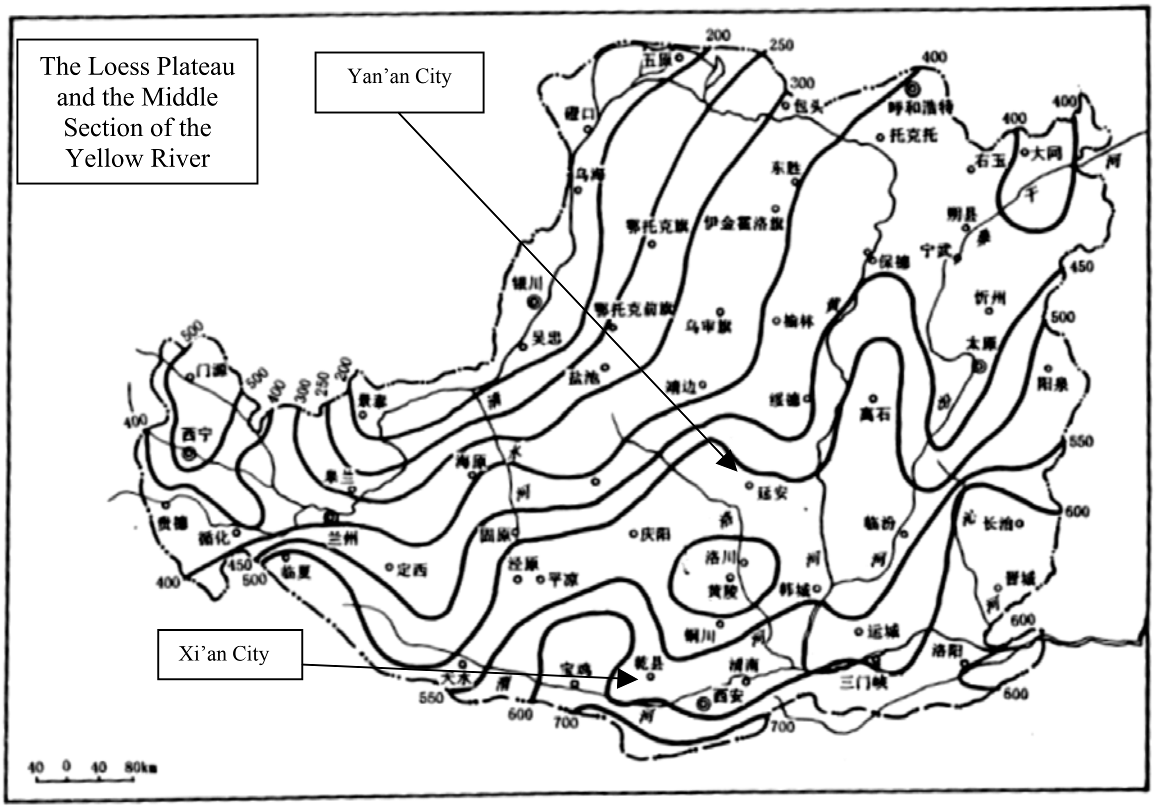

图 1-4 黄土高原地区平均降水量分布图

Individual rainfall events are often characterized by their high intensity and often result in flooding, land slides, and damage of agricultural crops. Such rainstorms are often followed by long periods without any precipitation. In most areas of the *Loess Plateau*, the total annual rainfall occurs on less than 100 days while continuous period with no rain can last up to 50 to 100 days (WANG & LIU, 1993; CHENG & WAN, 2002).

Fluctuations in rainfall between two different years are often very large. Since rainfall on the *Loess Plateau* mainly originates from water-loaded monsoonal air masses transported to the inner parts of the continent, variations in the monsoonal dynamics cause annual precipitation patterns to fluctuate significantly. Between a wet year and a dry year, the difference in total rainfall can be as big as 2 to 5 times.

Annual relative variations in rainfall is about 20 to 30%, with the largest variation occurring during spring. The instability of precipitation during April to June is often larger than that during July to September. In *Yan'an* and *Yulin*, for example, total precipitation in the first six months of every third year is 25% less than the long-term annual average (ZOU et al., 1997).

Evaporation on the *Loess Plateau* tends to follow an opposite trend than precipitation with potential evaporation in the central, northern and western parts of the plateau being significantly higher than in the south of the plateau. Most parts of northern *Shaanxi*, for example, have an estimated potential evaporation of 1400 to 2000 mm. In terms of annual variation in evaporation, the smallest evaporation rates occur in winter, while the largest evaporation occurs in late spring and early summer. This is because during this time, skies are still clear with relatively high wind speeds, while day temperatures are already increasing. Although day temperatures are even higher in July and August, evaporation declines because the weather is cloudy, rainy and of relative high atmospheric humidity.

The ratio between annual rainfall and potential evaporation is an important indicator to reflect the climatic nature of a particular area. Temperature, solar radiation, air moisture as well as soil surface conditions are the major factors to influence evaporation rates. Aridity as measured by the Penman Index based on overall water and heat conditions differs between 1.5 to 4.0 over the *Loess Plateau*, indicating a south north-directed gradient from moist (humid) to dry (arid). Based on this ratio, most parts of the plateau of Shaanxi can be classified as semi-humid to semi-arid (tab. 2-2). Arid parts can only be found in the far north of the province.

2.3.5 Other Climatic Features

The *Loess Plateau* is one of the wind and sand-storm-stricken areas of China. Seasonally, highest wind speeds occur in spring while lowest wind speeds are recorded for late summer and autumn. During the winter months, mostly cold winds from the north and northwest prevail, while in summer warm and humid winds from the south and southeast influence most areas of the *Loess Plateau*. During spring and autumn, wind circulation is largely reduced and shows no obvious trend or direction. Wind events are, in general, also influenced and transformed by location and landform.

2.4 Vegetation Zones and Species Distribution

2.4.1 General Observations

A clear horizontal sequence of vegetation zones over the *Loess Plateau* emerges from these climatic characteristics. The Chinese literature, although with small differences in determining individual borders and transition areas, distinguishes between five different horizontal vegetation zones. These zones are arranged in southeast-northwest direction (SONG, 1983; HOU, 1986; CAS, 1995; CHEN,1992, CHEN et al., 2002, CHENG & WAN, 2002) (fig. 2-5).

Tab. 2-2: Vegetation Zones of the Loess Plateau (Zou et al., 1997, Chen et al., 2002)

Vegetation Zone	Annual Precipitation (mm)	Mean Annual Temperature (°C)	Aridity (Penman)	Climate- Humidity Conditions
I. Broadleaved Forests	550 – 700	12 – 13	1.3 – 1.5	Warm temperate/ semi humid
II. Forest Steppes (Transitional)	450 – 550	9 – 10	1.4 – 1.8	Warm temperate/ semi humid to semi arid
III. Typical Steppes	300 – 450	8 – 9	1.8 – 2.2	Warm temperate/ Semi arid
IV. Desert Steppes (Transitional)	200 – 300	8-9	2.4 – 3.5	Warm temperate/ semi arid to arid
V. Desert Zone	< 200	9 – 10	> 4	Warm temperate/ arid

2.4.2 Warm Temperate Broadleaved Deciduous Forests

The *zone of warm temperate broadleaved deciduous forests* extends over the southern and southeastern areas of the *Loess Plateau*, and covers parts of the provinces of *Gansu, Shaanxi, Shanx*i and *Henan*. In *Shaanxi*, the areas of the *Wei River* watershed, lower parts of the *Luo River* watershed as well as a line along *Long, Bin, Yijun* and *Huanglong* counties delineate the northern part of this zone. Mean annual temperatures are between 12 to 13oC in the valley areas and between 8 to 10oC in the hilly and mid mountain areas. Annual average precipitation is around 550 to 650 mm and 800 mm in mountain areas (CAS, 1995).

The natural vegetation of which today only small scattered patches can be found in this zone is mainly composed of mixed oak forests with major tree species being *Quercus accutissima, Q. aliena, Q. liaotungensis, Q. mongolica*, and *Quercus variabilis*. The genus *Quercus*, although not growing at its maximum—is the characteristic tree species of this zone. The northern border of this zone together with the following forests and grasslands belt marks the edge of the distribution of oak species in northwestern China. Other frequently occurring deciduous genera are, for example: *Ailanthus, Betula, Fraxinus, Koelreuteria, Populus, Tilia, Ulmus, Salix* as well as several Gymnosperm genera such as *Pinus, Sabina, Platycladus*. In the shrub layer, deciduous genera such as *Cotinus, Forsythia, Syringa, Vitex, Lespedeza, Spiraea* and *Rosa* can be found. Typical species of the ground vegetation and secondary meadow grasslands transformed by man are *Carex lanceolata, Dendranthema indicum, Themedea triandra var. japonica, Bothriochloa ischaemum, Stipa bungeana, Sophora davidii*, and *Ziziphus jujuba*.

Today, the original natural forests of this zone have been largely converted to agricultural land, whereas major agricultural crops are wheat, maize, and millets. In addition, this zone is characterized by large fruit tree plantations of apple, peach, pear, apricot, Chinese date (*Ziziphus jujuba*), Chinese pepper (*Zanthoxylum bungeanum*), persimon (*Diospyros kaki*), pomegranate (*Pumica granatum*), and chestnut (*Castanea mollisima*).

2.4.3 Warm Temperate Forests and Grasslands

The *zone of warm temperate forests and grasslands (forest steppe zone)* describes the transition between the originally continuous and closed forests and the typical grasslands of northwest China. Prior to forest clearing, land transformation, and intensive cultivation, this transition zone is often described as originally having been a mosaic of different forest, shrub, and grassland vegetation types (GAN & SANG, 2002).

This transition zone extends north and northwest of the forest zone and mainly includes the central parts of *Shanxi* and *Shaanxi* provinces around the upper reaches of Fen and *Lu rivers*. In *Shaanxi*, the counties of *Ansai, Suide, Zichang* and *Zhidan* mark its boundary to the typical grassland zone. General landscape features are rolling loess topography at 1000 to 1200 meters elevation. Mean annual temperatures with around 9 to 10°C (6 to 8oC in mountain areas) are lower than in the forest zone, and with annual rainfall between 450 to 550 mm (up to 600 mm in mountain areas), this transition zone is somewhat drier than the southern areas. Closed forests mainly occur in remote hilly and mountain areas.

Typical species of the forest zone, such as *Quercus aliena, Q. variabilis* and *Pinus bungeana* are no longer found here, whereas *Q. liaotungensis* forests are now the dominating forest vegetation type. Other common species of the tree layer are *Betula platyphylla, Acer stenolobum, Populus davidiana, Pinus tabulaeformis, Platycladus orientalis, Ulmus spec.*, and *Tilia spec.* (CAS, 1995).

Grassland vegetation types, which are often secondary, occur on southern slopes, hilltops, and on abandoned farmland. They are often comprised of *Sophora davidii, Syringa spec., Prinsepia uniflora, Periploca sepium, Wikstroemia chamaephne, Vitex negundo* and *Artemisia spec., Bothriochloa ischaemum, Lespedeza bicolor, Stipa bungeana* as well as other typical grassland species. Secondary shrub communities following the destruction of forests are composed of *Ostryopsis davidiana, Spiraea hirsuta, Rosa xanthina*, and *Hippophae rhamnoides.*

The forests and grasslands transition zone is a dry-land agricultural area with only one harvesting season per year. Agricultural productivity is already reduced as compared to the previous zone. Main crops are winter wheat, maize, millets, sorghum and potato. Besides farming, fruit tree plantations are still of major importance for the rural economy. Planted are apple, Chinese date, and apricot trees. Furthermore, this area is characterized by some artificial afforestation on fallow lands and loess hills, mainly with *Armeniaca sibirica* (wild apricot), *Caragana korshinskii, Hippophae rhamnoides*, and *Robinia pseudoacacia* (CAS, 1995).

2.4.4 Warm Temperate Typical Grasslands

The zone of *typical grasslands (steppe zone)* is located northwest of the *forest steppe zone* and, in *Shaanxi*, stretches along the line from the counties of *Dingbian, Jingbian, Hengshan*, and *Yulin District*. It also covers large parts of *Gansu, Inner Mongolia* and *Ningxia*. Mean annual temperatures average 7°C, while annual precipitation decreases to 300 to 400 mm.

The vegetation mainly consists of typical steppe communities composed of species such as *Agopyrum mongolicum, Artemisia giraldii, Stipa bungeana, S. grandis* etc. while species such as *Bothriochloa ischaemum*, which was largely distributed in the previous zone, do not occur here anymore. Several shrub species such as *Caragana, Wikstroemia, Ziziphus*, and *Sophora* also occur naturally (CAS, 1995).

Agricultural activities in this zone are of lesser importance because of unfavorable climate conditions such as frequent drought and wind events as well as reduced soil fertility on increasingly sandy soils. Summer wheat, millet, hemp and potato are still cultivated in some areas. Animal husbandry is economically becoming more relevant in this zone. The typical grassland zone has been heavily degraded in large parts in recent decades and become a focal area for afforestation and desertification combating efforts with tree and shrub species. Woody species suitable for planting in this area are, for example, *Caragana korshinskii, C. microphylla, Eleagnus angustifolia, Hippophae rhamnoides, Juniperus rigida, Pinus tabulaeformis, Platylcadus orientalis, Populus simonii, Prunus spec., Robinia pseudoacacia, Salix matsudana*), *Sabina vulgaris,* and *Ulmus spec.* (Li, 1998).

2.4.5 Warm Temperate Desert Grasslands

Further to the north and northwest, the *zone of desert grasslands* continues as a narrow transition belt toward the typical desert zone covering large parts of *Inner Mongolia, Ningxia, Gansu*, and *Qinghai*. This belt also marks the transition toward mostly sandy and gravelly areas with rare occurrences of typical loess deposits. Mean annual temperatures are around 6oC; and annual precipitation decreases to 200 to 300 mm. Typical vegetation elements are arid grassland species such as *Artemisia desertorum, Stipa breviflora, S. bungeana.*

In the agricultural sector, animal husbandry is of major importance for the local economy. Farming is here only possible in valley locations or on small irrigated patches where sporadically summer wheat, buckwheat, hemp, melon, and potato are cultivated (CAS, 1995).

2.4.6 Warm Temperate Deserts

The *desert zone* describes the northwestern border areas of the *Loess Plateau* and includes the far northern parts of *Inner Mongolia* and *Ningxia*. Mean annual temperature is between 9 to 10oC (3 to 10oC in mountain areas); and annual rainfall amounts to less than 200 mm.

Vegetation cover is sparse and dominated by drought resistant species of the genera of *Artemisia, Stipa* etc. Farming is only possible with irrigation and mostly concentrated in the *Yellow River* valley around *Yinchuan* and *Hetao (Ningxia)*. The desert zone is also home to the nomad communities of China and an important area of animal husbandry.

*Fig. 2-5: Vegetation Zones - Central Loess Plateau (*Cheng *&* Wan*, 2002)*

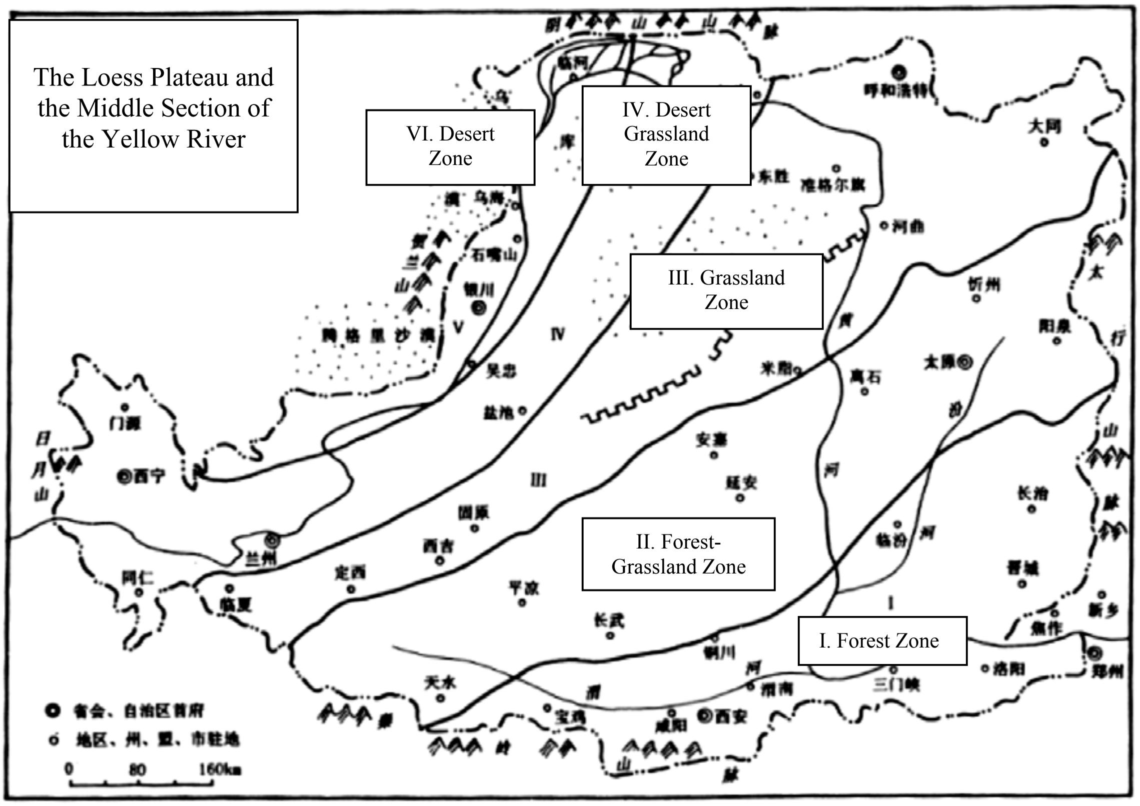

图 1-6 黄土高原地区植被地带

Note: I: Forest Zone; II: Forest Grassland Zone; III: Typical Grassland Zone; IV: Desert Grassland Zone; V: Desert Zone

2.4.7 Vertical Vegetation Zones

In addition to the general horizontal vegetation patterns of the *Loess Plateau*, distinct vertical vegetation belts—often significantly differing between southern and northern slopes—are described for all major mountain ranges of the *Loess Plateau*, such as *Guandi, Wutai, Yunzhong, Luyu, Lüliang, Zhongtiao (Shanxi), Huanglong, Ziwu (Shaanxi), Liupan, Quwu, Helan (Ningxia, Gansu)*, and *Riyue (Qinghai)* (CAS, 1995).

The vegetation of the mountain ranges that rise above the actual loess depositions is comprised of complex plant communities including cold to warm-temperate evergreen and broad-leaved coniferous forests, evergreen coniferous and non-coniferous shrubs, and alpine meadows. Typical tree species of the mountain and alpine areas are: *Abies fargesii, Betula albo-sinensis, Juniperus rigida, Larix principes-ruprechtii, L. chinensis, L. potaninii, Picea asperata, P. megeri, P. crassifolia, P. purpurea, Pinus tabuleaformis, P. bungeana, P. armandii, Platylcadus orientalis, Rhododendron spec., Sabina przewalskii.*

3. Overview of Research and Literature

3.1 Organization of Ecological Research

A major component of ecological research in China—besides research conducted in national and provincial level research institutes—are networks of monitoring stations that are distributed all over the country and often associated with national and provincial research institutes.

The *China Ecological Research Network (CERN)* is currently the largest ecological monitoring system with a history of over 20 years. It is administered by the *Chinese Academy of Sciences* and covers about permanent 40 research stations over all climate zones in China. Focal areas of research, among others, are forest, agriculture, grassland, and freshwater ecosystem monitoring.

The *Monitoring System of Forest Ecological Benefits of Forest Programs* was established in 1998 by the Central Government to focus on natural forests and plantation forestry in the *Yellow* and *Yangtze Rivers* watersheds. Altogether, this monitoring system consists of 27 research stations. A third country-wide research network is the *China Forest Ecology Research Network (CFERN)* established in the early 1980's by the *Ministry of Forestry* (today: *State Forestry Administration*). Altogether, 11 permanent research stations are in place representing all major climate zones and major ecological forest vegetation types. The focus is on general forestry research including ecological functions of forest, production of timber and non-timber forest products and on agro-forestry and inter-cropping systems (ZHOU et al., 1998). A key reference of CFERN is the report *Long-term Research on China's Forest Ecosystems*, published in 1994 by the Ministry of Forestry.

Semi-governmental institutions with a direct research focus on the Loess Plateau are, for example, the *Soil and Water Conservation Society of China*, *Soil Science Society of China* (soil erosion), and *Water Resources Science Society of China* (sedimentation). Universities involved in relevant research are the *Beijing Forestry University*, *Northwestern Science and Technology University of Agriculture and Forestry (NWSTUAF)*, *Northwestern University*, *Shanxi Agricultural University*, *Gansu Agricultural University* and others (TANG, 1987). A special research institute previously under the direction of the *Chinese Academy of Sciences* is the *Northwestern Institute of Soil and Water Conservation* in Yangling (Shaanxi), which was recently incorporated into the *NWSTUAF*.

3.2 Review of Chinese Scientific Literature

3.2.1 Fields related to Study Purpose

The available literature is enormous and covers all aspects of the *Loess Plateau*'s geography, vegetation, history, land utilization and environmental issues. It is by no means possible to provide an exhausting review of the existing knowledge; and the presented selection is a subjective statement based on comparatively easily accessible materials and personal communication with individuals involved in environmental research on the *Loess Plateau*. A major impediment to such a review is also the fact that research reports and material collections are mostly published in Chinese.

As for the research purpose of this study, written sources included into this review are divided into three broader themes, namely:

1. general vegetation studies;
2. studies on the relationship between vegetation and erosion;
3. studies on environmental rehabilitation and vegetation restoration.

3.2.2 Vegetation Studies

Comprehensive overviews of vegetation zones and major vegetation types over all climatic and eco-geographical zones are given, for example, by the SONG (1983) and HOU (1986). An exhausting overview of China's forests is provided by WU (2000) in the more recently published *Forests of China* (4 volumes). In contrast to the above bio-geographical classification systems, the latter represents a rather schematic silvicultural perspective to forest vegetation and distinguishes forests on the basis of dominant tree and shrub species. It also includes information on distribution ranges, tree growth, eco-physiological features of individual species at the stand level.

With regard to the natural vegetation of the *Loess Plateau*, JIANG (1997), CHENG & WAN (2002), WANG & LIU (1993) and ZOU et. al. (1997) provide roughly similar macro-regional descriptions in which all authors distinguish between three to five vegetation zones over the *Loess Plateau* along temperature, precipitation and aridity characteristics. Their descriptions include, however, only selective and limited listings of tree, shrub and other species from the southeast to the northwest of the plateau. Similarly, CHEN (1997) provides a descriptive account of mountain forest vegetation of the temperate northern regions of China with focus on coniferous forests, although he is more detailed with regard to ecological and distribution features. HOU & CHANG (1992) also focuses on mountain vegetation belts and general eco-geographical characteristics. SUN & FEOLI (1992) present one of the few analytical vegetation classifications for China based on multidimensional climatic modeling.

In addition to these rather general overviews of large-scale vegetation distribution patterns there are also several location-specific floristic descriptions for the *Loess Plateau* such as for the *Qilian Mountains (Gansu)* by ZHOU (1992) and the *Liu Pan Mountains (Shaanxi)* by ZUO & ZHANG (1992). Studies with focus on distribution patterns and ecological characteristics of single genera and species can be found for *Quercus spec*. and *Platycladus orientalis*.

CHEN (1992) provides a summary of the distribution range of *Quercus spec*. For example, he confines the distribution range *Quercus* forests to the region between 32°30‘ to 42°30 N and 103°30‘ to 124°10‘ E and discusses floral elements and life form characteristics of those forests. YANG (1998) analyzes the ecological niche of different oak species in central *Shaanxi*. His major findings are that tree layers in these forests are generally poor in species. Species diversity (*Shannon-Wiener Index*) varies along exposition making site-specific moisture conditions a major factor in determining diversity in this region.

BO et al. (1998) and HUO et al. (2002) both analyze growth dynamics of artificial *P. orientalis* stands on the *Loess Plateau* on the basis of regression models with soil water content and soil temperature as predictor variables, and variance analysis.

Major findings are that growth performance is determined by temperature and moisture conditions and statistically discernable between different slope aspects. In general, artificial stands of this species exhibit a better growth performance in terms of height and diameter growth on sunny slopes during the first decade after planting and thereafter perform better on shady slopes.

Historical perspectives on forest exploitation, timber utilization as well as ancient replanting practices are given by ZHOU et al. (1996) and ZHOU & FAN (1997).

In general, floristic-sociological studies and studies with a focus on dynamic aspects of vegetation development, e.g. studies on vegetation succession, are comparatively rare. ZHU (1993), for example, provides an account of natural vegetation succession for northern *Shaanxi*. He argues that with an end to human disturbance degraded *Artemisia* steppes of today will develop into *Sophora-Hippophae-Rosa* shrubs and ultimately return to *Quercus liaotungensis* forests. During the initial succession stages, changes in edaphic conditions predominantly drive vegetation development while competition between species becomes a major factor in influencing the succession at later stages. However, while the author is able to discuss the first steps of the succession path based on research findings, the ultimate natural rehabilitation of oak forests he proposes is only based on the author’s assumptions.

Finally, DAI et al. (1990) and DAI (1993) present two numerical studies on vegetation differentiation under the influence of different human disturbance regimes for different shrublands (*Vitex negundo, Quercus liaotungensis, Spiraea trilobata*) in northern China. Their findings are that variations in species composition can be related to the disturbance regime but are difficult to discern from climatic and other environmental factors. In general, plots with higher incidences of human disturbances contain fewer shrub species and show an increase of below ground biomass combined with an increase of the number geophytes. Beyond this indicative observation, other conclusions appear ambiguous.

3.2.3 Vegetation Cover, Hydrological Cycles, Erosion and Sedimentation

Research in this field has been extensive. Most of the reviewed literature and summarized findings are derived from plot-level and small watershed-level research accumulated large amounts of data and descriptive approaches to erosion quantification and evaluation in the early and mid 1990s. Since the late 1990s, more analytical studies have been published, which also take a broader perspective on watershed and regional scales.

ZHOU & YE (1992) present an experimental study from loess areas in *Shandong* province on the effects of different vegetation covers and management regimes, e.g. degree of grazing, on runoff, soil erosion and loss of soil nutrients. Vegetation types investigated included *Robinia pseudoacacia, Quercus accutissima, Pinus tabulaeformis, Platycladus orientalis, Vitex negundo, Ziziphus jujuba, Themedea triandra* and *Bothriochloa ischaemum*. The authors conclude that forest and grass vegetation cover significantly reduces runoff, nutrient loss and erosion as compared to barren (agricultural) land. In addition they find that forest stands and grasslands exhibit similar effects with regard to the amount of erosion reduction.

Water conservation functions, for example, are evaluated for *Pinus tabulaeformis* by ZHANG et al. (1998), for *Quercus spec.* by ZHOU & DENG (1998), and for *P. tabulaeformis* and *Ziziphus jujuba* by LUO (1995a) and compared to other natural and artificial vegetation types and farmland in different sites of the *Loess Plateau*. Variables chosen for evaluation are rainfall intensity, infiltration rates, canopy density, runoff, soil nutrient loss sediment yield. These authors find that erosion is the highest on bare ground and on steep slopes. Rainfall intensity and stand density are important determinants of the total amount of eroded soil. Oak forests followed by Pine forests compare most favorable in terms of soil conservation, while clear-cut areas and artificial grasslands take a medium position between forests and farmland. LUO (1995a) estimates for the *Huocun watershed (Shaanxi)* that artificially planted protection forest can reduce the total annual erosion by 75% from 2731 t / sq. kilometer (bare ground) to 711 t / sq. kilometer under forest.

Similarly, CHE et al. (1994) measured runoff and soil erosion patterns of forest, shrubs and grassland plots under different management intensities in the *Qilian Mountains* in *Gansu* over a period of five years. Out of the variables of slope degree, exposition, rainfall duration and intensity, rainfall intensity was found to be the key variable affecting the amount of surface runoff and eroded soil. Surface runoff and soil erosion on heavily grazed lands were significantly higher than on land of moderate or light grazing pressure, while basically no surface runoff and erosion occurred on forest plots.

On the other hand, ZHOU et al. (1994), in a plot-level study of *Quercus mongolica* forests (different ecological compartments) in *Inner Mongolia*, and DANG (1994) in the *Qinling Mountains (Shaanxi)* of different forest stands provide less conclusive results on the effects of forest management interventions in terms of water conservation value. Comparing clear-cut areas, thinned forests and unmanaged control plots, ZHOU finds that runoff tends to increase with decreasing forest coverage, but seasonal variations in precipitation significantly affect water systems of forests as well. DANG concludes that water runoff characteristics are mainly determined by rainfall intensity and soil water regimes shortly before or during the rain event. In general, runoff duration appears to be longer in broadleaved forests than in coniferous forests. Both acknowledge that further research is needed to satisfactorily explain these complex interactions.

At the watershed level, a study by WANG & LIN (1994) conducted in *Gansu*, is inconclusive on the effects of forests on influencing water drainage systems. They report for three different sites that runoff and drainage are the highest during the rainy season (Juli to September) and the lowest during the dry season (October to March). But it is difficult to link this pattern to differences in forest cover or management. They conclude that small watershed systems are mainly shaped by seasonal variations in precipitation.

LI (1996) and LUO (1995b) emphasize the importance of water and soil conservation forests and grasslands as being ecological measures of integrated small watershed development projects. Based on study results from the experimental research station in *Yangshou (Shaanxi)*, LUO argues that an integrated "environmental engineering approach" including inter-cropping systems, high yielding economic forests and multi-species protection forests leads to diversified and more appropriate land management systems with a significant potential to reduce soil erosion and runoff.

LIU et al. (2002) contribute to the analytical work at the watershed scale with their study on environmental and economic impacts of integrated watershed development. Based on a set of physical and chemical soil indictors (antiscourability, infiltration rate, aggregate stability, cohesion, organic content), the authors approximate the ecosystem value of different land-use types (cropland, artificial woodland, artificial and natural grassland) and vegetation types (crops, species) and extrapolate these values to the watershed level.

By estimating changes in the proportions of these landuse and vegetation types over a period of 60 years (1939 to 1999), they are able to quantify the effects of environmental rehabilitation measures. Results are that integrated watershed development including the construction of productive terraces, revegetation of unused land etc. yield direct effects on the above soil properties that together with increased vegetation cover translate into improved ecosystem health, reduced erosion and increased agricultural productivity. Effects on economic indicators (income, off-farm-employment etc.) seem to be less conclusive as these are in part exogenously determined and often independent from geo-morphological and climate conditions.

YIN (2002) takes a macro-perspective on the whole *Yellow River Watershed* and points out that sedimentation in the river's lower reaches turns out to be the overarching problem in the region's watershed management. He finds that the ratio of sediment output to input into the *Yellow River* has increased by about 75% over the last decades leading to excessive uncontrolled sedimentation.

This sedimentation is attributed to two factors: firstly, excessive water consumption in upstream agriculture beyond sustainability leads to a decrease in the overall water discharge (and thus an accumulation in sediment); secondly, a trend toward a drier climate with less precipitation emerges from recent climate data. While average annual water input into the region was 48 billion cubic meters during 1950s, this amount decreased to an average of 15 billion cubic meters during 1996 to 1999. The author proposes water savings in agriculture and reducing soil erosion as major alleviation strategies. QIN et al. (2002), by using data and models from the *International Panel on Climate Change* (IPCC), predict a worsening of desertification and erosion due to increasing temperatures during the next 50 years.

YANG et al. (2002) quantitatively assess trends in soil erosion for the whole *Loess Plateau* region in a geographical information system (GIS) and by regressing erosion and sediment discharge (erosion intensity), precipitation (rainy season), soil particle composition, vegetation cover, erosion gully density, and proportion of sloping farmland. They confirm that erosion intensity is positively correlated with precipitation, gully density and proportion of sloping land to total land while vegetation cover and soil aggregates are negatively related to the amount of soil eroded.

In a study on land degradation in China, HUANG (2000) examines differences in erosion and salinity across regions and estimates changes over time in order to asses economic cost and provide recommendations for environmental policies. With data from the *Ministry of Water Resources, Ministry of Agriculture, State Environmental Protection Agency* and *State Statistical Bureau*, this study provides a comprehensive overview of the available data. It is organized along administrative and eco-geographical regions.

By linking topographical and erosion characteristics with rural income levels, he finds that there is a significant relationship between rising incomes and reduction in erosion.

However, this relationship is not exhaustingly explored in that the cause-effect relationship between these variables remains unclear. His analysis further reveals that despite efforts in controlling erosion—especially integrated watershed management systems—the erosion area has been growing, possibly being a combined impact of population growth, agricultural expansion, urbanization, industrialization etc.

The above review indicates that the interactions between vegetation cover, agricultural landuse systems, hydrological cycles and soil erosion are generally well understood at different levels of scale. It appears that with integrated watershed planning including ecological rehabilitation measures, appropriate approaches have been developed and put into practice in many areas to reduce erosion from agricultural areas. The majority of the studies also confirm the important roles that different natural and artificial types of vegetation cover play in erosion reduction and regulating hydrological cycles. However, discussions on reducing soil erosion and sedimentation are largely concentrated on upland farming, which is seen as the major contributor to these problems. So far, there are only few attempts to assess the relative contribution of upland farming to total erosion and sedimentation against other land intensive sectors such as mining, infrastructure development and urban construction.

3.2.4 Environmental Rehabilitation and Vegetation Restoration

With the implementation of the *Sloping Land Conversion Program*[2] (SCLP) in 2000, numerous studies have focused on the multi-sectoral implications of this program and other environmental improvement measures including the establishment of vegetation cover. It appears that most of the studies concerned with soil erosion and vegetation rehabilitation do not distinguish between environmental and ecological implications but rather use these two terms interchangeably in the context of land development and adjustments of landuse structures.

Comparatively little work has been carried out to study natural vegetation rehabilitation processes and restoring natural ecosystems from a community ecology perspective; and this research—including the understanding or process and mechanisms of natural vegetation recovery and biodiversity considerations—appears to be underrepresented in the current discussion on landscape rehabilitation. The main areas frequently and extensively covered in the present research are exemplarily summarized below.

YU et al. (2002) take a general perspective on land conversion and argue that land conversion needs to be implemented with appropriate policies, compensation schemes and legal instruments and in place. With regard to vegetation restoration, he recommends that this should be oriented along natural geographic characteristic and horizontal vegetation distribution patterns (vegetation zones). WU et al. (1995), LI et al. (2002), and ZHANG et al. (2002) provide further schematic accounts of tree/shrub species suited for planting along optimized landuse systems. PENG et al. (2002) propose a GIS-based decision tool for prioritizing land conversion projects on the basis of farmland availability, erosion threat, proportion of steep sloping land and other criteria.

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[2] The SLCP, initiated in 2000 by the Chinese Government, promotes the conversion of steep sloping farmland to forests and grasslands and is implemented nationwide. The program calls for greening of degraded lands and barren hills and provides compensation payments and grain subsidies for farmers participating in the program.

On the basis of watershed-level data, XU et al. (2002) calculate required investments for land development measures such as terrace construction, garden land development and areas to be replanted in order to achieve an environmentally sound landuse structure.

SHAN (2002) discusses external environmental effects of woodland, its public goods nature and the establishment of appropriate compensation schemes to farmers to sustain such benefits. CAI et al. (2002) argue that the SLCP, the construction of highly productive terraces and the guarantee of a minimum amount of high-quality farmland per capita will potentially correct market failures in that the loss of quality farmland for urban and infrastructure construction will be reduced as farmland value becomes more competitive because of increased productivity. Finally, GAN & SANG (2002), LI (2002), and CHEN (2002) discuss farmland conversion and replanting in terms of regional characteristics of natural vegetation and propose a more differentiated approach to revegetation by taking the characteristics of geographical and vegetation zones into consideration when designing reforestation activities.

4. Geo-morphological Characteristics of the Study Area

4.1 Shaanxi Province

4.1.1 General Overview

Shaanxi extends over an area of 205 600 sq. kilometers from 31°43’ to 39°34’ N and 105°29’ to 111°14’ E. In 1997, the total population was 35.4 million people of which 12 million (34%) were registered as urban population (CSY, 1997). The province is subdivided into eight city districts and prefectures and 89 counties. The population is mainly Han Chinese but altogether more than 40 ethnic minorities inhabit the province.

Shaanxi is a transitional region in central China. The humid and semi-humid forest regions of the east and southeast gradually transit into semi-arid grasslands and deserts grasslands where agriculture is successively replaced by pastoral herding from south to north. In addition, the mountain ranges of *Qinling* and *Daba* in the south of *Shaanxi* mark the boundary between the temperate and subtropical climate zones in China. The *Qinling Mountains* also separate the watersheds of the *Yellow River* in the north from the *Yangtze River* in the south of China.

For the parts of *Shaanxi* that belong to the *Loess Plateau*, three characteristic landscape types can be distinguished: the *Wei River Plain*, the *Central Tableland* and the *Northern Loess Hills* (fig. 4-1).

4.1.2 The Wei River Plain (Guanzhong Plain)

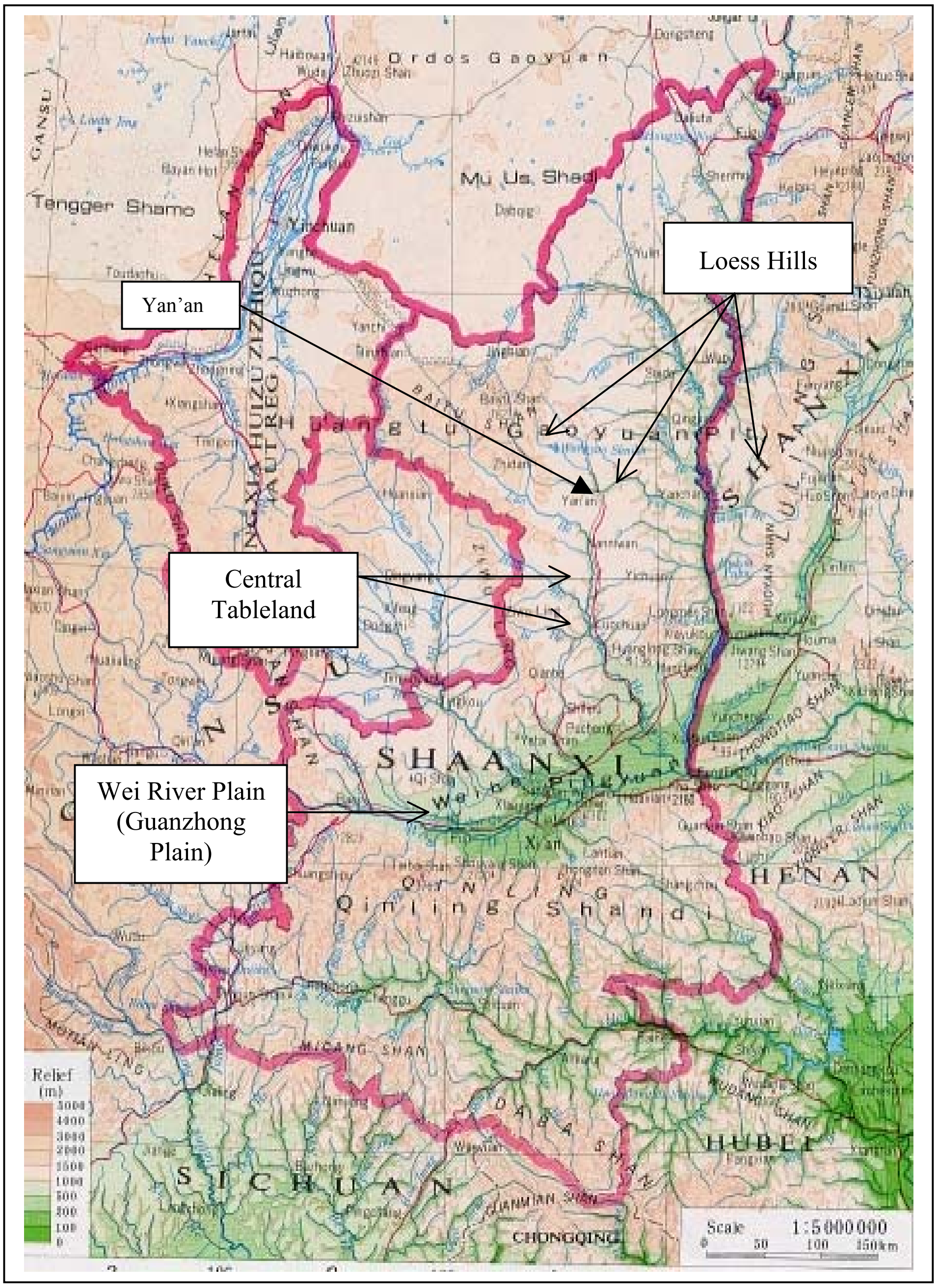
The lowlands around the *Wei River*, the largest tributary of the *Yellow River*, are comprised of fertile alluvial soils and, for several thousand years, have been the agricultural and cultural center of *Shaanxi*. The *Wei River Valley* is also known as the *Guanzhong Plain*.

The long-term continued sedimentation of silty and loamy loess material during periodic flood events has led to several distinct river terraces, which today are intensively used for agriculture. The so-called *lao tu* (long-time cultivated loessial soils) is characterized by its high content of clay and also classified as *clayey loess, fluvio-aquic soil* or *cultivated cumulic cinnamon soil* (LIU, 1985; MACKINNON et al., 1996).

Average elevation in the *Guanzhong Plain* is between 300 to 800 m. Located north of the foothills of the *Qinling Mountains*, the plain is influenced by warm foen winds from the mountains, making the plain to be one of the warmest areas in temperate China. However, its distinct east-west direction opens the plain for cold air masses intruding from the *Qinghai-Tibet Plateau* as well as sudden cold spells from the north during the summer. Often, the changing weather conditions result in damages to the agricultural production.

In the *Guanzhong Plain*, soil erosion is of minor importance as compared to other parts of the plateau. Instead, continued sedimentation and accumulation loess material originating from the highlands poses a serious threat to flood control measures downstream and raises costs for removal of sediments, dike raising, irrigation systems, and water traffic infrastructure (WORLD BANK, 2000).

Fig. 4-1: Topographical Map of Shaanxi Province and Landscape Types (CCPH, 1999)



4.1.3 The Central Tableland

The central tableland is part of the loess highlands (chin.: *shan bei*) that include all areas north of the *Wei River* valley. These highlands constitute about 45 % of the total area of *Shaanxi*. Typical loess tablelands are found in central *Shaanxi* around *Luochuan* and *Fu* counties. Elevations in these areas average between 800 to 1300 m. Loess and loessial soils contain relatively large fractions of sandy loess; and zonal soil types are described as *developed dark loessial soil, skeleton loessial soil* or *cinnamon soil* (LIU, 1985).

As the *Wei River* plain, the tableland has been cultivated for several thousand years. It has become one of the erosion areas of the *Loess Plateau*. Depending on the erosion history, tablelands (chin.: *yuan*) exist in form of large high plains or small flat ridges. Tablelands are frequently dissected by steep erosion gullies of up to 150 to 200 meters depth. As erosion proceeds, gullies gradually extend headward into the table area, further dissecting and separating the plains into narrow ridges (chin.: *liang*) and circular knolls (chin.: *mao*).

Erosion dynamics in the tableland area are characterized by massive shifts of huge amounts of loess material that occur at the edges of the table sections. Such shifts result in a continued loss of agricultural land and infrastructure facilities. This is especially serious as the tablelands are the most productive areas in this landscape type. They form stable surfaces and retain higher proportions of nutrients, organic material, and moisture than sloping land. Over time, the original high plain tableland is transformed into a dissected hilly landscape with an increasing proportion of broader valleys.

4.1.4 The Loess Hills

The central-northern part of *Shaanxi* mainly consists of a rolling landscape of loess hills that is also typical for large parts of the neighboring *Gansu* and *Shanxi* provinces. Further to the north, the loess hills gradually flatten out and transit into the sandy areas of the *Mu Us Desert* and the *Ordos Plateau*.

The loess hills are characterized by extensive oval or rounded loess ridges dissected by steep valleys and broader river plains, and form numerous small water catchments. The length of these ridges varies between several hundreds of meters up to several kilometers whereas the hilltops can be as wide as several hundred meters. The ridges are gently sloped with slopes between 5 to 10 degrees while the typical sloping lands following the hilltops are much steeper often with slopes between 10 to 35 degrees.

The loess hills have been shaped by erosion and sedimentation processes. Intensive wind erosion carry off loess material mainly from the barren sloping lands while more visible denudation of larger loess packages—often triggered by rainstorm events—occurs at the edges of gullies and steep valleys.

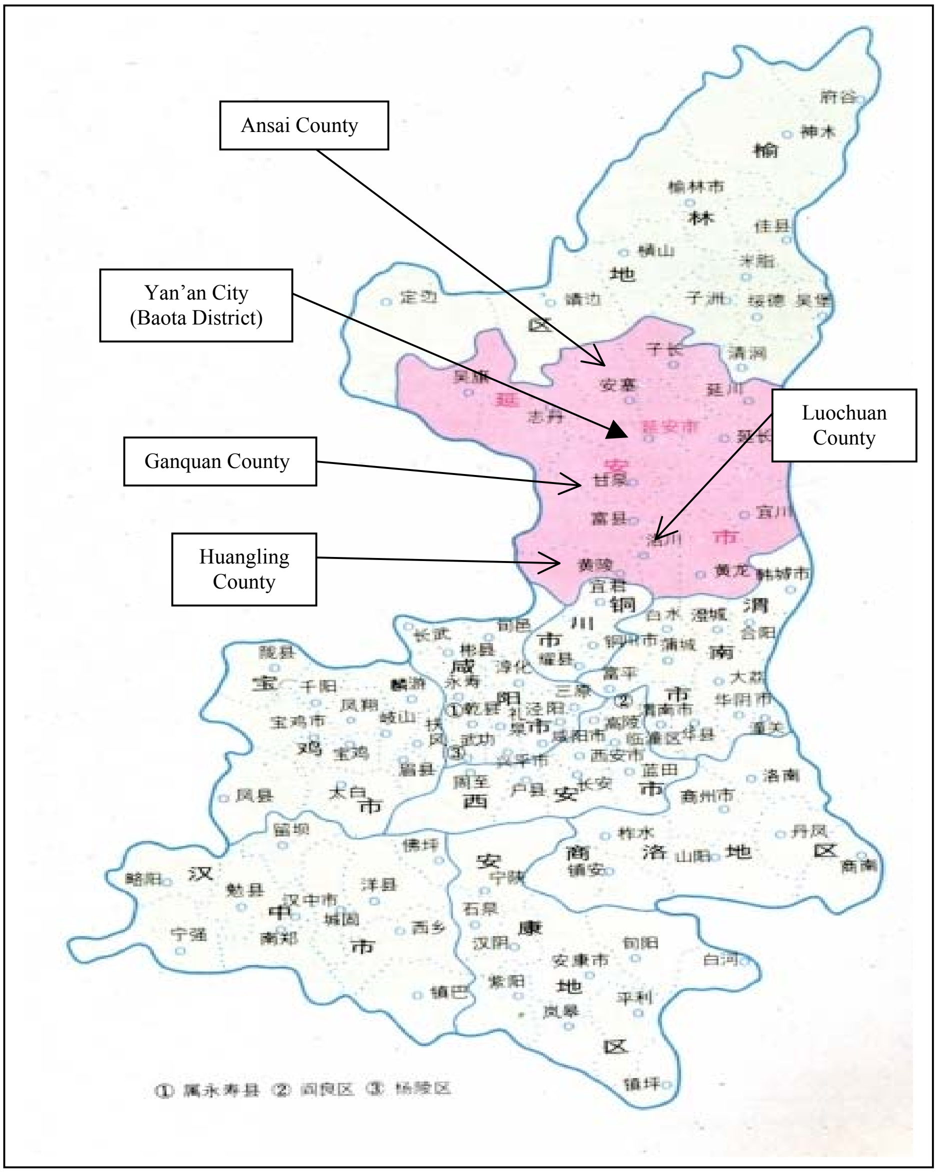
WANG & JIAO (2002) estimate that more than 50% of the total erosion and sediment yield originates from these northern loess hills while soil erosion in the tableland region only comprises about 9% of total erosion in the *Loess Plateau*. Moreover, erosion rates per sq. kilometres are much higher in the northern hills—often with an annual amount of more than 5000 to 10 000 tons per sq. kilometres—while rates in the tableland area are much smaller.

4.2 Yan'an Prefecture

Yan'an Prefecture (*Yan'an City*: 109° 18' to 110° 15' E and 36° 05' to 37° 05' N) is a typical part of the loess highlands of *Shaanxi*, including loess hill landscapes in the north and tablelands in the south. The district covers an area of 37 000 sq. kilometers and is divided into 12 counties, 196 townships, and 3426 administrative villages (ANONYMOUS, 2000a) (fig. 4-2).

Altogether, from the northern to the southern boundary of the prefecture over a distance of ca. 240 kilometers, six counties were selected for vegetation and socioeconomic data collection. Of these, *Ansai, Baota,* and *Ganquan* counties are located in the loess hill area while *Fu, Luochuan* and *Huangling* counties are located in the loess tableland.

Fig. 4-2: Administrative Map of Yan'an Prefecture (Shaanxi) (SSDC, 2001)



Within each county, townships and villages as well as adjacent areas with forests and degraded vegetation were selected for data collection to represent a broad cross-section of local vegetation types and plant communities, landuse systems, and socioeconomic conditions. Vegetation studies were conducted in *Baota, Luochuan*, and *Huangling* counties. Socioeconomic surveys were carried out in *Ansai, Baota, Ganquan, Fu*, and *Luochuan* counties. The selection process and characteristics of the individual study sites are further described in Chapter 5.

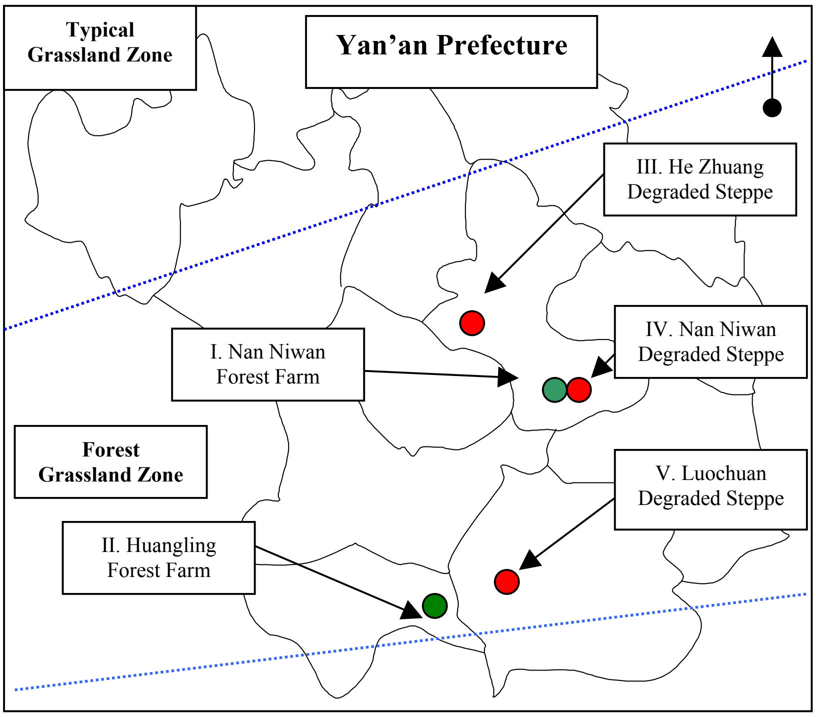
5. Data Collection and Analysis

5.1 Data Collection – Vegetation

5.1.1 General Approach

Field surveys were carried out in five study locations in *Yan'an Prefecture* during 2000 to 2002 from June to September (fig. 5-1). Vegetation relevés covering secondary natural forests and degraded secondary steppes were collected by recording vascular plant species and estimating individual cover degrees. In each location, sample plots were placed to cover all slope aspects and generate a number of replicate relevés for each exposition.

Fig. 5-1: Location of Vegetation Research Locations in Yan'an Prefecture



Note: Administrative Map of Yan'an showing county borders. Research Locations I, III, IV are located in Baota County. Location II and V are situated in Huangling County and Luochuan County, respectively. (Green symbols represent forest sites, while red symbols rerpresent degraded secondary steppe sites.)

Stratification according to slope aspect was based on the following assumptions:

1. Slope aspect as environmental parameter reflects site-specific moisture and temperature conditions and appropriately explains vegetation differentiation in an area of homogenous substratum (soil nutrient) conditions, i.e. New Loess as parent material for loessial soils over the study area.
2. Slope aspect is equally indicative of site-specific moisture and temperature conditions in secondary forests as well as in heavily degraded secondary steppes.

The stratification of sample plots seemed plausible as already during an initial field visit differences in vegetation patterns between northern and southern slopes were observed. Stratification and replication of an equal number of redundant sample plots helped to prevent potentially biased sampling due to difficult site accessibility. Stratification thus also contributed to covering the broadest possible range of relevant of vegetation types and plant communities in this area. Finally, a systematic placement of plots in form of a grid was impracticable as topographical maps and a Global Positioning System (GPS) were not available for fieldwork.

A general sample size of 100 sq. meters (10 x 10 meters marked out quadrats) was chosen based on local experiences and sample areas proposed for broadleaved deciduous temperate forests by DIERSCHKE (1994) and FISCHER (2002). The total number of recorded sample plots differed between study locations due to practical reasons but covered an equal number of replications (between 5 to 15) for each aspect per location. Sample plots were selected according to floristic homogeneity and representation. For plots located in secondary steppe areas, recent landuse history visually assessed or inquired from farmers for each site to limit sampling sites to those that had not been under cultivation for at least for three to five years. Individual sample plots were located at least 300 meters apart from each other.

For each plot, vascular plants were recorded according to three height classes: ground vegetation layer (< 1 meter), shrub layer (1-3 meters), tree layer (> 3 meters). Cover degree and height class of individual species were estimated according to a modified *Braun-Blanquet* cover scale with individual species numbers per plot not being recorded (tab. 5-1). Mean cover of individual species and total cover per sample plot were selected as variables for the statistical analysis.

Tab. 5-1: Cover Degree Scale (FISCHER, 2002)

Cover Degree								
Symbol	+	1a	1b	2a	2b	3	4	5
Cover (%)	< 1	1-3	3-5	5-12.5	12.5-25	25-50	50-75	75-100
Mean Cover (%)	0.5	2	4	8.25	18.75	37.5	62.5	87.5

The nomenclature of vascular plants was according to the FLORA LOESS PLATEAU SINICA (1989, 1992, 2000 and unpublished manuscripts). At the time of field work, species keys of the above publication were only available in Chinese. Plant identification, therefore, was done in close cooperation with researchers from the NWSTUAF. Species that could not be identified in the field were collected for later identification at the NWSTUAF. Altogether, 354 vegetation relevés were generated in the five study locations. Of these, 162 were located in secondary natural forests; and 192 were located in areas of degraded secondary steppe vegetation. After a general data editing, relevés were compiled separately for the five individual locations.

For secondary natural forest vegetation (green symbols fig 5.1), data sets I (*Nan Niwan Forest Farm*) and II (*Huangling Forest Farm*) were analyzed to study forest vegetation communities in *Yan'an Prefecture*. Data sets (red symbols) III (*He Zhuang*), IV (*Nan Niwan*), and V (*Luochuan*) were analyzed to derive a general overview of degraded secondary steppe vegetation communities over *Yan'an*. In a subsequent step, the latter three data sets were evaluated separately to produce a detailed insight in local plant communities and site conditions (tab. 5-2).

Tab. 5-2: Vegetation Data Sets Tabulated for Numerical Analysis

Sample Site	County	Vegetation Type	Number of Relevés	Vertical Vegetation Zone
I. Nan Niwan Forest Farm	Baota	Secondary natural forest	125	Forest-Grassland Zone
II. Huangling Forest Farm	Huangling	Secondary natural forest	37	Forest-Grassland Zone
III. He Zhuang	Baota	Degraded secondary steppe	92	Forest-Grassland Zone
IV. Nan Niwan	Baota	Degraded secondary steppe	49	Forest-Grassland Zone
V. Luochuan	Luochuan	Degraded secondary steppe	51	Forest-Grassland Zone

5.1.2 Site Parameters

5.1.2.1 Slope Aspect (Exposition), Slope Degree, Relief

Slope aspect, slope degree and relief (position in the local terrain) of a particular site—besides the overall precipitation and temperature regimes—shape the development and differentiation of vegetation communities to a considerable extent, especially when local substratum conditions are largely homogenous. More specifically, slope aspect, slope degree and relief all determine the amount of solar radiation influx and sunshine duration a particular site receives and, thus, control the site-specific temperature and moisture regimes, evaporation and transpiration, and the duration of the vegetation period.

For example, southeastern to western steep slopes (~110° to 290°) receive higher sunshine rates and experience higher temperatures during the day and throughout the year than shaded slopes of northwest to eastern aspects (~290° to 110°). At the same time, southern to western slopes also experience higher evapo-transpiration rates leading to a local moisture regime that creates much different conditions for plant growth than on shady northern slopes. Similarly, plain areas and gentle slopes can be characterized as more humid sites with more balanced moisture conditions than steep slopes where water run-off rates are higher and water retention capacity is reduced. Often organic litter and soil humus that improve the capacity of the soil to retain water are quickly transported downward from such slopes and accumulate at lower and less steep locations. In general, steep slopes are more erosion-prone than other locations.

Finally, hilltops and upper slopes can be rather dry locations as they are exposed to intensive sunshine during the day and high run-off rates of rainwater. In contrast, middle and lower slopes as well as valley locations often display more balanced moisture conditions.

It is important to note that these relief-driven differences in local climate conditions, in general, are more pronounced during sunshine periods than during cloudy and rainy periods. For the research area, it can be assumed that the interaction between vegetation and microclimatic differences is most prevalent during late spring and early summer when day temperatures rapidly increase but monsoonal circulation with increased precipitation has not yet started (see chapter 2.3). Similar weather patterns might also prevail during drought periods in the summer half-year.

During the field studies, slope aspect was measured for each site by a compass (with 10 degrees accuracy) and recorded according to eight main directions, i.e. north, northeast, east, southeast, south, southwest, west, and northwest. For the analysis, exposition values were transformed by the trigonometrical cosine function (tab. 5-3).

Tab. 5-3: Transformation of Exposition Values

Exposition	**N**	**NE**	**E**	**SE**	**S**	**SW**	**W**	**NW**
Degree	337.5-22.5	22.5-67.5	67.5-112.5	112.5-157.5	157.5-202.5	202.5-247.5	247.5-292.5	292.5-337.5
Cosine	1	0.71	0	- 0.71	-1	- 0.71	0	0.71

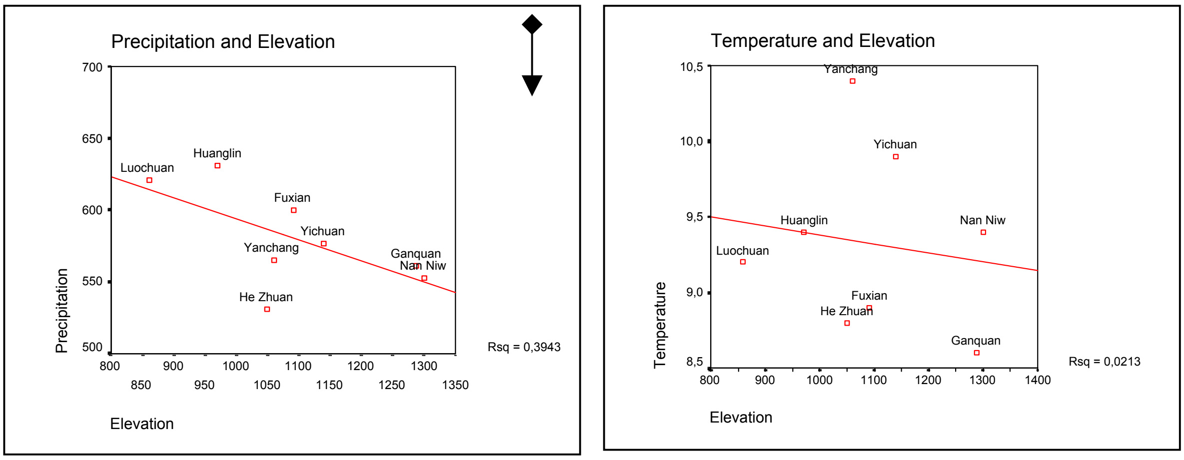
Slope was measured for each sample plot in degrees and in form of absolute values included into the analysis. Relief (local terrain) of each site was assessed on-site. Locational information was transformed into three dummy-variables: hilltop and upper slope (0/1), middle slope (0/1), and lower slope and valley (0/1).

5.1.2.2 Elevation – Vertical Precipitation and Temperature Gradients

Precipitation and temperature regimes often display a close relationship with elevation. Depending on the spatial scale under consideration, this relation can be reflected in distinct vertical vegetation belts. Such elevational gradients often provide the basis for the interpretation of vegetation patterns in addition to site-specific (micro-level) conditions, e.g. slope aspect, and latitudional climate gradients over larger areas (macro-level).

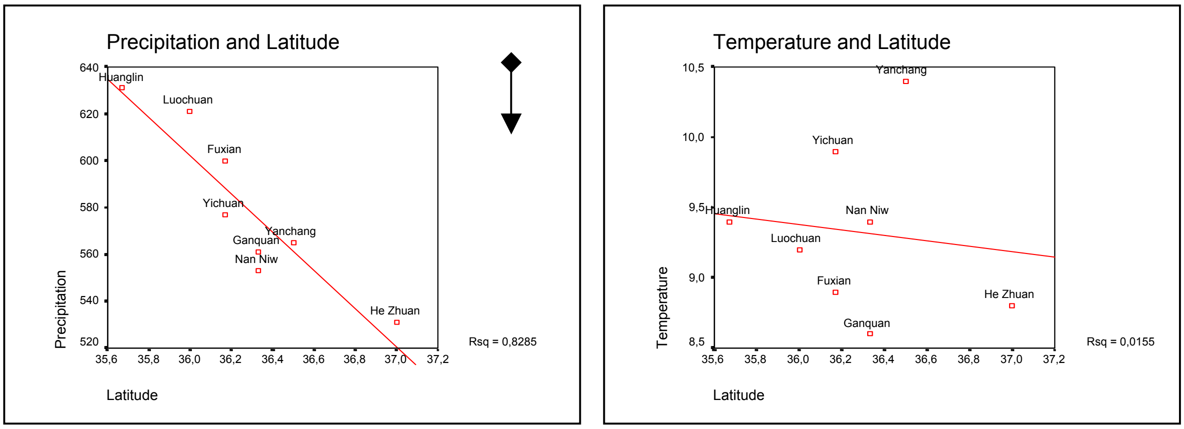
Elevation was measured for each plot with a height measure and included as absolute value. Average elevation between the study locations ranged from 860 meters in *Luochuan* to 970 meters in *Huangling*, 1300 meters in *Nan Niwan*, and 1050 meters in *He Zhuang* with a difference of about 440 meters between the lowest and highest location. In order to derive a general picture of vertical and horizontal climate gradients over the research area, climate data was inquired at county administrations where climate data is recorded. The relationships between elevation and the variables average annual precipitation and mean annual temperature were then estimated for the research area with a simple linear regression model and correlation analysis (fig. 5-2).

Fig. 5-2: Elevation, Precipitation and Temperature in Yan'an Prefecture



In addition, the relationships between geographical latitude and these variables were estimated in the same way with geographical angle degrees transformed into decimal degrees (fig. 5.3).

Fig. 5-3: Latitude, Precipitation and Temperature in Yan'an Prefecture



The regression lines in fig. 5-2 and 5-3 (left scatter plots) reveal a negative relationship between elevation and precipitation (r^2=0.39) as well as latitude and precipitation (r^2=0.83). The precipitation regime in *Yan'an* exhibits the same decreasing trend from south to north that has been described in Chapter 2 for the *Loess Plateau* as a whole. Although elevation is increasing from the south to north over *Yan'an*, there is no indication that precipitation is to rise with elevation in this particular area.

Because of the south (top)-north (bottom) orientation of sites in fig. 5-2 (black arrow), this relationship again reflects the trend of decreasing precipitation independent of elevation as one moves from south to north. On the basis of the available data, it seems thus unlikely to expect an elevation-dependent precipitation gradient that could lead to distinct vertical vegetation zones in *Yan'an*. It is more likely that (at this scale) vegetation differentiation in *Yan'an* is largely dependent on the south-north oriented negative precipitation gradient.

The analysis of the temperature data (fig 5.2 to 5.3, right scatter plots) reveals only a weak relationship between mean annual temperature, elevation (r^2=0.02), and latitude (r^2= 0.01) with temperature slightly decreasing from south to north and at higher elevations. Again, these trends have already been described for the *Loess Plateau* above.

5.1.2.3 Soil Parameters

In terms of soil diagenesis and properties, soils of the degraded and sparsely covered secondary steppe areas in *Yan'an* can be characterized as undeveloped loose carbonate syrosems with (Ai)-lCn profiles. These soils basically consist of the original undisturbed loess layers.

Under permanent forest and shrub vegetation cover, soils show some accumulation of humified organic matter mixed into the mineral fraction (Ah horizon) and initial carbonate weathering with Ah-(Cv)-*Cn* profiles (para-rendzine). In general, the high carbonate content (strong alkaline conditions) are likely to restrict plant-available phosphorus, potassium, iron and manganese.

Soil nutrient conditions might be slightly improved under permanent forest cover where organic matter is accumulated and initial soil development has taken place. Furthermore, organic litter and humus improve the water retention capacity and seed germination conditions. Finally, some conclusions concerning landuse history can be drawn from the existence of organic layers in that they indicate a longer period of permanent vegetation cover and undisturbed soil development.

During fieldwork, soil reaction to acids was tested with hydrochloric acid (HCl, 10%). On all plots, an energetic reaction with fizzing noise indicated a high content of carbonate in the first 20 cm soil depth. Even under long-term forest cover and in humus layers, a strong reaction with HCl was common. Clay illuvial Bt-horizons as diagnostic elements of para-brown soils were nowhere observed. From the above, it was concluded that dissolution of carbonates in upper soil strata is negligible; and even under long-term forest cover soils remain to be a highly alkaline medium. For sample plots located in secondary natural forests, thickness of organic litter and organic mineral horizon were measured as descriptive information.

With regard to soil particle composition and its interaction with soil moisture conditions, there is a trend of decreasing clay and silt contents and increasing sand content from south to north over the plateau. The potential implications for vegetation differentiation and rehabilitation are discussed in Chapter 6 on the basis of existing studies.

Tab. 5-4, finally, summarizes the environmental parameters recorded during fieldwork.

Tab. 5-4: Site Parameters and Type of Measurement

Site Parameter	**Measurement Scale**	**Measurement Method**
Slope Aspect	10 °	Compass
Slope	5 °	Compass/Clinometer
Location (Relief)	Dummy variable (0/1)	On-site Assessment
Elevation	10 m	Height Measure
(Organic) Ah-Horizon	Soil Profile in 2-cm steps	Tape Measure

5.1.2.4 Life Forms

Morphological characteristics of plants often represent behavioral strategies to adapt to environmental conditions (ZAVALA-HURTADO et al., 1995, FISCHER, 2002). They can serve as important ecological indicators to detect or confirm certain ecological gradients and thus supplement the environmental interpretation floristic-sociological studies. Here, life-forms of vascular plants were documented according to the system proposed by RAUNKIAER (1937) (MÜLLER-DOMBOIS & ELLENBERG, 1974) as follows:

Phanerophytes (P):	Long-lived woody tree or tall shrub, > 50 cm tall, with buds permanently above ground;
Chamaephytes (C):	Short woody plants, < 50 cm tall, with buds permanently above ground;
Hemikryptophytes (H):	Woody or herbaceous perennial plants that die back to ground in winter, growth initiated at ground, e.g. grasses;

Geophytes (K):	Non-woody, annual or perennial herbs that have below-ground organs; survive in winter as bulb;
Therophytes (Th):	Non-woody, annual herbs that have below-ground organs; survive seeds.

Life-forms proportions were determined for forest vegetation communities in the study site of *Nan Niwan* (data set I) and included as explanatory variables into the numerical analysis. Species for which life-form type could not be determined from the available literature were classified as unknown.

5.1.2.5 Human Site Factors

In addition to environmental parameters, it was observed that steppe and forest areas are frequently used by farmers for livestock grazing and fuelwood cutting. As land titles in the research area appear to be diffuse and unclear, such sites tend to be open access resources without proper management systems, e.g. grazing or harvesting regulations.

To gain an understanding of the interaction between the population and forests (*Nan Niwan I, Huangling II*), utilization patterns were estimated as follows: firstly, the degree of timber cutting in each stand was assessed by counting stumps and describing overall stand structure and canopy cover; secondly, the degree of grazing was estimated on the basis of livestock traces and dung. However, due to the difficulty to accurately assess spatial and timing patterns of such open access utilization and the lack of control areas, generated data was insufficient for numerical evaluation. Instead, a general descriptive picture of utilization patterns was drawn and interpreted based on the field observations and information provided by local farmers.

5.2 Vegetation Data Analysis

5.2.1 Multivariate Methods

5.2.1.1 General Characteristics

Multivariate analysis of vegetation data (*pattern analysis*) aims at summarizing complex data sets, revealing intrinsic data structures, and communicating results with regard to specific research objectives. Multivariate vegetation analysis is similar to the classical floristic-sociological approach in that both conceive plant communities as distinct and hierarchically placed species assemblages that can solely be recognized by their floristic composition apart from environmental factors. Multivariate (numerical) vegetation analysis provides a formalized description of species composition and relationships of plant communities (GAUCH, 1992). However, the objectivity of results is constrained by the variables and data transformations chosen by the individual researcher (MUCINA, 1997). Multivariate analysis principally contributes to generating or refining statistical hypotheses that can be tested separately in subsequent analytical steps.

Multivariate analysis organizes vegetation data on the basis of species redundancy, i.e. species respond to environmental factors in coordinated patterns, and cover degree. The analysis of environmental parameters and interpretation of interactions between the environment and species and plant communities is conceptually different and separate. Only by combining the results of these distinct analytical steps, an ecological interpretation of the relationship between species, plant communities, and environmental parameters can be completed and translated into specific landuse recommendations, e.g. forest rehabilitation.

Since the 1970s, multivariate vegetation analysis has become more and more important in community ecology with its different methodologies and techniques continuously being tested, refined and improved. Today, multivariate techniques represent standard tools in community ecology. Detailed and comprehensive treatments and evaluations of multivariate analysis techniques are, for example, provided by GAUCH (1982), JONGMAN et al. (1995), HAIR et al. (1995), MCCUNE & MEFFORD (1999).

5.2.1.2 Properties of Vegetation Data

Vegetation data that are organized in a two-way data matrix and quantified by individual species cover (presence/absence in its extreme) represent a multivariate data set. Every sample plot (dependent variable) is thereby described by the cover degree of any species (independent variable) occurring on this particular plot. Analogously, every species (dependent variable) is described by its cover degree on all sample plots (independent variable). In graphical terms, the two-way data matrix determines a multi-dimensional space in which either the sample plots represent the axes of the space and the species space points (*sample space*) or the species represent the axis with sample plots representing the points (*species space*). Samples of similar species composition occupy nearby positions in the species space, whereas species of similar sample composition occupy nearby positions in the sample space.

Vegetation data sets are complex and bulky. They are characterized by (1) coordinated structures (redundancy), (2) uncoordinated variation (noise), and (3) outliers. Coordinated data structures refer to the simultaneous occurrence of certain species under homogeneous conditions and are often the result of similar effects of environmental gradients. Revealing and interpreting such environment-dependent redundancy patterns are the major aim of community studies. In contrast, data are uncoordinated when replicate samples despite homogenous environmental conditions are rather different from each other whereas the causes for this variation are complex and outside the actual research focus. Outliers, then, are single or groups of sample plots or species that exhibit low similarity to all other samples or species with regard to their species or sample variables. To detect redundancy patterns adequately, it is necessary to reduce noise in the data set and to eliminate outliers. Both concepts, however, are arbitrary in that noise and outliers can be defined by the researcher in broader or more narrow terms.

Prior to the actual analysis, the vegetation data sets generated in *Yan'an Prefecture* were edited and transformed in several steps so as to adequately consider the above described general features of the data.

5.2.1.3 Elimination of Outliers and Rare Species

The occurrence of rare species and outliers is often determined by chance rather than it represents an indication of site-specific environmental conditions. The occurrence of a certain singular species does not provide any basis for an environmental interpretation as there are no redundancy patterns, and, therefore, must not result in any conclusion with regard to species preferences or overall site-conditions (Gauch, 1982). In this study, species that occurred in less that 6% of the sample plots were treated as rare species and outliers, and were excluded from the numerical analysis.

5.2.1.4 Data Transformation

The primary species-sample data matrix contains species characterized by large cover degrees as well as species with low cover degrees. However, species with large coverage do not necessarily contain more information about specific environmental site-conditions than less densely distributed species. If species are weighted exclusively on the basis of cover degrees estimated in the field, the ecological information contained in species with low cover rates is arbitrarily suppressed. Standardization of cover values by down-weighting high cover values relative to low cover values ensures a more accurate consideration of the ecological information provided by the mere existence of species independently of individual cover degrees.

For the respective data sets, cover values were standardized by their square-root as follows:

Standardization:	a = x ij p	
where:	xij	original value of row i (sample) und column j (species)
	p	0.5 (square root transformation)
	a	transformed value that replaces the original value xij

A second transformation takes place to treat species occurring frequently with less frequent species moderately equitable. A relativization of species (matrix elements sorted in columns) by their maximum cover value was performed with resulting values ranging from 0 to 1:

Relativization:	b = x ij / x max j	
where:	x max jmaximum cover value of species j	
	b	value after relativization that replaces the original value xij

Following this data transformation, ordination (*Detrended Correspondence Analysis*) (Hill, 1979 in: McCune & Mefford, 1999) and classification (*Two-Way Indicator Species Analysis*) (Gauch, 1982; Hill, 1979 in: McCune & Mefford, 1999) were performed. Ordination and classification results were then used to generate and test several hypothesis on species and plant community distribution and environmental differences between plant communities.

5.2.2 Ordination – Detrended Correspondence Analysis (DCA)

The ultimate objective of any ordination technique is to reduce the multi-dimensionality of the primary species-sample matrix to a small number of major dimensions that sufficiently capture the intrinsic variability (variance) and structure of the data.

Ordination techniques such as reciprocal averaging (RA) or correspondence analysis (CA) compare samples and species on the conceptual basis of similarity or dissimilarity (distance) indices, e.g. chi-square distant measure, along abstract coordinate axes (gradients). Ordination is thus an eigenanalysis technique that is also known as indirect gradient analysis (GAUCH, 1982; JONGMAN et al., 1995).

Correspondence analysis (CA) involves computerized matrix algebra. It begins with randomly assigning weights to transformed species values and computing arbitrary sample scores from these weighted species. Then, in a second iteration, new species scores are obtained that again are used to compute new sample scores. This reciprocal averaging procedure (RA) is continued until scores for species and samples stabilize. Every data matrix (generally after 20 to 100 iterations) converges toward a single stable solution independently of the originally assigned weights.

Reciprocal averaging can be characterized as mathematical formalization of the classical phyto-sociological table work. Species and samples are rearranged until an optimum diagonal structure is obtained. In this matrix, the most dissimilar species and samples occupy the edges of the diagonal describing the maximum spread (variance) in the data set. The resulting ordination values (coordinates), then, determine the relative position of each sample or species along an eigenaxis or abstract vegetation gradient. The calculated eigenvalue represents the maximum spread or variance of the data along this axis. Further such abstract gradients can be extracted from the matrix whereas these are subject to the constraint of being uncorrelated to the previous axes and of decreasing eigenvalues (or spread). The final product of the ordination procedure is a two- to three dimensional abstract space (ordination diagram) in which species and sample plots are placed according to their relative position along the calculated gradients or axes.

The correspondence analysis (CA) or reciprocal averaging (RA) has mostly been replaced by a refined ordination technique called detrended correspondence analysis (DCA) that corrects two major faults of its methodological predecessor (GAUCH, 1982; JONGMAN et al., 1995):

(1) The correspondence analysis displays a distorting arch effect that arises from a systematic (quadratic) correlation between the first and second (and higher) ordination axes.

A particular outcome of this effect is that (ecologically important) vegetation gradients might be deferred to higher axis and, thus, invisible in a low-dimensional ordination space. Detrending, as performed by DCA, alleviates this arch effect by dividing the first axis into equal segments and adjusting ordination scores of the second axis to average zero per segment.

(2) The second short-coming of the CA is that first axis ends are compressed relative to the center of the axis. This compression prevents that samples that differ by the same amount of species (being equally dissimilar) are placed in equal distances along the axis.

DCA removes this compression by rescaling the axis ends by equalizing within site-variances. As a consequence of rescaling, species turnover occurs at a uniform rate and equal distances in the ordination space correspond to equal differences in species composition. In DCA, the distance between two samples or species is finally a uniform measure of their ecological dispersion.

The length of the vegetation gradient along each ordination axis, the coenocline, is a measure of the ecological β-diversity and represents the change in species composition from one end of the axis to the other, i.e. within the respective sample or study area. It is an important element in that it reflects the differences from one habitat to the next. The greater the species difference, i.e. the gradient length, the greater the species diversity in a given area.

In general, the main gradient (greatest variability) is displayed along the first ordination axis, where the sample plots or species points are most spreaded out. Vegetation gradients of higher axes are normally shorter and species and samples less dispersed. Consequently, ecological interpretability is decreasing as one moves from the first axis to higher axes. On the basis of studies with simulated data sets, VAN GROENEWOOD (1992), for example, points out that ordination techniques while delivering reliable results for the first ordination axis might provide less robust results for vegetation gradients of higher order. As a consequence, the ecological interpretation of the ordination space (ecological space) should be restricted to only the first few axes.

The length of the gradient is often measured in half-change units (HC), i.e. the ecological distance between two sample plots that have 50% of their species inventories in common. An alternative measure of gradient length is the average standard deviation of species turnover (SD). According to this measure, a full species turnover—a species appears, culminates and disappears—ranges over a span of about 4 SD. This measure is based on the Gaussian normal distribution and assumes that species are unimodally distributed with an average standard deviation of 1. In data sets free of noise, one HC corresponds to about 1.39 SD. In data sets with a large proportion of uncoordinated data both measures reach unity as uncoordinated noise artificially increases the ecologically relevant species turnover and makes this turnover appearing much larger than it is in reality. When interpreting vegetation gradients and ordination results, it is therefore necessary to appropriately deal with noisy data (GAUCH, 1982).

Ordination results are graphically summarized as perceptual maps or ordination diagrams that portray sample plots and species in their relative positions in the floristic space. The ordination is finally based on the fact that despite the obvious multi-dimensionality of original data matrix, the intrinsic dimensionality of vegetation data is much lower. This is because environmental parameters are often correlated in their ecological effects, e.g. slope aspect and slope are both related to moisture, and promote coordinated species responses into only few (or one single) and easy comprehensible ecological dimensions. The ordination is thus a powerful tool that efficiently summarizes complex floristic data and offers a range of interpretation options by generating a low-dimensional floristic (ecological) space.

Prior to any formal classification of vegetation data, the ordination is directed at interpreting the ecological continuum. Along the computed gradients and coordinates, floristically and—when site parameters are included—ecologically different species groups and sample clusters can be distinguished in the ordination diagram.

Further analysis procedures integrated into the DCA can compute correlation coefficients and regressions with transformed species values as independent and ordination sample scores as dependent variables. In this way, distribution centers of species and indicator species marking the extreme ends of the vegetation gradients can be formally extracted from the data.

However, such ordination score-species correlations do not provide insights into the ecological amplitude of individual species nor do they ultimately prove the ecological characteristics of an individual species. They simply indicate that certain relationships between species and (environmental) gradients exist, which then form the basis for plant distribution hypotheses.

5.2.3 Analysis of Environmental Site Parameters

For an environmental interpretation of the vegetation data (external analysis), environment parameters are arranged in a second matrix, which is related to the main species-sample plot matrix and ordination results. Scores of sample plots, for example, are treated as dependent variables and site parameters as independent variables. Site parameters can be defined as quantitative, categorical and binary variables.

Environmental parameters, e.g. slope aspect, elevation, slope, position in the terrain, that are examined for their correlation with species and sample ordination scores can be displayed as vectors in the ordination diagram. Length and angles of these vectors represent the direction and strength of the individual correlation with the cosine between ordination axes and vector angles being the respective the correlation coefficient for each axis. Ordination scores can also be interpreted as responses (dependent variables) to environmental parameters; and this relationship can again be explored by least-square regression analysis.

5.2.4 Classification – Two-Way Indicator Species Analysis (TWINSPAN)

Classification refers to the assembly or division of vegetation data into distinct and recognizable units of species and samples. The main purpose of such a classification is to aid the understanding of plant communities and their potential environmental determinants (GAUCH, 1982; JONGMAN et al., 1995). As community variation is to a large extent continuous along gradients, the assignment of sample plots or species to specific groups and the construction of a hierarchical vegetation classification, however, has a strong arbitrary component.

Despite its arbitrariness, vegetation classification is a necessary step. The research objectives of this study demand a separation of the vegetation continuum and a delineation of plant communities that can be described and perceived as characteristically different from each other. Forest communities need to be derived to serve as an operational guide on where specific forest ecosystems can be restored in the given spectrum of environmental conditions. The classification of such communities complements the knowledge gained by the ordination and external analysis and, hence, is a prerequisite for an efficient planning, communication, and rehabilitation of natural secondary forest vegetation.

Two-Way Indicator Species Analysis (TWINSPAN) was applied in this study. TWINSPAN is a polythetic, divisive, and hierarchical classification technique. Like correspondence analysis, TWINSPAN considers individual cover degrees and is based on reciprocal averaging. Classification results, therefore, can be compared and interpreted together with the results of the ordination.

TWINSPAN emphasizes those species that characterize the extremes of the ordination axis and, in a first step, divides the sample set into two clusters breaking the axis near its center. These sample subsets are classified by indicator and preferential species that best describe the poles of the ordination axis. The division is repeated for both subsets to give four clusters that again are characterized by indicator and preferential species. TWINSPAN continues to divide the data into progressively smaller units until the marginal benefit of further division and interpretation is reached for the researcher.

Correspondingly to the sample classification, TWINSPAN also produces a formal species classification based on indicator and preferential plots (GAUCH, 1982; JONGMAN et al., 1995). The reciprocal classification of samples and species finally results in an arranged (diagonal) matrix, that displays the whole data set similar to an arranged Braun-Blanquet table. In this table, sample and species groups represent a floristic-sociological hierarchy of vegetation units, that can be distinguished by indicator and differential species.

In this study, classified vegetation units were named according to the dominating tree species in each unit. Ordination and classification procedures were performed with the software program PC-ORD-Multivariate Analysis of Ecological Data, Version 4.17 (MCCUNE & MEFFORD, 1999).

5.2.5 Hypothesis Generation and Statistical Testing (Analysis of Variance)

The results of the ordination and classification generally suggest that, in terms of the distribution of individual species as well as environmental parameters, differences between the classified plant communities exist. In order to provide a statistical proof of such differences, the above results can be used to formulate and test hypotheses about distribution center of certain species and the difference in environmental site conditions across plant communities.

For the study location *Nan Niwan* (I), a set of hypotheses was formulated to test if the distributions of major tree species between TWINSPAN communities vary statistically discernable or if differences are to be attributed to natural fluctuations alone. Forest communities were treated as different samples to be compared. *One-way analysis of variance* (ANOVA) was performed to calculate the F-ratio between within-unit variability and between-unit variability of log-transformed cover degree values of species of interest. Statistical discernability was tested at the 95% confidence level. The null-hypothesis was stated as zero difference between the sample units. Finally, to pinpoint where exactly statistical differences are to be found between the communities, a *Bonferoni multiple comparison procedure* was performed.

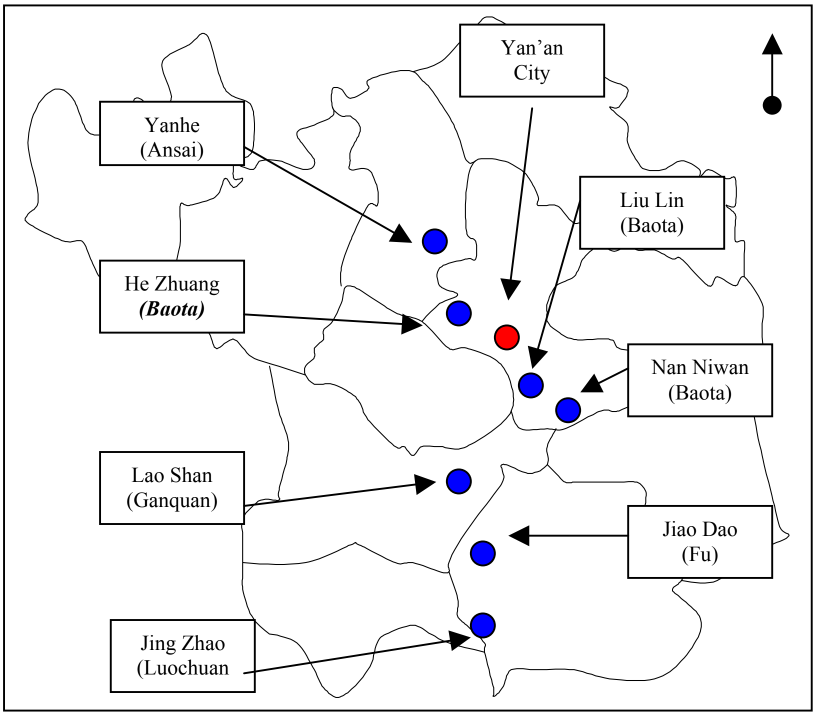
5.3 Data Collection – Socio-economy

5.3.1 Study Design and Amount of Data Generated

Socioeconomic surveys were conducted during the summer months from 2000 to 2002. Surveys took place along a north-south oriented transect of roughly 240 kilometers length along the Provincial Highway No. 210, covering seven townships—*Yanhe, He Zhuang, Liu Lin, Nan Niwan, Lao Shan, Jiao Dao* and *Jing*—in five counties of *Yan'an Prefecture* (*Ansai, Baota, Ganquan, Fu, Luochuan*) (fig. 5-4).

Townships consisted of between 10 to 28 administrative villages[3] with between 1000 to 3500 farmer households and a total population of 4000 to 20 000 people. At the time of the surveys, over 90% of the population were registered as rural population. The total area of the townships ranged from 42 to 363 sq. kilometers.

Fig. 5-4: Location of Townships selected for Socioeconomic Studies in Yan'an Prefecture



Note: Administrative Map of Yan'an showing county borders. Blue symbols indicate survey locations.

The socioeconomic surveys were designed as a two-step observational study representing a broad cross-section of the economic and natural conditions in *Yan'an*. Firstly, informal interviews with local officials of county and township administrations and technical personnel, e.g. from forestry and agriculture departments, were held to gain a general understanding of the local situation in each county and township. Interview topics were related to population, land-use, agricultural, industry, service and infrastructure sectors, and erosion combating and ecological restoration programs. Where available, secondary written materials were collected from the administrations.

Secondly, in each selected township, three to five villages were chosen. These villages were of approximately equal distance to the township center and the provincial highway as well as of comparable infrastructure conditions, e.g. connection to the township center by an earth road. Villages were either administrative villages, village groups or natural villages. Total population per surveyed village ranged from 120 to 850 people.

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[3] Administrative village (chin.: *xingzheng cun*): smallest administrative unit in the Chinese administrative system. Administrative villages consist of natural villages (chin.: *ziran cun*) and village groups (chin.: *dui*), which both are assemblies of households without administrative function.

In each village, two to six farmer households were randomly chosen for interviews. Altogether between 15 to 20 households were interviewed in each township. Household interviews conducted in 2000 and 2001 in *He Zhuang Township* served as pilot to test the feasibility of the survey, responsiveness of farmers and efficiency of the interview techniques. Altogether, 153 household interviews were conducted in 34 villages of which 130 were included into the later analysis (tab. 5-5). Some households interviewed during the first year were excluded as only incomplete responses were be generated during this test phase.

Tab. 5-5: Counties and Townships and Number of Surveyed Villages and Households

County	Township	Villages	Households
Ansai	Yanhe	7	20
Baota	He Zhuang (pilot) Liu Lin Nan Niwan	3 4 3	43 15 15
Ganquan	Lao Shan	7	20
Fu	Jiao Dao	4	20
Luochuan	Jing Zhao	6	20
TOTAL	**7**	**34**	**153**

5.3.2 Methodology

The emergence and history of participatory research approaches, such as *rapid rural appraisal* (RRA) and *participatory rural appraisal* (PRA) in farming and agro-ecosystems analysis, are discussed in detail by CHAMBERS (1994). Major objective of such approaches is to enable rural communities to analyze their living conditions and economic realities and to plan and act to improve such conditions. Major tools of participatory analysis are interviews with farmers, transects, informal mapping and diagramming, and ranking exercises. Although this study did not attempt to initiate planning for implementation of landuse changes and remained strictly observational, it has drawn on the methodologies of participatory approaches.

The farmer household was selected as the unit of analysis. The methods to collect relevant socioeconomic data were semi-structured interviews with farmers and group interviews in villages. Simple maps on landuse patterns and seasonal calendars were also generated. Interviews consisted of closed and open-ended questions and were conducted with great flexibility with regard to the order of questions and choice of issues for detailed discussions. Topics that had not been anticipated when the survey was designed but were of special interest to the farmers were included into the analysis as supplementary information.

Interviews were directed at gathering household-level data to describe the socioeconomic conditions of individual households and villages given the overall natural and economic conditions in *Yan'an*. A standard questionnaire served as a checklist during the interviews to ensure that all relevant data items were collected sufficiently and adequately from the interviewees (Annex III).

With regard to the general descriptive purpose of this survey, relevant data items were:

1. Number of family members economically dependent on the household;
2. Land resources, including farmland, fruit tree plantations, and wastelands;

3. Agricultural crops planted and average yields and market prices;
4. Gross income from farming, animal husbandry, off-farm-employment;
5. Annual living expenses, including taxes, expenses for heating, school fees, investments such as fertilizer and pesticides;
6. Household debt and interest payments;
7. Impacts of ecological reconstruction programs of the government, such as the Sloping Land Conversion Program (SLCP).

Annual gross income per household was selected as key characteristic to indicate income level and the standard of living of individual households. Income figures were calculated for the year in which the data was collected. As there was no data available for intertemporal comparisons, figures were not adjusted for inflation.

Annual gross income per household was calculated as follows:

1. Income from farming: calculated from individual crops planted, cultivation areas, reported average yields and market price. Grains and other agricultural products that were consumed in the household and not sold on the market were calculated as income and valued at their cash value;
2. Income from animal husbandry: calculated from reported income from sale of animals or animal products, i.e. wool, meat, eggs etc. When calculating the income from animal husbandry, only initial expenditures to purchase the animals were taken into account. Further expenses related to raising and feeding were not estimated;
3. Income from off-farm work: income received by all family members living in the household was estimated on the basis of information provided during interviews;
4. Other income: calculated on the basis of contributions from children living outside the household for several months but have not left the household yet.

Finally, annual expenses were estimated including overall expenses for food purchases, school expenses, expenses for fertilizer and pesticides, heating and cooking.

Interviews were mostly conducted during noontime when farmers and their families had returned from the morning's fieldwork or during rainy periods when farmers, in general, did not leave home for fieldwork. This strict timing helped to avoid an overrepresentation of elder people and women respondents, which normally stay at home all day. Interviews were, in general, conducted at farmers' homes but sometimes also in the field at the various working sites. Often, it was possible to interview the village leader and to supplement or correct information from the individual interviews. Interviews, on average, took between 45 minutes to one hour.

While this interview approach worked well in the field and enabled the researcher to generate a fairly detailed insight into local conditions, there are several weaknesses of such an observational approach with regard to quantitative analysis, such as hypothesis generation and statistical evaluation. For example, random selection of households to reduce the impact of confounding factors is extremely difficult as the researcher is often restricted by limited accessibility of sites, difficulty of household selection, responsiveness of local people, and potential bias introduced by local guides.

Furthermore, the randomness and lack of quantitative analysis makes it problematic to draw generalizations about the wider population and area (RAO & WOOLCOCK, 2002). There is also a trade off between the flexibility of the interview approach and the comparability of received responses. Furthermore, the assumptions that farmers have accurate knowledge of their socioeconomic conditions and are willing to openly report on agricultural yields, household incomes and expenses do not always hold. Generated data and information, thus, can only serve as an estimate of current socioeconomic conditions and trends.

5.4 Socioeconomic Analysis

For the analysis of the socioeconomic data and information gathered, an overall qualitative approach was chosen with the objective to describe overall landuse conditions and to assess opportunities for ecological reforestation with reference to local farmers' perspectives.

For the assessment and description of landuse systems, correspondence analysis (DCA) was selected as analytical tool. A two-way contingency table was generated similarly to a species-sample plot matrix with species replaced by agricultural crops and sample plots replaced by households. Individual crops were weighted by actual cropping area per household; and crops planted by less than 5% of all households were omitted from the numerical analysis. By generating a perceptual map (ordination diagram), similarities in farming patterns between individual households in different landscape types and across townships were detected and related to external variables. Variables for interpretation of landuse patterns were mean annual temperature, precipitation, landscape type, and proximity to secondary natural forests. The latter two variables were included as dummy variables as follows: loess tableland (0/1), loess hills (0/1), and forest access (0/1).

Income differences from farming, animal husbandry, off-farm employment, and the use of fertilizer and pesticides were tested for statistical signifcance between households of the two landscape types (tableland/loess hills) as well as between individual townships with *one-way analysis of variance* (ANOVA). A regression model was developed to explore the most important factors determining the overall farming income of households. Further characteristics, such as land resources distribution, total income and expenses, financial debts of households as well as perceptions on governmental restoration programs, are described in graphical form.

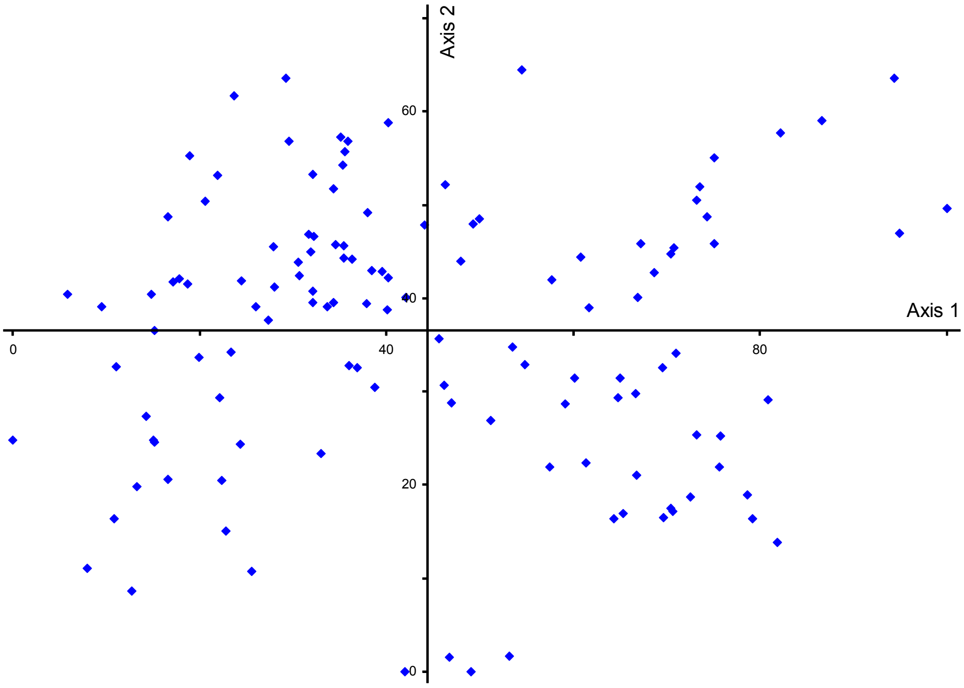
6. Vegetation and Ecological Site Conditions in Yan’an

6.1 Forest Vegetation of Nan Niwan

6.1.1 Ordination Results

The ordination results for the secondary natural forest vegetation of Nan Niwan, after the exclusion of outlier samples, illustrate an overall continuous vegetation distribution along both ordination axes with a rough disjunction of sample plots in the diagram center (fig. 6-1).

Fig. 6-1: Ordination Diagram – Secondary Natural Forests of Nan Niwan



Note: Positioning of sample plots in an abstract two-dimensional floristic space. Plots located far apart from each other, e.g. at the poles of the axes, are most dissimilar while plots located closely together are similar in terms of species composition. Axis scaling of the second axis is proportionate to axis 1 (100% spread).

As detrending and rescaling procedures do not allow to interpret calculated DCA-eigenvalues as explained variance (variability) along the ordination axes, the *coefficient of determination* r^2 (distance measure for original distance: relative Euclidean) was calculated for each axis (McCune & Meford, 1999). This measure explains how well distances in the two- or three-dimensional diagram correspond to the intrinsic variance of the original multidimensional two-way data matrix.

Accordingly, 35.2% of the variance are explained along the first axis, 13.9% along the second axis, and 6.1% along the third axis (not displayed in fig. 6-1). Altogether, the three-dimensional ordination space captures about 55% of the total variability of the forest vegetation of Nan Niwan. Eigenvalues and corresponding coefficients of determination are listed in tab. 6-1.

Tab. 6-1: Eigenvalues for Ordination Axes and Coefficients of Determination

	Eigenvalue λ (%)	**Coefficient of Determination r^2 (%)**
Axis 1	34.2	35.2
Axis 2	14.9	13.9
Axis 3	11.9	6.1

The length of the gradient along the first axis amounts to 3.16 standard deviation units (SD). As a complete turnover in species composition occurs at approximately 4.0 SD for normally distributed species (100% difference in species composition; see chap. 5.2.2), this gradient illustrates a rather low species turnover from one end to the other. Plots located at the poles of the diagram still have some of their species inventory in common. This implies that the habitats represented along the axes gradually transit into each other and are partly comprised of generalist species that are able to establish under (potentially) differing ecological conditions.

Furthermore, since forest vegetation in Nan Niwan has experienced various outside disturbances, the rate of species turnover might be somewhat inflated because of the existence of uncoordinated data. In other words, human disturbances such as selective tree cutting or grazing might also be factors that explain the variation along the axes.

The spread along axis 2 (fig.6-1) indicates that there is some variation in the vegetation along the vertical axis as well. With a gradient length of 2.0 SD, the vertical variability is, however, reduced compared to axis 1.

Species Combination in the Ordination Space

Species occupying the extreme ends of the horizontal ordination axis are evaluated on the basis of the calculated DCA ordination scores to infer from their occurrence and positioning to underlying ecological conditions. Species carrying negative scores are positioned in the left half of the ordination diagram while species with the positive coordinates are located in the right half. Without considering abundance and cover degree, tab. 6-2 lists tree and shrub species with negative and positive ordination scores for an approximately equal distance beginning from the respective ends of the first axis. The order of the species on either side of the table is according to the individual ordination scores.

Tab. 6-2: Tree and Shrub Species of the Pole Areas of the Ordination Diagram

Negative Ordination Space (left side)	**Positive Ordination Space (right side)**
Malus baccata	*Wikstroemia chamaedaphne*
Populus adenopoda	*Ulmus bergmanniana*
Cladrastris wilsonii	*Platycladus orientalis*
Ligustrum mollicum	*Amygdaldus davidiana*
Euonymus alatus	*Sophora davidii*
Populus cathayana	*Rhamnus rosthornii*
Celtis bungeana	*Ulmus macrocarpa*
Populus davidiana	*Xanthoceras sorbifolia*
Acer ginnala	
Quercus liaotungensis	

The two tentative species groups in tab. 6-2 illustrate the disjunction of the ordination space indicated above (fig. 6-1). They provide a first indication that the axis ends are possibly charaterized by different ecological site conditions. Referring to the differing ecological properties of the individual species members of the two groups above, the disjuntion reflects a division into species with higher demands on local moisture conditions (*mesic group*) on the left side and species better adaped to drought (*xeric group*) on the right side of the diagram. Obviously, the species composition of the extreme poles of the ordination space is related to differences in moisture conditions, whereby *xeric* or *mesic* are relative terms with regard to the local range of site conditions in this area.

The floristic composition of the forests of Nan Niwan, thus, exhibits a gradual transition from *mesic mixed deciduous forests*, i.e. *Quercus liatungensis* (left) toward more *xeric deciduous forests and evergreen coniferous forests*, i.e. *Platycladus orientalis,* (right). In addition, a large number of shrub and tree species as well as non-woody species exist, which cannot be assigned to one of the extremes of the ordination space but, instead, occupy the center area with less clear site preferences. Among these species are, for example: *Acer stenolobum, Armeniaca sibirica, Caragana arborescens Cotoneaster (C. multiflorus, C. ambiguus) Euonymus verrucosoides, Ostryopsis davidiana, Spiraea (S. hirsuta, S. mollifolia), Syringa vulgaris, Syringa komarowi* and *Viburnum sympodiale*.

Interpretation of Environmental Parameters

The parameters *slope aspect, elevation, slope* and the dummy variables (1) *valley/lower slope*, (2) *middle slope*, and (3) *upper slope/hilltop* were arranged for each sample plot in a second matrix. Correlation and regression analyses were performed for sample ordination scores (response variable) and these parameters (predictor variables) along each axis. Correlation coefficients along the first axis were the highest for *slope aspect*, the locational dummies *valley/lower slope*, *upper slope/hilltop* followed by *elevation*, *slope degree*, and *middle slope*.

Pearson correlation coefficients of site and stand parameters are summarized for the first two axes in tab. 6-3.

Tab. 6-3: Correlation Coefficents (Pearson) for Ordination Scores and Parameters

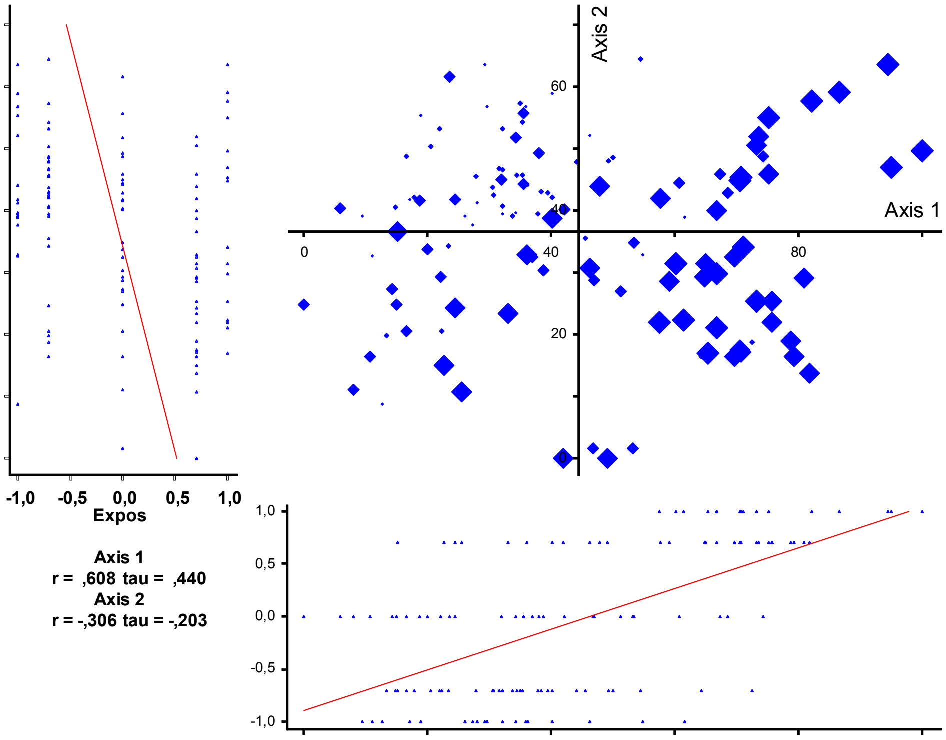
	Axis 1	**Axis 2**
Site Parameter	**Correlation Coefficient r**	
Slope Aspect	0.608	0.306
Valley/Lower Slope	- 0.547	0.345
Upper Slope/Hilltop	0.317	- 0.243
Elevation	0.313	- 0.118
Slope Degree	0.263	- 0.012
Middle Slope	0.200	- 0.113
Stand Parameter		
Species Number/Plot	- 0.414	0.509
Depth of Organic Mineral Horizon	- 0.712	- 0.024

With the detection of a relationship between vegetation data and environmental parameters, the above site parameters can be interpreted as elements of a *moisture complex-gradient*.

Accordingly, the vegetation dispersion along the first ordination axis (gradient) can be attributed to a change in moisture conditions. The strong correlation between the first axis and slope aspect (r=0.608) reflects the change from northern, northeastern, and eastern humid slopes (left side of the diagram) toward western, southwestern and southern dry slopes (right side). The change in exposition basically explains the gradual transition from mesic forest communities toward more xeric forest communities.

Fig. 6-2 further illustrates the results of the correlation and regression analyses for the parameter *slope aspect*. It shows how first and second axis ordination scores of sample plots are correlated with *slope aspect* as measured on each plot. The clustering of bold symbols in the main diagram represents the strength of this relationship with southern slopes being concentrated in the right half. The size of each plot symbol is proportional to the size of the observed parameter variable. In addition, regression lines are plotted in the two side diagrams to indicate the direction of this relationship along the axes. The scaled axes desribe the parameter observed while unscaled axes represent the sequence of sample ordination scores. Because of the transformation of exposition degrees into cosine values and sign reversal, regression lines are positively sloped for the first axis and negatively for the second axis.

Fig. 6-2: Correlation and Regression: Ordination Scores (Samples) and Slope Aspect

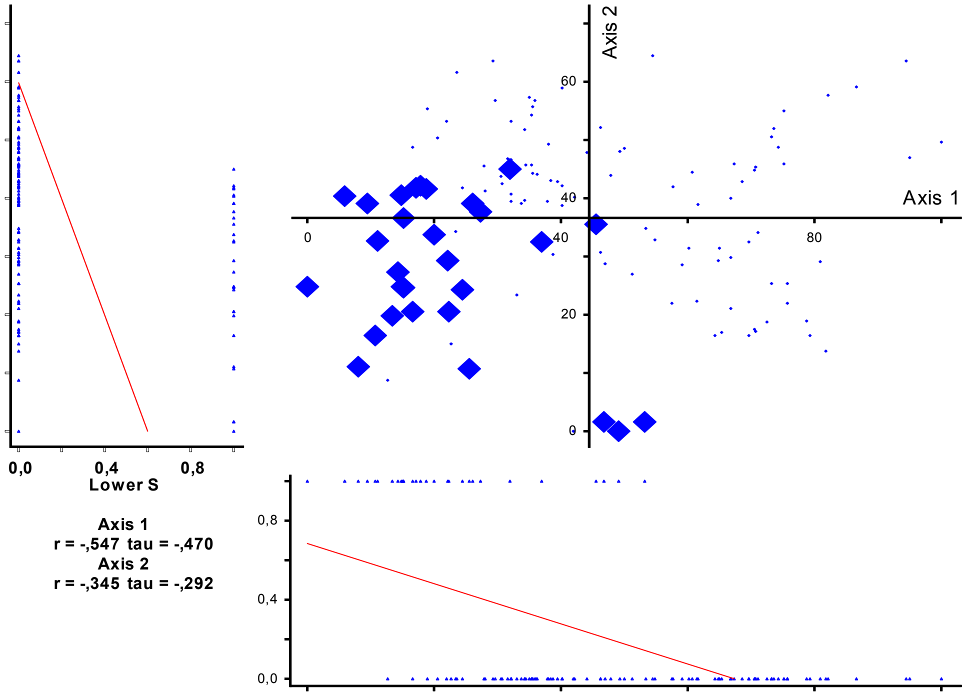


Note: Sample plots in an abstract two-dimensional floristic space. Symbol size indicates the relative size of the observed indpendent variable (parameter) on each plot (scaled in % of the largest single parameter value observed). Side diagrams illustrate the relationship between sample scores (response variable) and site parameter (independent variable: slope aspect) in form of a regression line for each axis. Correlation coefficients (r) are displayed for each axis. Axis scaling is as in fig.6-1.

Elevation and *relief* are parameters that describe the local topography and, in addition to slope aspect, are both characteristics of the site-specific moisture regime. The highest elevations in Nan Niwan Forest Farm coincide with upper slopes and hilltops, and the lowest elevations with lower slopes and valley locations. Therefore, the site-relevant information provided by these two parameters is actually redundant at the micro-scale, i.e. in this location. However, the correlation coefficient for the dummy variable *valley/lower slope* exhibits a stronger relationship than the coefficient for the variable *elevation* (tab. 6-3).

This observation implies that upper slopes and hilltops at higher elevation represent somewhat less favorable moisture conditions than valleys and lower slopes at lower elevation. However, these relationships are less pronounced than between slope aspect and vegetation as illustrated in figures 6-3 for the relationship between vegetation and the dummy *valley location/lower slope*.

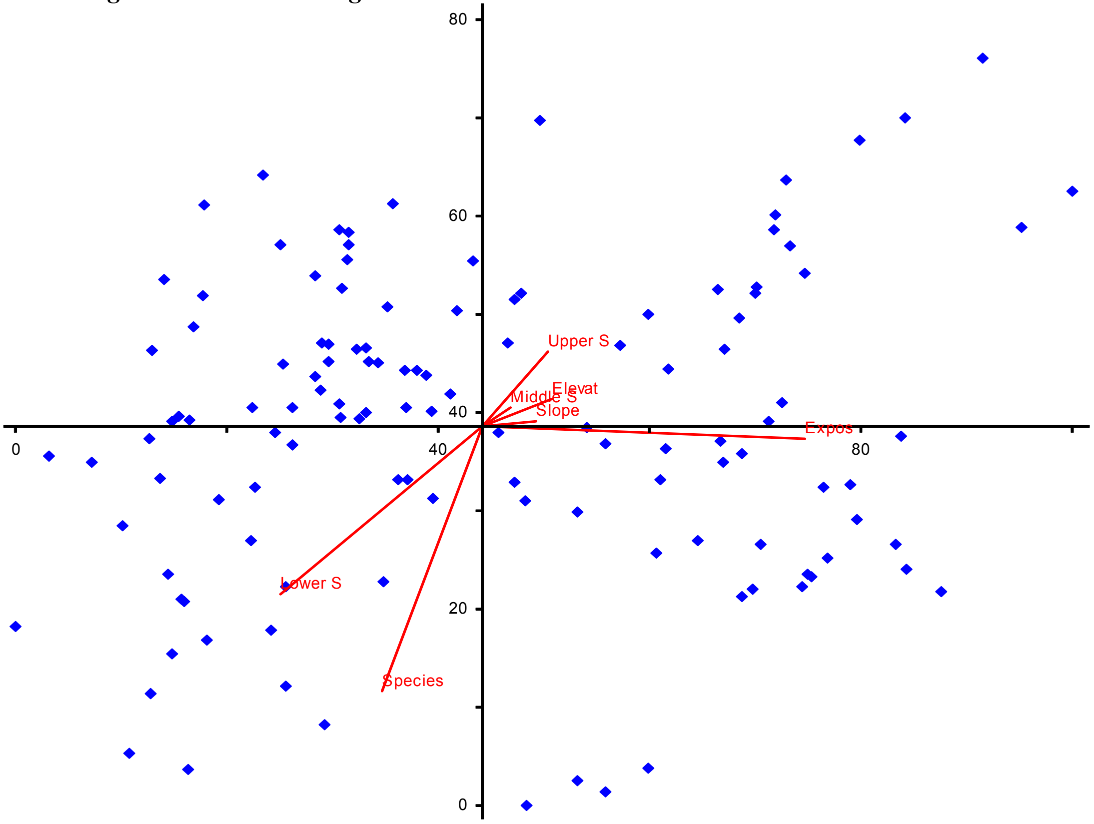
Fig. 6-3: Correlation and Regression: Ordination Scores (Samples) and Valley Location/L. Slope



Note: Sample plots in an abstract two-dimensional floristic space. Symbol size indicates the relative size of the observed indpendent variable (parameter) on each plot (scaled in % of the largest single parameter value observed). Side diagrams illustrate the relationship between sample scores (response variable) and site parameter (valley/lower slope) in form of a regression line for each axis. Correlation coefficients (r) are displayed for each axis. Axis scaling is as in fig.6-1.

Correlations of ordination scores and site parameters are illustrated simultaneously in the following joint plot (fig. 6-4) where location and length of each vector express the direction and strength of the relationships between ordinations scores and the respective site parameters. As can be seen, the exposition vector (*Expos*) is the most pronounced indicator of the moisture gradient along the horizontal axis. The vectors for elevation (*Elevat*), upper slope/hilltop (*Upper S*) and lower slope/valley (*Lower S*)—the latter two are positioned in opposite directions because of different signs—carry redundant information in that they form a continuous diagonal through the ordination space.

Fig. 6-4: Joint Plot – Vegetation Distribution and Site Paramenters in Nan Niwan



Note: Vector scaling 150%; Expos: exposition; Elevat: elevation; Upper S: upper slope/hilltop; Middle S: middle slope; Lower S: lower slope/valley location; Species:species total per plot; Slope: slope degree

All three vectors are roughly perpendicular to the exposition vector indicating that a second moisture gradient is present. This second moisture gradient points toward the lower left of the diagram where lower slope and valley location—sites at lower elevations—are concentrated.

Overall, the left half of the above ecological space can be characterized as range of improved moisture conditions compared to the sites on the right side. In addition, the lower left of the diagram is shaped by topographical conditions that indicate an especially improved moisture regime here that is possibly somewhat indpendent of the moisture regime created by the slope aspect. Finally, the variable slope degree (*Slope*) indicates a weak correlation along the first axis pointing to a relative concentration of steeper locations in the right half of the diagram.

The interpretation of the local vegetation differentiation along a complex ecological moisture gradient is further supported by the parameters *organic mineral horizon* (not displayed) and *species total per plot* (*Species* vector in fig. 6-4). Both parameters are strongly correlated with sample scores along Axis 1 (tab. 6-3) and point into the direction where the local moisture regime appears to be most favorable. Both can be characterized as dependent and intercorrelated variables of vegetation differentiation along improving site conditions. Obviously, a better moisture regime and soil humus conditions can explain the increasing species number per plot.

The detection of a two-dimensional ecological moisture gradient in Nan Niwan along correlations of site paratmeters and vegetation data leads to the conclusion that the difference in moisture conditions between sample sites causes a differentiation of the local vegetation. The ordination and external analysis results provide the basis to formulate the alternative hypothesis (HA ≠ 0) that local vegetation patterns from mesic to xeric vegetation types differ on a statistically discernable basis. The classification discussed below, then, provides the appropriate sample units to test this hypothesis.

6.1.2 Classification Results

Following the ordination and the description of tentative plant communities (mesic to xeric communities), TWINSPAN was applied to the data to derive a formalized and hierarchical classification of forest communities and to explore the floristic interdependencies between these communities in form of a dendrogram.

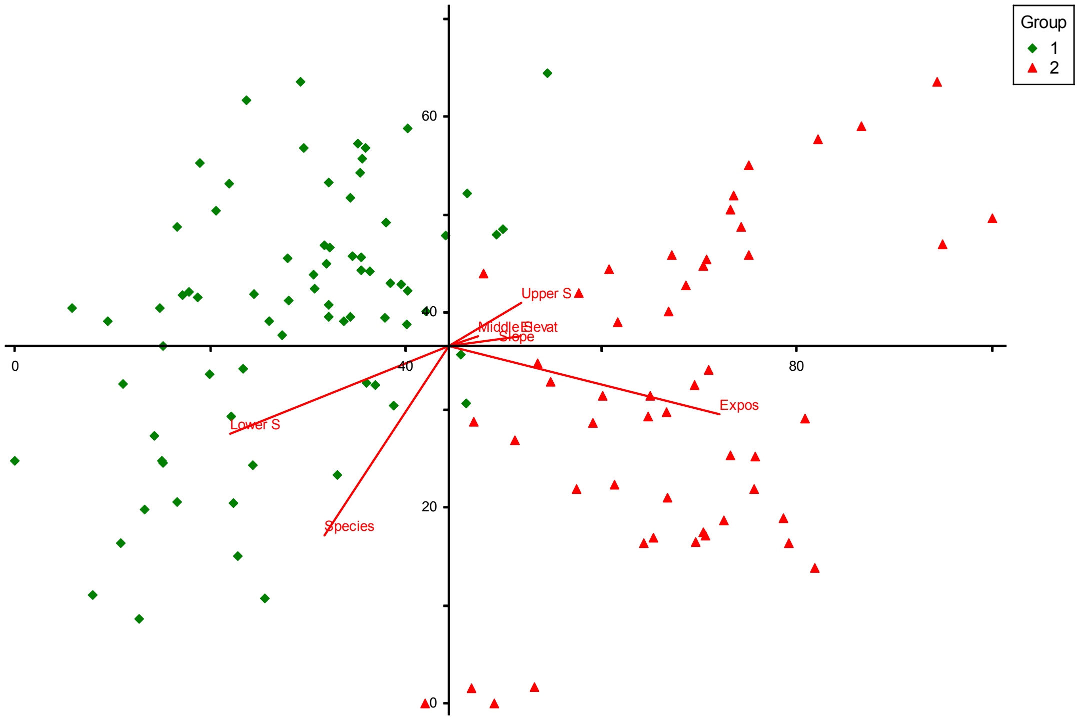
On the first level of division, TWINSPAN confirms the separation into a mesic and a xeric group. The mesic group (negative sign) is characterized by the indicator species *Quercus liaotungensis* and *Vitis piasezkii* while the xeric group (positive sign) is characterized by the indicator species *Sophora davidii* and *Artemisia mongolica*. Tab. 6-4 summarizes the species, which can be used to differentiate the two vegetation units. The resulting dichotomy of the data set is illustrated in fig. 6-5.

Tab. 6-4: Initial Dichotomy (TWINSPAN) along Moisture Gradient in Nan Niwan

Indicator Species – Mesic Group		**Indicator Species – Xeric Group**	
Quercus liaotungensis *Vitis piasezkii*		*Sophora davidii* *Artemisia mongolica*	
Differential Species – Mesic Group		**Differential Species – Xeric Group**	
Tree and Shrub Species	Ground Vegetation	Tree and Shrub Species	Ground Vegetation
Acer ginnala	*Adenophora potaninii*	*Amygdalus davidiana*	*Artemisia lavandulaefolia/giraldii*
Euonymus verrucosoides	*Aspidistra elatior*	*Armeniaca sibirica*	
Cerasus polytricha	*Patrinina scabiosaefolia*	*Lonicera hispida*	*Lespedeza caraganae*
Lonicera mackii		*Platycladus orientalis*	
Ostryopsis davidiana		*Rhamnus rosthornii*	*Polygala sibiricum*
Spiraea hirsuta		*Syringa komarowi*	
Spiraea mollifolia		*Xanthoceras sorbifolia*	
Vitis piasezkii			

With repeated dichotome divisions to the third level of division, TWINSPAN finally produces seven groups (numbered from 0 to 6). (An eighth group is not classified as group 6 is already defined on the second level of division and then not further divided because of the small number of plots included.) These groups finally provide an adequate overview of the secondary natural forest vegetation communities of Nan Niwan that can be recognized and determined in the field. The following table (tab. 6-5) summarize these communities and their floristic relationships.

Fig. 6-5: Ordination Diagram with Mesic (green) aud Xeric (red) Group (TWINSPAN)



Note: Separation of mesic (green) and xeric (red) groups (sample plots). Indicators for the mesic group: Quercus liaotungensis, Vitis piasezkii; indicators for the xeric group: Sophora davidii, Artemisia mongolica. For differential species of these groups see tab. 6-4.

Tab. 6-5: Forest Communities of Nan Niwan (TWINSPAN Groups and Dendrogram)

Floristic-sociological Distribution Patterns of Forest Vegetation in Nan Niwan						
Mixed Mesic Oak Forests				**Mixed Broadleaved and Coniferous Xeric Forests**		
Group 0 (n = 1)	**Group 1 (n = 19)**	**Group 2 (n = 41)**	**Group 3 (n = 19)**	**Group 4 (n = 26)**	**Group 5 (n = 15)**	**Group 6 (n = 3)**
---	*Quercus liaotungensis-Acer ginnala* commuity	*Quercus liaotungensis* community	*Acer stenolobumy*	Mixed Xeric Broadleaved Deciduous commuity	*Platycladus orientalis* community	*Koelreuteria paniculata* commuity

The classification procedure divides the *mixed mesic oak forests*—initially defined as *mesic group* with indicator species *Quercus liaotungensis* and *Vitis pisaszkii*—into four distinct groups (tab. 6-5). Group 0 consists of a single sample plot only. Because of its aberratic location in the ordination diagram, this plot cannot plausibly be assigned to group 1 and is excluded from the further interpretation.

Sample plots assigned to group 1 are summarized as *Quercus liaotungensis-Acer ginnala* community. Characteristic elements—besides the dominating tree species *Q. liaotungensis* and *A. ginnala*—are several differential species, which distinguish this community within the *mixed mesic oak forests* from the following communities (groups 2 and 3). Species nearly exclusively limited to the *Q. liaotungensis-A. ginnala* community are: *Aristolochia contorta, Cacalia delphiniphylla, Campylotropis macrocarpa, Chenopodium glaucum, Euonymus alatus, Fragraria ananassa, Galium bungei, Ligustrum molliculum, Malus baccata, Menispernum dauricum, Rubia cordifolia, Sonchus oleraceus,* and *Thladiantha dubia*.

Groups 2 and 3 are defined as *Quercus lioatungensis* community and *Acer stenolobum* community, respectively. A common species of these forest communities is *Ostryopsis davidiana*, a typical broadleaved shrub species of the oak forests of northwestern China. While both communities show no clear separation along the first two axes when highlighted in the ordination diagram (fig. 6-6), TWINSPAN discriminates these communities on the presence of *Acer ginnala* and *Lonicera maackii* in the *Quercus liaotungensis* community. On the other hand, the *Acer stenolobum* community is characterized by a higher abundance of tree species such as *A. stenolobum, Armeniaca sibirica, Euonymus verrucosoides* and *Lonicera stephanocarpa*. Finally, species with less demands on moisture, such as *Artemisia mongolica* and *Glycyrrhiza uralensis*, appear more frequently in the ground vegetation layer of the *A. stenolobum* community than in the *Q. liaotungensis* community.

In contrast to the *Q. liaotungensis-A. ginnala* community (1), no differential species exist to inambiguously separate the *Q. liaotungensis* community (2) from the *A. stenolobum* community (3). This partly explains that both forest communities overlap along the first two axes in the ordination space (fig. 6-6). Only when third axis scores are considered, these two forest communities disaggregate into to separate units, whereas this distinction is probably caused by differences in abundance and cover degree of certain species instead of the mere presence or absence of differential species (fig. 6-7).

With regard to the *mixed xeric forests* as represented by sample plots located in the right half of the diagram, the classification leads to three communities (tab. 6-5). Groups 4 and 5 can be characterized as spatially relevant forest communities, whereas group 6 is somewhat special in that it includes only a small number of sample plots that cannot properly be related to the complex moisture gradient of above. Group 6 is of little relevance in the spectrum of forest communities of Nan Niwan as discussed below.

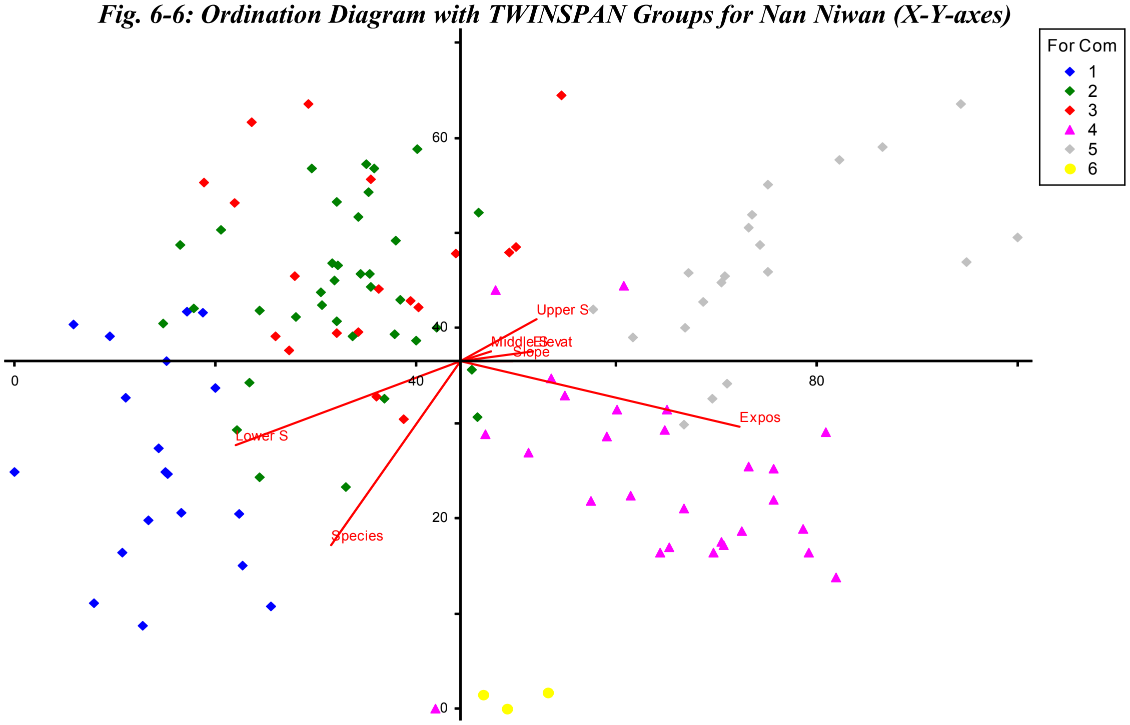
Group 4 is named *mixed xeric deciduous broadleaved community* (*mixed xeric forest community*). This community is characterized by a number of tree and shrub species, which are rarely found in the oak forests or the *Platycladus orientalis* community (group 5, discussed below). Among typcial species of this community are: *Amygdalus davidiana, Armeniaca sibirica, Lonicera hispida, Pyrus betulafolia Rhamnus rosthornii, Syringa komarowi, Ulmus macrocarpa, Xanthoceras sorbifolia*.

However, the *xeric deciduous* community and the *P. orientalis* community are both characterized by species such as *Bothriochloa ischaemum, Polygala sibiricum, Bupleurum longiradiatum* and *Sophora davidii*. The species *Siphonstegia chinensis* and *Wikstroemia chamaedaphne* are restricted to the *P. orientalis* community exclusively.

Group 6, finally, is termed *Koelreuteria paniculata* community and already determined on the second level of division in TWINSPAN. The community is characterized by species preferring sun-exposed and warm locations and, thus, from a floristic perspective is part of the xeric mixed forests. It is generally found at the bottom of loess cliffs and at the edges of cultivated open valleys.

The below ordination diagrams (fig. 6-6 and 6-7) synthesize the results of the vegetation analysis and present the formally classified forest vegetation communities of Nan Niwan together with major site parameters in a three-dimensional ecological space.

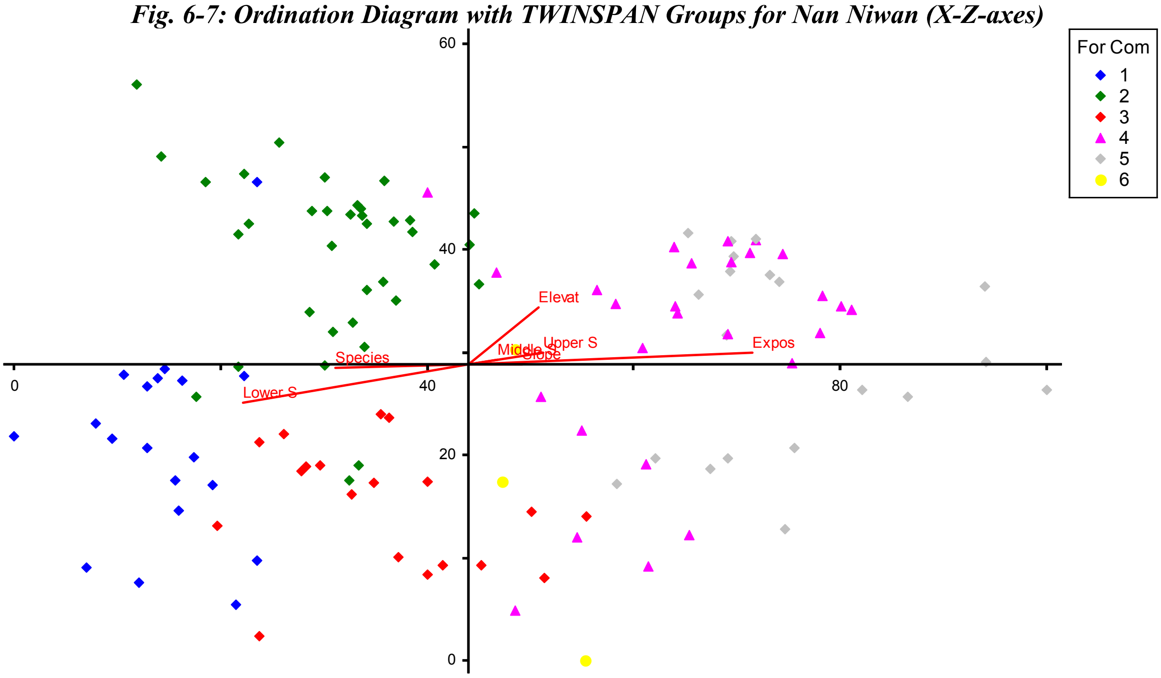
Fig. 6-6: Ordination Diagram with TWINSPAN Groups for Nan Niwan (X-Y-axes)



Note: Forest Communities: (1) Q. lioatungensis-A. ginnala community; (2) Q. liaotungensis community; (3) A. stenolobum community; (4) Mixed Xeric community; (5) P. orientalis community; (6) K. paniculata community

Both analytical steps—ordination and classification—have produced a complementary overview of the forests of Nan Niwan. While the ordination emphasized the vegetation continuum, the classification focused on specific and recognizable vegetation communities. The results are discussed in the framework of the Chinese zonal forest vegetation types of northern China in chapter 6.5 below.

Fig. 6-7: Ordination Diagram with TWINSPAN Groups for Nan Niwan (X-Z-axes)



Note: Forest Communities: (1) Q. lioatungensis-A. ginnala community; (2) Q. liaotungensis community;(3) A. stenolobum community; (4) mixed xeric com.; (5) P. orientalis com.; (6) K. paniculata com.

6.1.3 Statistical Significance: Site Parameters and Species Distribution

The differences in site parameters between the above six forest communities and the distribution patterns of several tree species were tested for statistical significance performing *one-way analysis of variance (ANOVA)* combined with a *Bonferoni test*. The null hypothesis was formulated for each site parameter and each tree species as zero difference between the forest communities. Six site parameters (*elevation, slope aspect, slope, three locational dummy variables*) and *species total per plot* were tested. In terms of species distribution, *mean cover degree* was selected as a variable to be tested. Only tree species spatially relevant were included, namely *Acer ginnala, A. stenolobum, Amygdalus davidiana, Armeniaca sibirica, Euonymus verrucosoides, Koelreuteria paniculata, Malus baccata, Platycladus orientalis, Pyrus betulafolia, Quercus lioatungensis, Sophora davidii,* and *Xanthoceras sorbifolia*.

Results of the ANOVA broadly confirm the above classification and tree species distribution centers and support the proposed ecological interpretation of the site parameter-species interaction. Tab. 6-6 below provides the resulting *p-values* of the Bonferoni multiple comparison for the site parameters elevation and the dummy lower slope/valley location for the *Q. liaotungensis-A. ginnala community*. Complete calculations are provided in Annex II.

The *Q. liaotungensis-Acer ginnala* community differs significantly in terms of elevation and location in the relief (lower slope/valley) from all other forest communities, except the *Koelreuteria paniculata* community (tab. 6-6). More specifically, the *Q. liaotungensis-A. ginnala* community is confined to the bottom locations in the local topography. Average species number per plot is also significantly higher in this community as compared to all other communities.

In terms of slope aspect—above identified as most pronounced indicator of site specific moisture conditions—signifcant differences exist between the three oak-dominated forest communities (*Q. liaotungensis-A. ginnala, Q. liaotungensis*, and *A. stenolobum* communities) and the mixed xeric forests (mixed xeric broadleaved deciduous community, *P. orientalis* community). Complete calculation results are provided in Annex II.

Tab. 6-6: p-Values for Site Paramters (Means) across Forest Communities (Samples)

Dependent Variable	Forest Community (TW Group)	Forest Community (TW Group)	p-value (* significant at 5% error level)
Elevation	*Q.liaotungensis-A.ginnala* –Community (Group 1)	Group 2	0.000*
		Group 3	0.014*
		Group 4	0.000*
		Group 5	0.000*
		Group 6	0.195
Lower Slope/Valley	*Q.liaotungensis-A.ginnala* –Community (Group 1)	Group 2	0.000*
		Group 3	0.000*
		Group 4	0.000*
		Group 5	0.000*
		Group 6	1.000

Note: Calculations were performed with SPSS 8.0 Guide to Data Analysis, Prentice Hall 1998.

Species distribution centers were approximated from individual cover degrees averaged for each community and, after logarithmic transformation of originally estimated cover values, compared over all forest communities of *Nan Niwan*. Although cover degree (and abundance) is only an insufficient indicator of a species' distributional range and ecological amplitude, differences in cover degrees—when carefully interpreted—still reveal some insights into individual distribution centers as shaped by local site conditions and competition. Especially in areas of rather low (abiotic/biotic) disturbances, competitive dominants under favorable conditions are likely to develop a dense canopy cover and high abundance that can be interpreted as distributional centers.

With significant differences in cover degree compared to all other forest communities, *A. ginnala* and *Malus baccata* (for the latter see Annex II) can be determined as the characteristic tree species of the *Q. liaotungensis-A. ginnala* community. No other species is so closely associated with this forest community. As discussed above, the *Q. liaotungensis-Acer ginnala* community differs significantly from all other forest communities in elevation and location in the terrain and, thus, in terms of its moisture regime is less dependent on the slope aspect.

Q. liaotungensis, on the other hand, exhibits a distribution center over the *Q. liaotungensis-A. ginnala* community and the *Q. liaotungensis* community with no significant differences in cover degree between these two communities. The dominance of *Q. liaotungensis*—as expressed in cover degree—declines, however, statistically discernable already toward the *A. stenolobum* community and the xeric forest communities (all p-values < 0.000). This indicates that *Q. liaotungensis* is rapidly becoming less competitive on sites that are shifted toward the drier section of the ecological moisture gradient. It also confirms the above observation that *A. stenolobum* serves as a transition species between the mesic and xeric sites where it by and large replaces *Q. liaotungensis*.

Regarding other spatially relevant tree species in Nan Niwan, *Euonymus verrucosoides* proves to be closely associated with the distribution of *Q. liaotungensis*. In contrast to *Q. liaotungensis*, however, this species does not show a discernable decline as early as in the *A. stenolobum* community. Its ecological amplitude appears to stretch out further toward the drier part of the spectrum with cover degrees significantly declining only in the mixed xeric (group 4) and *P. orientalis* communities (group 5).

Amygdalus davidiana can be characterized as the typical species of the mixed xeric community, here significantly different in cover degree from all other communities. *Armeniaca sibirica, Pyrus betulafolia*, and *Xanthocers sorbifolia* cover a broader distribution range in that they cannot always be statistically confined to the xeric mixed community. They appear to be accompanying species in all communities besides the *Q. liaotungensis-A. ginnala* and the *P. orientalis* community. *Sophora davidii*, a xerothermic broadleaved shrub, is statistically confined to the mixed xeric and the *P. orientalis* community. Finally, the distribution center of *P. orientalis* proves to be significantly different from all other communities. Its ecological amplitude is shifted to the most extreme sites at the dry end of the local ecological gradient.

Tab. 6-7: p-Values for Distribution Centers of Selected Tree Species

Dependent Variable	Forest Community (TW Group)	Forest Community (TW Group)	p-value (* significant at 5% error level)
Acer ginnala	*Q. liaotungensis-A.ginnala* community (Group 1)	Group 2	0.000*
		Group 3	0.000*
		Group 4	0.000*
		Group 5	0.000*
		Group 6	0.010*
Quercus liaotungensis	*Q. liaotungensis-A.ginnala* community (Group 1)	Group 2	0.073
		Group 3	0.174
		Group 4	0.000*
		Group 5	0.000*
		Group 6	0.005*
Platycladus orientalis	*Q. liaotungensis-A.ginnala* community (Group 1)	Group 2	0.000*
		Group 3	0.000*
		Group 4	0.000*
		Group 5	0.000*
		Group 6	1.000

Tab. 6-7 above shows the ANOVA results for *A. ginnala, Q. liaotungensis,* and *P. orientalis* for the first set of comparisons. Complete results are provided again in Annex II. A detailed description and interpretation of the classified forest communities is provided in chapter 6.1.4.

6.1.4 The Forest Types and Communities of Nan Niwan

6.1.4.1 The Mesic Oak Forests of Nan Niwan

Quercus liaotungensis-Acer ginnala **Community**

The *Quercus liaotungensis-Acer ginnala* community (*Quercus-A. ginnala community*) (group 1; see annex 1) is distributed over Nan Niwan exclusively in valley locations and on lower slopes. As this community occupies the lowest elevations, it can also be characterized at the micro-scale as the first element in a vertically oriented vegetation distribution in Nan Niwan.

Narrow valley locations shield the vegetation from direct solar radiation and comparatively longer shadow periods reduce evapo-transpiration. Site conditions are further shaped by intensive sub-surface water run-off from upper slopes as well as occasional root contact to the groundwater level. Overall, sites of this community are the most favorable and balanced in terms of soil moisture conditions in Nan Niwan. In the ordination diagram, sample plots of the *Quercus-A. ginnala* community represent the moist site spectrum of Nan Niwan, which is basically not affected by periodic summerly drought periods.

Layers of organic litter and organic mineral horizons (Ah) are well developed. Organic litter reaches on average 4 cm, while the Ah-horizon averages 8 cm (maximum 14 cm) over all plots. Dense vegetation cover results in continuous delivery of organic litter while balanced temperature and moisture conditions combined with favorable soil ventiliation of loess lead to its quick and complete transformation and humification by soil organisms. Both layers still contain carbonate. The high content of organic material possibly improves the water retention capacity and nutrient conditions of soils under the *Q. liaotungensis-A. ginnala* community as compared to other sites. Because of such favorable conditions, individual trees reach maximum heights up to 30 meters and diameters in breast height (dbh) up to 40 cm. Average height ranges from 18 to 20 meters and average dbh from 26 to 28 cm. Remains of *Salix spec.*, sporadically found along small creeks with diameters of up to 90 cm, give an indication of the excellent growth potential of these sites.

Stands of the *Q. liaotungensis-A. ginnala* community, in general, show a closed to open canopy with rich and well-developed understorey vegetation as light conditions improve. The tree layer is comprised of *Q. liaotungensis, A. ginnala, Malus baccata*, and *Euonymus verrucosoides* whereas, species such as *Caragana arborescens, Celastrus orbiculatus, Cotoneaster (C. multiflorus, C. ambiguus), Lonicera maackii, Spiraea (S. hirsuta, S. mollifolia)* and *Viburnum sympodiale* are recurrent elements of the shrub layer. Species, such as *Aristolochia contorta, Cacalia delphiniphylla* and *Galium bungei*, are closely associated with the *Quercus-A. ginnala* community (differential species) and indicative for the advantageous moisture conditions here. With an average species total of 38 species per plot (max. 47 species), the *Quercus-A. ginnala* community shows the highest species number of all communities.

Commercial forestry in Nan Niwan ended in 1999 with the imposition of the *Natural Forest Protection Progam* (NFPP) of the Chinese government. Prior to 1999, regular timber cutting was carried out in the area but it remains unclear to what extent and frequency the stands were utilized. Although stands of the *Quercus-A. ginnala* community are easily accessible by forest roads and, thus, well suited for silvicultural interventions, stands examined during the field surveys, in general, appeared to be relatively undisturbed and no signs of recent timber cuttings were found during 2000 and 2001.

***Quercus liaotungensis* Community**

The *Quercus liaotungensis* community (group 2; annex 1) succeeds the *Quercus-A. ginnala* community in the ordination diagram to the right and above (fig. 6-8). Because of its large spatial extent the *Quercus liaotungensis* community can be characterized as the most visible and predominating forest community of Nan Niwan.

The *Q. liaotungensis* community—mostly pure *Q. liaotungensis* stands—advances to middle and upper slopes. With rising elevation, slope aspect becomes a more prominent factor in the vegetation differentiation. Northern and eastern slopes are nearly exclusively dominated by *Q. liaotungensis* whereas on western slopes mixed *Q. liaotungensis* and *A. stenolobum*, i.e. the *A. stenolobum* community, is present. As discussed above, the transition between these communities is gradual despite the fact that statistically discernable differences in cover degree of selected species could be detected between communities. Species closely associated with the previous *Quercus-A. ginnala* community such as *Acer ginnala, Malus baccata, Lonicera maackii, Rubia cordifolia* and *Carpesium abrotanoides* gradually disappear in this community.

Q. liaotungensis forms homogenous stands with an often densely closed canopy. In undisturbed stands, there is often no distinct shrub layer developed, possibly because of reduced light conditions. Ground vegetation, however, is generally well developed with cover degrees of up to 75%. Very often the ground layer is dominated by *Carex lanceolata*. Average tree heights reach 12 meters (max. 20 meters) reflecting the comparatively good moisture and nutrient conditions on these sites. Average dbh is between 20 to 24 cm (maximum 40 cm). However, tree growth appears to be already reduced as compared to the previous community. The Ah-horizon averages 6 cm indicating that these stands exist already for a long time and some soil development has taken place without major disturbances. Upper soil layers as well as organic litter still contain carbonate that partly originates from continued silt import and deposition from nearby agricultural areas—a dynamic that affects all sites in Nan Niwan.

In some areas, sporadic human disturbances in the form of cutting of single or groups of trees have opened the closed canopy and led to mosaic-like stand structures with rich shrub and ground vegetation covers in the more open parts. Frequently found, then, are shrub species such as *Caragana arborescens, Cerasus polytricha, Cotoneaster (C. multiflorus, C. ambiguus, Spiraea (S. hirsuta, S. mollifolia),* and *Viburnum sympodiale*, with the latter being distributed over all expositions in Nan Niwan. A characteristic element of the shrub layer is *Crataegus cunneata* whose distribution is confined to the *Q. liaotungensis* community.

Besides species such as *Carex lanceolata, Dioscorea opposita* or *Lespedeza juncea*, which are found over all sites in Nan Niwan, the ground vegetation is characterized by those species confined to better moisture conditions, for example*, Ixeris polycephala, Aspidistra elatior, Vitis piasetzkii, Polygonatum odoratum*. With an average of 26 species per plot, species number is already smaller as in the previous community.

Human disturbances are found close to villages or neighbouring farmland where the local population more frequently interacts and utilizes the forests. In general, such utilization is irregular and depends on the specific needs of individual farmers in terms of time and quantity of wood needed. Multi-stemmed trees, dwarf shrubs as well as re-growth out of stumps are typical indications of such irregular non-commercial forest utilization.

Acer stenolobum Community

The *Acer stenolobum* community (group 3; annex 1) represents a transitional forest community positioned between the oak forests and the more drought-adapted xeric forest communities found on sites of more intense sunlight exposure and higher temperature and evaporation regimes. However, this community is still interpreted as an element of the oak forests of northwestern China.

Sample plots representing the *A. stenolobum* community are situated roughly in the center of the ordination diagram and describe the middle spectrum of the local humidity conditions along the expositon-dependent moisture gradient. A further indication of the ecological center position of this community between mesic oak forests and xeric forest communities is that individuals of *A. stenolobum* are found in the tree layer of the latter communities.

The *A. stenolobum* community is mainly concentrated on western and northwestern slopes. It is only sporadically found on northern, eastern, and southeastern slopes. Here, the community is confined to upper slopes and hilltops succeeding the *Quercus community* with gradually deteriorating moisture conditions. Hence, the *A. stenolobum* community can be characterized as a forest community that vertically as well as horizontally replaces the *Quercus* community along the ecological moisture complex-gradient toward its drier ends. This interpretation is confirmed by the differentiation of the communities along the first and third ordination axes (fig.6-7) whereas, however, the exposition-dependent moisture differentiation prevails.

A. stenolobum dominates the tree layer with an average height of 6 to 8 meters. It is frequently accompanied by *Euonymus verrucosoides*, while *Q. liaotungensis* is rarely found. The shrub layer is comprised of species like *Cerasus polytricha* or *Caragana arborescens* that are also found in the previous two communities as well as species that indicate already drier conditions, e.g. *Amygdalus davidiana, Armeniaca sibirica, Artemisia mongolica*.

With an average of 29 species per plot, the *A. stenolobum* community exhibits a similar species diversity as the *Q. liaotungensis* community. The humified mineral horizon with an average of 4 cm is small possibly because of reduced delivery of organic litter due to less dense canopy cover. Also possible is an increased export of organic material through higher wind erosion exposure on hilltops and upper slopes.

The evaluation and interpretation of human disturbances with regard to the observed stand structures in this community is difficult. The open canopy tree-shurb mosaic of the *A. stenolobum* community is possibly a purely ecological characteristic due to diminshed moisture and higher evapo-transpiration rates that result in reduced vegetation cover and slowed tree growth as well as more open areas and a higher proportion of shrubs without a distinct tree layer.

Such features, however, are also likely to be outcomes of human disturbances. Judging from the history of landuse in this area, it is apparent that there has been a long-term and often destructive interaction between man and forests, which could have resulted in such vegetation structures. Two interpretations of a possibly human-shaped vegetation community seem plausible as explained below.

Firstly, for many decades, local farmers of nearby villages have impacted these forests by harvesting trees for construction and other purposes in irregular intervals and used these areas as grazing grounds for livestock and fuelwood cutting. The alternation of closed stands of *A. stenolobum* and *E. verrucosoides* with areas of only single tree individuals (up to 12 meters high and with dbh of about 30 cm) within a dense shrub layer (*S. hirsuta, S. molliofolia, Ostryopsis davidiana, Viburnum sympodiale, Lonicera stephanocarpa, Lonicera maackii, Caragana arborescens, Rosa xanthina* etc.) supports this interpretation. Also, in many cases, stumps and patches of shrubs without a distinct tree layer are found adjacent to farmland and give some indication of the interaction between the rural population and the forests.

Secondly, with regard to the forest management framework of the Nan Niwan Forest Farm, it seems possible that the *A. stenolobum* community represents earlier cut-over areas. In the course of commercial timber harvesting several years before the imposition of the logging ban, the economically higher valued oak trees could have been removed while other less attractive species, such as *A. stenolobum*, remained. With natural regeneration on-going, it seems possible that former clear-cut patches steadily develop back into mixed oak stands. Then, stands of *A. stenolobum* would only represent a temporary formation that will disappear over time.

However, as to judge from the results of the ordination and the analysis of environmental site factors, it is indisputable that the *A. stenolobum* community is part of the vegetation continuum of Nan Niwan. Its position between the oak forests and the xeric forests can clearly be attributed to a gradual change in local humidity conditions along the identified gradients. From this perspective, the *A. stenolobum* community is interpreted here as a naturally occurring forest community of Nan Niwan that—floristic-sociologically—is an element of the mesic oak forests.

Finally, a common feature of all three forest communities and, thus the dominating forest type of Yan'an is that the life form spectrum is dominated by phanerophytes (57% of all species), followed by hemicryptophytes (19%), cryptophytes (12%), chamephytes (4%), and therophytes (4%). This is in line with other research findings in the northern China broadleaved deciduous oak forest zone (CHEN, 1992) and in the *Liu Pan Mountains* of the western part of the *Loess Plateau* (ZUO & ZHANG, 1992), where phanerophytes and hemicryptophytes are described as the dominating and characteristic life-forms of this forest type. Possibly, deep-rooted woody species as well as hemicryptophytes can better cope with the climatic and soil conditions of this vegetation zone as well as human disturbances.

6.1.4.2 Mixed Broadleaved and Coniferous Xeric Forests

Mixed Xeric Broadleaved Deciduous Community

On west-exposed to southwest-exposed slopes, the *A. stenolobum* community is replaced by the *xeric broadleaved deciduous* community (*xeric forest* community) (group 4; annex 1). Together with the *P. orientalis* community, this community exhibits a distribution center over the sun-exposed drier sites and is positioned in the right half of the ordination space (fig. 6-6).

Floristically, the *xeric forest* community is composed of a species rich tree and shrub layer with its overall character more appropriately described as an open woodland. Characteristic species are *Amygdalus davidiana, Armeniaca sibirica, Pyrus betulafolia,* and *Ulmus bergmanniana*. As noted above, *A. stenolobum* is still a common element of the tree layer while individual of *Q. liaotungensis* hardly found any more.

Besides these tree species, several drought adapted shrub species are common that are not present in the mesic oak forests. Among them are *Lonicera hispida, Platycladus orientalis, Rhamnus rosthornii, Sophora davidii, Syringa komarowi, Ulmus macrocarpa* and *Xanthoceras sorbifolia. Sophora davidii* and *Rhamnus rosthornii* are very closely associated with the community and, accordingly, can be identified as differential species of this community. Further differential species that can be used to distinguish this community from the oak forests are *Artemisia mongolica, Polygala sibirica, Bupleurum longiradiatum*, and *Bothriochloa ischaemum* of the sparsely developed ground vegetation layer. Finally, *Prinsepia uniflora*, a dwarf-shrub (< 1 meter) and *Speranskia tuberculata* could only be documented for the xeric forest community.

Average species total per sample plots is 29 in this community, with the life-form spectrum similar to that of the oak forests (phanerophytes 56%, chamaephytes 6%, cryptophytes 12%, hemicryptophytes 20%, therophytes 2%). Total cover of all three layers does not exceed 50%.

The organic mineral horizon is only incompletely developed and a layer of organic litter is rarely found. Besides the generally drier conditions, which slow down the accumulation of humified material in the mineral soil, the comparatively sparse vegetation cover provides only little organic debris. Furthermore, summerly rainstorms and strong winds during winter in these open woodlands possibly contribute to the impoverishment in organic material in that such material is washed out or blown away. Only on sites with lower slopes and less exposure, organic litter and humus accumulate to a certain extent.

An exhausting and concluding evaluation of structural aspects, ecological site conditions and human interferences in the natural vegetation development of the xeric forest community is difficult as already indicated above. Human disturbances are surely one of the factors shaping the vegetation; and stumps from earlier cuttings, animal traces, and many multi-stemmed short-grown individuals of *Armeniaca sibirica* or *Amygdalus davidiana* point toward frequent activities of humans in these areas. On the other hand, as emphasized above, this community is even further shifted toward the end of the local vegetation gradient and closely correlated with drier and less favorable growth conditions as can be judged from declining growth in height and diameter of trees here.

An interpretation that forest communities of the middle spectrum of local site conditions seem to be frequently impacted by humans, is offered as follows: Farmland is often located on similar sites as the *A. stenolobum* community and the xeric forest community, i.e. on sun-exposed on western and southwestern upper slopes where higher temperatures combined with sufficient rainfall during the summer months provide favorable growth conditions for agricultural crops. With the coincidental proximity of farmland to the above forest communities, human disturbances are automatically more frequent in these areas and impacts are more visible than in other locations.

Similarly, because of higher day temperatures during winter and spring as compared to northern and eastern slopes, freely moving livestock of nearby villages, i.e. goats, prefer these sites as grazing grounds and thus disproportionately impact vegetation development. The relative concentration of grazing might be even reinforced as those sites provide fresh green earlier in the year. From this interpretation, grazing would potentially be a considerable factor in site specific local vegetation development. Alternatively, it is also plausible that today's sites of the xeric forests had been farmland areas in earlier times that were abandoned several years ago and are now in midth of a natural succession process toward mixed oak and maple forests.

***Platycladus orientalis* Community**

The *Platycladus orientalis* community (group 5; annex 1) is nearly exclusively found on steep to extremely steep south-exposed slopes. The corresponding sample plots are located in the upper right of the ordination diagram (fig. 6-6). The sites on which the community is distributed are the most extreme in terms of water scarcity, temperature and evaporation conditions. Furthermore, natural stands of *P. orientalis* are mostly concentrated in the northern part of the Nan Niwan mountains where precipitation appears to be reduced as compared to the southern ridges, which present a more effective barrier to moist summerly air masses from the south and benefit from increased precipitation here.

Basically no layers of organic material—organic litter and humified mineral soil—exist in these stands. Litter is quickly transported downward and steepness prevents its accumulation and transformation. Soils often consist of undeveloped raw loess.

P. orientalis grows in open stands with heights between 6 to 7 meters (maximum height in Nan Niwan is 10 meters) with average dbh of 15 to 18 cm. Multi-stemmed individuals are frequently found with this feature likely being characteristic of the natural growth form of *P. orientalis*. On average, 22 species per plot were counted in the *P. orientalis* community, by far the smallest number over all forest communities of Nan Niwan. Total vegetation cover is generally below 50%. The low vegetation cover is probably due to the extreme site conditions here while disturbances by goats even on the extremely steep slopes above 50° are still visible. The life-form spectrum is similar to the above mentioned communities with 56% of the species being phanerophytes, 10% chamaephytes, 9% cryptophytes, 21% hemicryptophytes, and 1% therophytes.

Typical accompanying species of *P. orientalis* are *Sophora davidii* in the shrub layer and, among others, *Artemisia mongolica, Polygala sibirica* and *Carex lanceolata* in the ground layer. Also occurring are *Siphonostegia chinensis* and *Wikstroemia chamaedaphne*, a drought resistent dwarf-shrub distributed all over the semi-arid to arid central-northern part of the *Loess Plateau*.

When defining the forest communities it appears from the field observations that in the case of the *P. orientalis* community there is a more abrupt change in vegetation composition as compared to the more gradual transitions between the previous communities. Although, *P. orientalis* also occurs together with *Amygdalus davidiana* and *Armeniaca sibirica* in the *xeric forest* community, it seems that within the sites of the *P. orientalis* community conditions are at their extremes more or less completely preventing the establishment of other tree species and with *P. orientalis* being the most competitive species at this side of the moisture gradient.

Koelreutheria paniculata Community

The *Koelreutheria paniculata* community (group 6; annex 1) is an exception in the local vegetation range of Nan Niwan. It is represented by only three sample plots in the center and bottom of the ordination diagram and spatially of no importance.

The *K. paniculata* community can be found at the edges of open valleys that are often used for farming and dissect the forests on the loess hills. There, it is located at sun-exposed western and southwestern facing corners at the bottom of loess hills benefiting from rainwater downflowing from the above hills. Stands of *K. paniculata*, thus, are characterized by a much improved moisture regime as compared to the above situated xeric forest or *P. orientalis* communities while temperature and evaporation regimes are roughly similar. It is likely that this community emerged only after the valleys were opened up and cultivated by farmers, and therefore can be characterized as a secondary plant community. The species *K. paniculata* is only rarely found in the forests of Nan Niwan as it prefers light and open areas. As a floristic element of the forest vegetation of Nan Niwan, it is confined to the *xeric forests*.

6.2 Forest Vegetation of Huangling

6.2.1 Ordination Results

Natural forest vegetation in the southern part of *Yan'an* was examined in *Huangling State Forest Farm (Huangling County)*. After data compilation, 34 relevés were included into the analysis. Similarly to Nan Niwan, forest vegetation in Huangling appears to be continuously distributed along the first axis, again, with a disjuntion roughly in the middle of the ordination space. Plots are spread out vertically along axis 2 as well.

The vegetation gradient along axis 1 extents over 2.58 SD, along axis 2 over 1.92 SD, and along axis 3 over 1.76 SD. The relative shortness of this gradient—sample plots at its opposite ends are to some extent similar in their species inventory—points toward relatively small habitat differences in this area. Calculation results of the ordination are summarized in tab. 6-8 and illustrated together with classification results in fig. 6-8.

Tab. 6-8: Eigenvalues for Ordination Axes and Coefficients of Determination

	Eigenvalue λ (%)	**Coefficient of Determination (%)**
Axis 1	37.1	37.6
Axis 2	17.4	13.7
Axis 3	11.2	6.3

Species Combination in the Ordination Space

Species groups of the ordination pole areas differ in composition from those identified in Nan Niwan expressing the general large-scale trend of vegetation differentiation over an environmentally differentiated region. At the local (micro) level, however, pole areas indicate an analogous separation into a *mesic group* in the left and a *xeric group* in the right half of the diagram.

Despite the differences in overall species composition, *Acer ginnala* and *Quercus liaotungensis* are again elements of the moist range of local site conditions while *Platycladus orientalis*, *Ulmus bergmanniana*, and *Sophora davidii* are confined to the xeric domain in the local site spectrum. This result suggests that an ecological moisture gradient is responsible for the vegetation differentiation in Huangling as well. Tab. 6-9 lists tree and shrub species of these tentative groups (poles) according to their relative position (ordination value) over a roughly similar distance from the ends of the first axis 1.

Tab. 6-9: Tree and Shrub Species of the Pole Areas of the Ordination Diagram

Negative Ordination Space	Positive Ordination Space
Lonicera tragophylla	*Ulmus bergmanniana*
Toxicodendron vernicifluum	*Sageretia pycnophylla*
Rhus potaninii	*Platycladus orientalis*
Betula platyphylla	*Vitex negundo*
Rhamnus utilis	*Amygdalus davidiana*
Quercus liaotungensis	*Rhamnus rosthornii*
Acer ginnala	*Sophora davidii*

Interpretation of Ecological Site Parameters

The results of the site parameter analysis illustrate that vegetation differentiation in Huangling is even more closely correlated with slope aspect (r=0.84) as compared to Nan Niwan (r=0.61). With northern to northeastern slopes concentrated in the left half and southern to soutwestern slopes on the right side of the diagram, slope aspect appears to be the dominant factor in determining local moisture conditions and vegetation differentiation (tab. 6-10). Slope degree arises to be the second most important element in defining moisture conditions. Steep slopes are concentrated on the right and correspond to the generally drier sites in Huangling. Because of the weaker correlation (r=0.39), slope degree is only secondary when evaluating moisture-dependent vegetation differentiation.

Tab. 6-10: Correlation Coefficients (Pearson) for Ordination Scores and Site Parameters

	Axis 1	**Axis 2**
Site Parameter	**Correlation Coefficients r**	
Slope Aspect	0.838	0.096
Slope Degree	0.386	-0.078
Elevation	- 0.287	0.354
Valley/Lower Slope	-0.283	0.114
Middle Slope	0.106	-0.263
Upper Slope	0.030	0.203
Stand Parameter		
Species Number/Plot	-0.095	-0.206

Further parameters, such as elevation and binary relief variables, are less closely correlated with ordination scores along axis 1 than the above two parameters and as compared to Nan Niwan. However, they indicate that the relief, e.g. valley location or hilltop, is also of some relevance along axis 2, especially in the left half of the diagram, where sample plots are more spread out.

Here, sites at higher elevations, i.e. hilltops, are mostly located in the upper half of the diagram where the lower half contains middle and lower slope locations. Finally, the trend of decreasing species total per sample plot toward the drier end of the gradient, which was detected in Nan Niwan along the first ordination axis, cannot be confirmed for the forests of Huangling (tab. 6-10).

The joint plot diagram (fig. 6-8) displays the vectors of the three controlling parameters (exposition, elevation, slope) and supports the interpretation that a transition in species composition from less drought-adapted mesic communities (left) toward better-drought adapted xeric communities (right) takes place. With this differentiation, a causal relationship between small-scale site specific moisture conditions and vegetation differentiation seems plausibel in the same way as it was detected and discussed in Nan Niwan.

6.2.2 Classification Results

As in Nan Niwan, TWINSPAN confirms the existence of a mesic and xeric species group in Huangling (tab. 6-11). Indicator species such as *Acer ginnala* and *Patrinia scabiosaefolia* characterize the mesic (negative) group whereas *Platycladus orientalis* and *Amygdalus davidiana* are indicators for the xeric (positive) group.

Tab. 6-11: Dichotomy of TWINSPAN Groups along Moisture Gradient in Huangling

Indicator Species – Mesic Group		Indicator Species – Xeric Group	
Acer ginnala *Patrinia scabiosaefolia*		*Platycladus orientalis* *Amygdalus davidiana*	
Differential Species – Mesic Group		**Differential Species – Xeric Group**	
Tree and Shrub Species	Ground Vegetation	Tree and Shrub Species	Ground Vegetation
Betula platyphylla *Cornus macrocarpa* *Crataegus kansuensis* *Quercus liaotungensis* *Rhus potaninii* *Toxicodendron vernicifluum* *Vitis piasezkii*	*Agrimonia pillosa* *Anemone tomentosa* *Dioscora opposita* *Gelchoma longituba*	*Forsythia suspensa* *Rhamnus rosthornii* *Sageretia pycnophylla* *Sophora davidii* *Ulmus bergmanniana* *Vitex negundo* *Ziziphus jujuba*	*Artemisia lavandulaefolia/giraldii* *Artemisia mongolica* *Cynanchum sibiricum* *Polygala sibiricum*

On the third division level, TWINSPAN groups were inspected for their relative positioning in the ordination space and then merged into five groups for interpretation. When complemented with ordination results and field observations, these groups more adequately summarize the patterns of vegetation differentation in terms of forest types and communities in Huangling than TWINSPAN division alone.

As has been discussed earlier, the strict dichotomy of TWINSPAN divisions sometimes results in plant communities that are floristically nearly identical but were—ecologically implausible—separated because of symmetry reasons within the calculation procedure. The refined classification results, in conclusion, mirror the gradual change from oak-dominated mixed deciduous broadleaved forests (mixed mesic oak forests) under more favorable moisture conditions toward *Amygdalus davidiana* and *Platycladus orientalis* dominated forests under less favorable moisture conditions. In contrast to the *mixed xeric forests* of Nan Niwan, the range in the vegetation space between the mesic oak forests and the *P.orientalis* forests in Huangling is more clearly dominated by a single tree species, namely *Amydgalus davidana*.

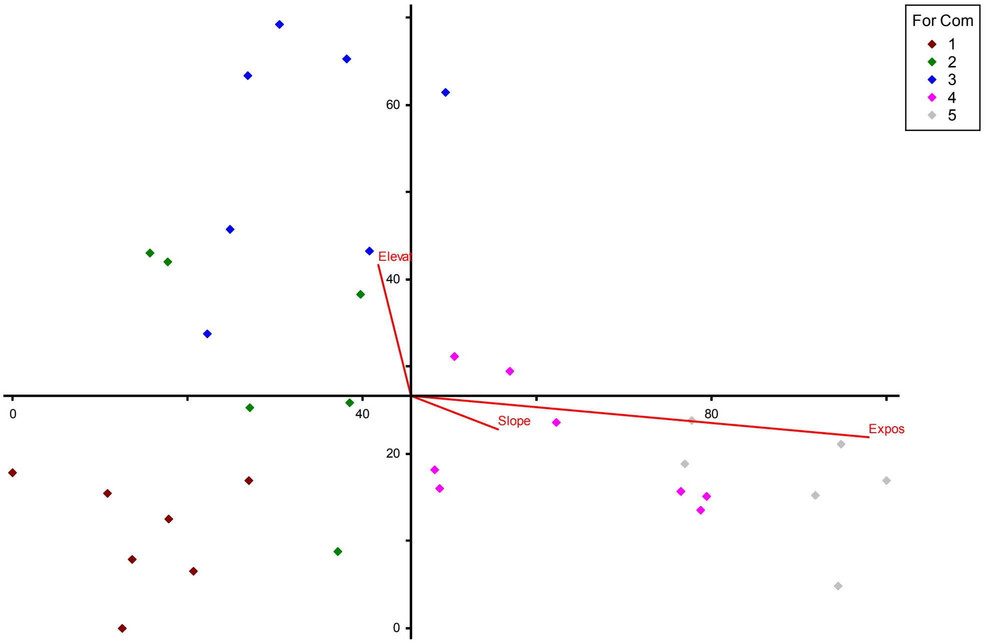
Classified forest communities of Huangling are summarized in tab. 6-12.

Tab. 6-12: Forest Communities of Huangling (TWINSPAN Groups and Dendrogram)

Phyto-sociological Distribution Patterns of Forest Vegetation in Huangling				
Mixed Mesic Oak Forests			**Mixed Broadleaved and Coniferous Forests**	
Group 1 **(n = 7)**	**Group 2** **(n = 6)**	**Group 3** **(n = 7)**	**Group 4** **(n = 8)**	**Group 5** **(n = 6)**
Q. liaotungensis-Betula platyphylla community	*Q. liaotungensis – Acer ginnala* community	*Q. liaotungensis* community	*Amygdalus davidiana* community	*Platycladus orientalis* community

Forest communities in Huangling are distributed over the range of local sites conditions in similar patterns as in Nan Niwan. The transition from mesic to xeric communities is basically indentical between these two locations. However, there are also differences in species composition of these communities as well as an increase of total species number in Huangling. These differences are to be attributed to differences in climate (generally more favorable as compared to Nan Niwan) and landuse history. According to the Chinese vegetation zonation system, Huangling is already closely located to the typical oak forest zone of northern China; and oak species other than *Q. liaotungensis*, such as *Q. aliena* and *Q. accutissima*, become more and more prevalent in this region (CHENG & WAN, 2002). Fig. 6-8 summarizes the above forest communities in their relative positioning within the ecological space. As these forest communities are sufficiently separated already along the first two ordination axes, their respective relationships are not further elaborated on in a third dimension.

Fig. 6-8: Ordination Diagram with TWINSPAN Groups for Huangling (X-Y-axes)



Note: Forest Communities: (1) Q. lioatungensis-B. platyphylla community; (2) Q. lioatungensis-A. ginnala community; (3) Q. liaotungensis community; (4) Amygdalus davidiana community; (5) P. orientalis com.

6.2.3 The Forest Types and Communities of Huangling

6.2.3.1 Mesic Oak Forests of Huangling

Within the mixed mesic oak forests of Huangling (see also annex 1), which include the *Quercus liaotungensis-Betula platyphylla* community (group 1), the *Quercus liaotungensis-Acer ginnala* community (group 2), and the *Quercus liaotungensis* community (group 3), species such as *Betula platyphylla, Quercus aliena, Rhus potaninii* and *Toxicodendron vernicifluum* appear in the tree layer as accompanying species. Species such as *Rhamnus glutinosa, Cornus macrocarpa, Rhamnus utilis, Picrasma quassioides* etc. frequently occur in the shrub layer. All these species could not be documented in Nan Niwan. They are mostly species that exhibit a distribution range throughout the northern China temperate deciduous broadleaved forest zone but often have their distribution centers in the *Qinling Mountains*, which are one of the extremely rich biodiversity centers in China (ZHENG et al., 1982). In general, these species are no longer found as the overall climate changes from humid (Huangling) toward semi-humid to semi-arid conditions (Nan Niwan and beyond) and vegetation gradually converses toward forest steppe and steppe vegetation types.

The *Q. liaotungensis-B. platyphylla* community appears to occupy those sites in Huangling, which are characterized by the most favorable moisture conditions. It is followed by the *A. ginnala-Q. liaotungensis* and the *Q. liaotungensis* communities with a weak indication that *Q. liaotungensis* being shifted toward relatively higher positions in the local terrain (as indicated by the elevation vector in fig. 6-8) with slightly reduced moisture conditions on hilltops of northern and northwestern slopes. However, it is difficult to establish a definite ecological separation and interpretation of these communities. Generally, *Betula platyphylla* and *Acer ginnala*, by and large, represent accompanying tree species of *Quercus spec.* in this region and appear and disappear on a narrow scale with slight changes in site conditions. The mesic mixed oak forests, however, are the dominating zonal forest vegetation type in this region.

The *A. stenolobum* community, which was defined as a transitional community between the oak forests and the mixed xeric forests of Nan Niwan cannot be found in Huangling at all. *A. stenolobum* as well as *Euonymus verrucosioides* rarely occur in Huangling and seem to be more confined to the center of the forest steppe transition zone where Nan Niwan is located. However, no further evidence for this assumption could be gained from the literature and landuse history might also be a factor on explaining this observation. For example, *Pinus tabulaeformis* was found on sites where *A. stenolobum* as well as *Euonymus verrucosioides* were to be expected. It is plausible that timber cutting resulted in the disapperance of both species whereas *P. tabulaeformis* stands were artifically established through air seeding or planting. However, it is equally plausible that the *P. tabulaeformis* stands in this area are natural stands and the presence of *P. tabulaeformis* cannot be related to the absence of these two species.

6.2.3.2 Mixed Broadleaved and Coniferous Xeric Forests

The *Amygdalus davidiana* and *Platylcadus orientalis* communities occupy the drier end of the ecological gradient in Huangling with the latter shifted to the relative most extreme sites, i.e. steep, fully-sun exposed southern and southwestern slopes. The *A. davidiana* community of Huangling differs from the corresponding *mixed xeric* forests of Nan Niwan in that *A. davidiana* more obviously dominates the tree layer of these stands, while other species such as *Armeniaca sibirica* and *Xanthoceras sorbifolia* are less frequent than in Nan Niwan.

The *A. davidiana* community forms dense stands of three to five meters height with a rich understorey of a variety of shrub species. Typical here are *Forsythia suspensa, Jasminum uniflorum, Quercus accutissima, Sageretia pycgnophylla, Vitex negundo* and *Ziziphus jujuba*. Overall, the *A. davidiana* community cannot be characterized as an open woodland as the mixed xeric forests of Nan Niwan. It also seems that these forests are much less influenced by grazing animals and fuelwood cutting. This latter observation gives a strong indication that the *A. davidiana* community is a natural element of the local vegetation continuum and *A. davidiana* as its competitive dominant species is favoured by the low disturbances here.

The *Platycladus orientalis* community, finally, is characterized as the local forest community dwelling in sites where other tree species are no longer competitive under the prevailing moisture conditions. *P. orientalis* in Huangling is characterized by indivdiuals that appear to grow larger in dimension (height and diameter) as compared to the growth potential of this species in Nan Niwan. This indicates that, despite *P. orientalis* is growing under conditions that are at their relative extrems, this species also benefits from the increased precipitation and temperature in the far south of Yan'an.

6.3 Degraded Secondary Steppe Communities of Yan'an

6.3.1 Ordination Results

Secondary steppe vegetation was examined in areas around *Luochuan County* (*southern Yan'an*) and the townships of *He Zhuang* and *Nan Niwan* (*northern and central Yan'an*). All three study sites are intensively used agricultural areas and characterized by a largely degraded secondary steppe vegetation with nearly no natural vegetation—assumingly forests and shrublands—remaining.

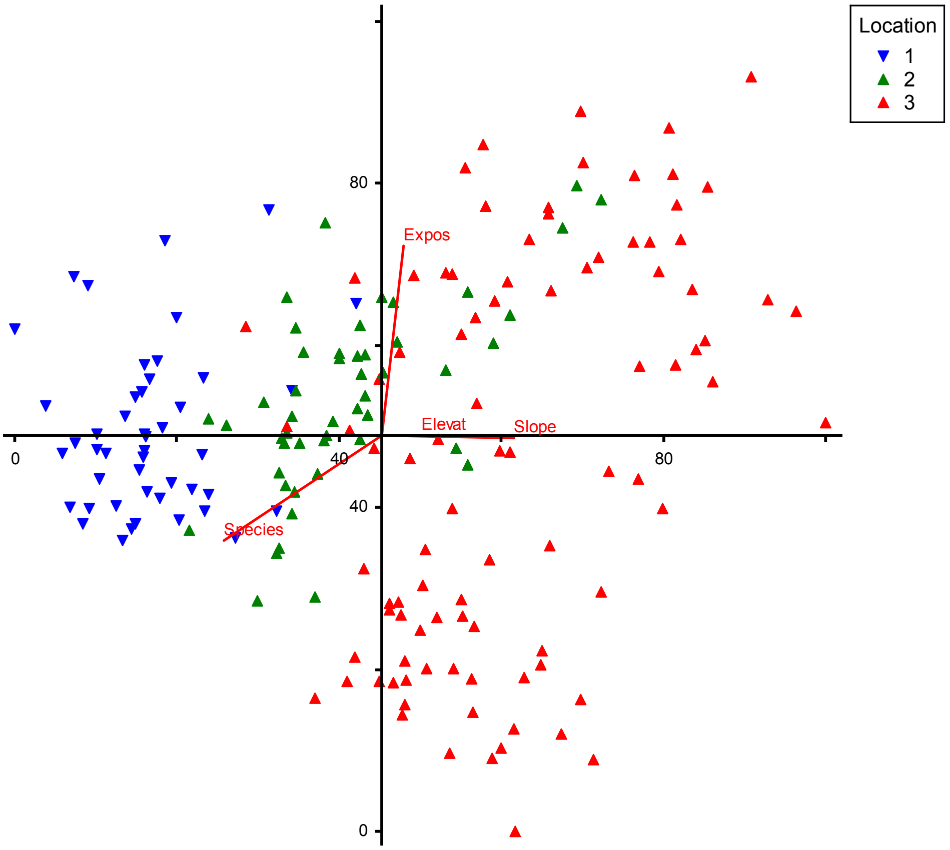
The ordination diagram below (fig. 6-9) illustrates a clear horizontal separation of sample plots of the three study sites according to their geographical location from south (left) to north (right) along the first ordination axis. Sample plots of *Luochuan* (location 1) are relatively densely grouped on the left side indicating a rather homogenous species composition. Sample plots of *Nan Niwan* (location 2) are located in the center of the diagram exhibiting an already somewhat less compact structure while sample plots of *He Zhuang* (location 3) in the right half of the diagram show a clear differentiation and clustering along the second axis (fig. 6-9).

Gradients along axes 1 and 2 are calculated at 3.2 and 2.8 SD, respectively, indicating that two vegetation gradients exist simultaneously as axes lengths differ only at a small margin. About 25% of total variance is captured along the first and second axis each (cumulative 50%) with both axes contributing about equally to the explanation of data variability. Eigenvalues and determination coefficients for the first three axes are summarized in tab. 6-13.

Tab. 6-13: Eigenvalues for Ordination Axes and Coefficients of Determination

	Eigenvalue λ (%)	**Coefficient of Determination (%)**
Axis 1	31.4	26.3
Axis 2	22.3	24.5
Axis 3	14.5	8.0

Fig. 6-9: Ordination Diagram of Degraded Secondary Steppes in Yan'an Prefecture



Note: Positioning of sample plots of secondary degraded steppe vegetation of Yan'an in a two-dimensional abstract floristic space. Location 1: Luochuan; location 2: Nan Niwan 2; location 3: He Zhuang

Species Combination in the Ordination Space

The ordination diagram reflects that the simultaneous evaluation of the three study sites basically captures two different levels of scale. Because of a distance of roughly 250 kilometers between the southernmost (*Luochuan*) and the northernmost (*He Zhuang*) study sites, the change in vegetation composition along the first ordination axis can be explained as a regional climatic vegetation gradient.

As to be judged from the corresponding species of the pole areas, vegetation gradually alters from the south to the north mirroring the overall climatic gradient over *Yan'an*. This gradient is visible despite the currently serious degradation of the vegetation. For example, elements of the Northern China Temperate Forest Zone, such as *Bothriochloa ischaemum, Oxytropis hirta, Potentilla saschinensis, Pyrus betulafolia, Rosa xanthina, Spiraea hirsuta* are relatively more often found in the south of *Yan'an* than in the north, which is already part of the transition to the Eurasian-Mongolian steppes. Here, for example, typical and frequently found species are *Astragalus melilotoides, Leontopodium leontopodoides, Setaria glauca, S. viridis, Stipa spec.* (tab. 6-14).

Tab. 6-14: Species of the Pole Areas of the Ordination Diagram

Negative Ordination Space (Southern Part)	Positive Ordination Space (Northern Part)
Vitex negundo	*Prinsepia uniflora*
Bothriochloa ischaemum	*Budleija alternifolia*
Miscanthus sacchariflorus	*Artemisia annua*
Anemone tomentosa	*Salsona collina*
Roegneria kamoji	*Wikstroemia chamaedaphne*
Lotus corniculatus	*Setaria viridis*
Pyrus betulafolia	*Setaria glauca*
Rosa xanthina	*Sophora davidii*
Spiraea hirstua	*Periploca sepium*

Interpretation of Ecological Site Parameters

The parameters *elevation* and *slope degree* are closely correlated with ordination scores along the first axis, i.e. with the three study locations. In contrast to the forest communities of Nan Niwan and Huangling, these correlations are, however, not to be interpreted as an indication of local site-specific ecological conditions. Because of the much larger area under consideration, these correlations much more express the large-scale trends in geographical features and land-use conditions over the prefecture. For example, direction and position of the vector representing *elevation* reflect the gradual increase in elevation from south to north over the *Loess Plateau*. While average elevation for sample plots in *Luochuan* was measured at 865 meters, elevation was at 1300 meters in *Nan Niwan* and at 1050 meters in *He Zhuang*.

The relatively strong correlation between vegetation patterns and *slope degree* (r=0.55) can possibly be attributed to a systematic overrepresentation of sample plots on steep slopes in the northern study location of *He Zhuang* in the *loess hills* (tab. 6-15). Until today, sloping land is intensively used for farming and, thus, a perennial secondary steppe vegetation (selected as sample areas) can only establish on the steepest and inaccessible areas. Secondary natural steppe vegetation is generally not found on plain areas or areas of more gentle slopes as these areas are used for agriculture.

In *Luochuan* in the south (*loess tableland*), however, farming has long experienced a restructuring, which is also related to more favorable climate conditions. By limiting agricultural activities to the most productive plain areas of the *tableland*, nearly all other areas are not cultivated any more and already covered by secondary steppe communities. Nan Niwan in central *Yan'an* is in an intermediary position between the two typical landscape types.

Finally, the vector representing *species total per plot* indicates that a south to north directed gradient exists with species number decreasing toward the northern part of the study area (fig. 6-9). When interpreting this gradient, however, it is difficult to plausibly attribute the decrease in species number to either climatic differences or differences in landuse patterns. Decreased rainfall and temperature in the north and relatively longer periods of undisturbed vegetation development in the south resulting from different landuse patterns, might both be causal for this trend.

Tab. 6-15: Correlation Coefficients (Pearson) for Ordination Scores and Site Parameters

	Axis 1	**Axis 2**
Site Parameter	**Correlation Coefficients r**	
Slope Aspect	0.228	0.644
Elevation	0.305	0.002
Slope Degree	0.546	-0.082
Stand (Plot) Parameter		
Species Number per Plot	- 0.595	-0.448

Of all recorded site parameters, slope aspect exhibits the strongest correlation with the vegetation with this relationship being shifted to the second ordination axis (tab. 6-15). Slope aspect is again correlated with a site-specific vegetation differentiation that is most pronounced in *He Zhuang* in the form of two distinct clusters of sample plots (fig. 6-9).

A similar pattern can also be uncovered for *Nan Niwan* and *Luochuan*, whereas the relation between slope aspect and sample scores is the weakest in the latter case. Based on this result, a causal relationship between vegetation differentiation and site-specific moisture regime seems likely for all three study sites. Although secondary natural vegetation is seriously degraded in these areas and shows basically no resemblance with the original forest or steppe vegetation, its differentiation is still along the site-specific moisture and evaporation regimes.

6.3.2 Classification Results

The classification of the degraded secondary steppe vegetation confirms for all three study locations the results of the above synpotic ordination and parameter analysis (see also annex 1). When separately examining the three study sites, a strong correlation between vegetation and slope aspect, and, thus, a moisture-determined vegetation differentiation can be detected in all three locations (tab. 6-16). This relationship is also evident from the existence of a plant community less adapted and a community better adapted to drought conditions in each location (tab. 6-17).

Correlation coefficients for sample ordination scores and slope aspect exceed other vegetation-envrionmental parameter relationships in all three locations. In general, other site parameters do not offer any further common interpretation option as they seem to be highly variable among the three locations. These are not further elaborated on as no additional insight into vegetation patterns is expected. Next to slope aspect, however, species number per plot is closely correlated along the first ordination axis in all three locations in addition to the more general south-north trend discovered above.

Here, the relationship displays a site-specific gradient with species number decreasing from northern slopes with better moisture conditions toward southern and southwestern slopes of lesser moisture conditions. As this pattern has been observed already for the forests of Nan Niwan, it can be assumed that the decreasing number of species toward the drier sites in a specific location is a general characteristic for this region and not to be attributed to the impacts of landuse and disturbances on the vegetation.

Tab. 6-16: Correlation Coefficients (Pearson) for Ordination Scores and Site Paramters

	He Zhuang		**Nan Niwan**		**Luochuan**	
	Axis 1	**Axis 2**	**Axis 1**	**Axis 2**	**Axis 1**	**Axis 2**
Site Parameter	**r**		**r**		**r**	
Slope Aspect	**0.819**	-0.286	**0.789**	-0.173	**0.804**	0.016
Elevation	-0.255	-0.111	0.082	0.263	-0.651	-0.558
Slope Degree	0.057	-0.473	0.352	0.032	0.318	0.118
Valley/Lower Slope	-0.307	0.001	-0.389	-0.159	-0.121	-0.113
Middle Slope	-0.079	-0.004	0.469	-0.141	0.243	0.095
Upper Slope/Hilltop	-0.210	0.003	-0.248	0.232	-0.214	0.031
Stand Parameter						
Species Number/Plot	**-0.737**	0.317	**-0.698**	0.158	**-0.759**	0.419

Regarding the classification of vegetation communities, the manifold transformations of the original natural vegetation and the rudimentary nature of the existing degraded secondary steppes in *Yan'an* limit the options to properly identify and interpret hierarchially-arranged floristic-sociological plant communities as such disturbances can overrule structures generated by the habitat. Possibly, vegetation elements, i.e. species and species groups, disappeared from the natural species spectrum or new non-native species were introduced into the area. Erosion, grazing and other external stress factors have greatly reshaped the original vegetation composition and ecological relationships between species, which all could lead to an inappropriate delineation and account of plant communities. Furthermore, temporal aspects, such as succession periods and recurrent disturbances remain largely unclear in their effects on the vegetation in these areas.

For the purpose of this study, it is sufficient to provide a classification of plant communities as obtained at the first division level in TWINSPAN. This division allows to plausibly separate communities slightly less adapted to drought conditions from those that are slightly better adapted to drought conditions for all three locations. This classification is also satisfying in that it confirms the dominance of a site-specific moisture gradient for different parts of the *Central Loess Plateau*. Further divisions only mask these relevant findings and are of no further value to the interpretation (see annex 1).

Tab. 6-17 summarizes indicator and preferential species for the less drought-adapted and better drought-adapted communities for each location. In contrast to the hierarchically arranged forest communities of Nan Niwan and Huangling that represent a more long-term view of the ecological environment in terms of forest vegetation types and communities (potentially being near-climax communities), the below listed communities represent a one-time picture of currently prevailing vegetation patterns in the heavily degraded areas of the *Loess Plateau*. As a consequence, terming these communities is only useful, if the specific locations are examined separately. The proposed classification, however, provides a baseline against which the effects of changes in underlying conditions can be monitored in the future.

In all three locations, vegetation communities are characterized by the occurrence of *Artemisia capillaris, A. giraldii, A. lavandulaefolia* and *A. mongolica* and, therefore, can be categorized as degraded secondary *Artemisia*-steppes. Further species, which do not exhibit any location or site preferences and are distributed all over the region, are *Geranium wilfordii, Pyrus betulafolia, Siphonostegia chinensis* and *Viola dissecta*.

Tab. 6-17: Ecological Species Groups of the Degraded Secondary Steppes in Yan'an

Ecological Species Groups of the Degraded Secondary Steppe Vegetation in Yan'an Prefecture					
Luochuan County		**Nan Niwan Township**		**He Zhuang Township**	
***Artemisia*-Secondary Steppe**	***Artemisia-Sophora davidii-Ziziphus jujuba* Shrublands**	***Artemisia*-Forest Shrublands**	***Artemisia-Sophora davidii*-Secondary Steppe**	***Artemisia*-Secondary Steppe**	***Artemisia-Sophora davidii* Secondary Steppe**
Indicators (-) *Miscanthus sacchariflorus* *Patrinia scabiosaefolia*	Indicators (+) *Sophora davidii*	Indicators (-) *Rubus mesogaeus* *Vicia villosa*	Indicators (+) *Bothriochloa ischaemum*	Indicators (-) *Patrinia scabiosaefolia* *Vicia villosa*	Indicators (+) *Sophora davidii*
Differential Species *Artemisia japonica* *Carex lanceolata* *Oxytropis hirta* *Roegneria kamoji* *Vicia villosa*	Differential Species *Cynanchum paniculatum* *Potentilla saschinensis* *Ziziphis jujuba*	Differential Species *Acer stenolobum* *Cotoneaster ambiguus* *Ostryopsis davidiana* *Patrinia scabiosaefolia* *Quercus liaotungensis* *Vitis piasezkii*	Differential Species *Budleijia alternifolia* *Rhamnus erythroxilon* *Rhamnus rosthornii* *Salsona collina* *Sophora davidii*	Differential Species *Carex lanceolata* *Phragmites communis* *Setaria glauca* *Setaria viridis* *Ulmus pumila* *Wikstroemia chamaedaphne*	Differential Species *Bothriochloa ischaemum* *Budlleija alternifolia* *Prinsepia uniflora* *Ziziphus jujuba*

In addition to the extensive and unspecific occurrence of *Artemisia spec.*, a moisture-specific differentiation into a relatively dry (positive) and relatively moist (negative) group can be observed. Species associated with the moist end of the ecological gradient and continually distributed over northern and northeastern exposition in all locations of *Yan'an* are *Anaphalis sinica, Bupleurum longiradiatum, Carex lanceolata, Cirisum segetum Hemistepta lyrata, Ixeris polycephala, Ledebouriella seseloides, Patrinia scabiosaefolia, Phragmites communis, Rubia lanceolata, Rubus mesogaeus, Taraxacum dissectum* and *Viola yedoensis*. On the other and, species such as *Bothriochloa ischaemum, Sophora davidii* and *Ziziphus jujuba* occupy the dry end of the gradient all over *Yan'an*.

Beyond the species that are common to all locations, there are characteristic differences in the species inventory between the three study sites.

In *He Zhuang*, in the north of the *Yan'an Prefecture*, the moisture-dependent gradient, according the ordination results, is more pronounced than in the other two locations (fig.6-9). Presumingly, the generally more extreme temperature and humidity regimes in the northern border region between temperate forests and steppes together with intensive land utilization and grazing determine an obvious differentiation into moisture-dependent communities on northern and northeastern slopes and xeric communities on southern and southwestern slopes.

The degraded secondary steppes of *Nan Niwan*, in the center of *Yan'an*, clearly reflect the influence of the nearby forests. Many typcial forest species such as *Acer stenolobum, Armeniaca sibirica, Cotoneaster ambiguus, Ostryopsis davidiana, Platycladus orientalis* and *Quercus liaotungensis* can be documented in the ground vegetation of the steppe communities here, while they cannot be found in the two other locations.

Being consistent with the findings from the above forest vegetation analysis, typical forest species occur outside the forests only on sites that, in their ecological conditions, correspond to sites within the forests where the respective species expose a distribution center. For example, while *Q. liaotungensis* is restricted to northern to northeastern slopes outside the forests, *P. orientalis* can only be found in the ground layer of southern to southwestern exposed slopes.

The degraded secondary steppe communities of *Luochuan*, despite their rather homogenous species composition as indicated in the diagram (fig. 6-9), also demonstrate that a change in species from less-drought-adapted to better-drought-adapted conditions takes place. However, this change is less visible in the field as compared to the previous two locations. Characteristic species for the moist sites are *Adenophora wawreana, Campylotropis macrocarpa, Lotus corniculatus, Patrinia scabiosaefolia* etc., while drier sites are characterized by species such as *Periploca sepium, Potentilla saschinensis, Sophora davidii* and *Ziziphus jujuba*.

6.4 Conclusion

Compared to the forest communities of *Yan'an*, which are comparatively well-preserved primarily because of the existence of state forest farms, human disturbances obviously have a much greater influence on vegetation distribution and differentiation in all three investigated locations of degraded secondary steppes. Impacts such as grazing and soil erosion are human-induced complex processes that partly overlap and obscure natural ecological site conditions and can lead to an impoverishment in the local species pool.

During the last decades landuse systems in *Yan'an* have experienced many changes that—to different degrees—have impacted the vegetation. Periods of more intensive land utilization with an accelerated environmental transformation have changed local species pools more rapidly than periods of less land intensive utilization. Currently, it seems that through the implementation of the Sloping Land Conversion Program (SLCP) and a general reduction of farming on sloping land, a large-scale succession process takes place in many areas of the *Loess Plateau* (including the study area) that has led to a rapid revegetation in many areas. From this background, the classification of the degraded secondary steppe vegetation communities is an attempt to capture the current status of the vegetation in a highly dynamic environment, where human and natural processes are at work at the same time.

The analysis of vegetation and site parameters, however, has revealed that, even for the degraded secondary steppe communities, a correlation between the site-specific moisture regime as (expressed in the slope aspect) and the vegetation differentiation exists. This leads to the conclusion that, in an area of rather homogenous soil and macro-climatic conditions, this site-specific moisture regime is the major ecological determinant in terms of different vegetation communities. As this relationship is prevalent in the forested areas of *Yan'an Prefecture* as well as in largely degraded areas, it represents an important component when formulating an ecological rehabilitation strategy for this particular area.

The relationship between site-specific moisture conditions and the potential for natural forest rehabilitation in today's degraded areas is further elaborated in the following section.

6.5 Developing a Scheme for Natural Forest Rehabilitation

6.5.1 Forest Communities of Yan'an as Part of China's Temperate Forests

Oak forests are the characteristic forest type of the temperate deciduous broadleaved forest zone of northern China. The overall macro-climatic conditions in *Yan'an*, thus, determine the dominance of mesophytic oak forests in Nan Niwan and Huangling. The forests of these two locations vary in their species composition somewhat but, more importantly, show recurrent compositional patterns along ecologically equivalent site conditions as shown in the analysis. Principally, ecologically motivated forest rehabilitation should recognize that oak forests are the most appropriate forest type when natural vegetation is to be restored or rehabilitated in this particular region. However, this proposition can be further detailed as is discussed below.

The Chinese forest vegetation classification differentiates between 12 sub-zones within the temperate oak forest belt of northern China. This classification is based mainly on the dominance of different oak species in different areas. For example, sub-zones of *Quercus mongolica, Q. liaotungensis, Q. acutissima, Q. variabilis, Q. dentata, Q. aliena etc.* are distinguished, whereas this distinction is also related to climatic variations between these sub-zones, i.e. annual precipitation, mean annual temperature etc. (WU, 2000).

According to this zonation, *Yan'an Prefecture* is part of the *Q. liaotungensis* sub-zone, which extends as a narrow belt of the warm-temperate climate zone from *Liaoning, Hebei, Shanxi* to *Shaanxi, Ningxia and Gansu*. In *Shaanxi*, *Q. liaotungensis* grows in the (northern) *Qinling Mountains* and the *Loess Plateau* with mean annual temperatures between 7 to 10°C and annual precipitation between 700 to 1000 mm. *Q. liaotungensis* forests do not occur any more when rainfall decreases to below 500 mm (WU, 2000). The current literature acknowledges that *Q. liaotungensis* is often mixed with other species (CHEN, 1992; CAS, 1995) but rarely discusses site-specific changes in species composition and their underlying ecological causes (ZHENG, 1998). It is thus often implied that the overall character of an oak-dominated forest doesn't change over its respective distribution zone. In line with these arguments, recent proposals to reforestation in the *Loess Plateau* favor to implement reforestation along the main features of such vegetation zones (CHEN et al., 2002).

The above study results largely support these proposals. However, there is also more room for refinement and more specific recommendations. With its community ecology perspective, this study further complements the somewhat simplifying approach of species-specific vegetation zonation and sub-zonation in that it proposes a more complete picture of vegetation patterns along locality-specific environmental gradients at the micro-scale.

While the oak forests of northern China in general and the *Q. liaotungensis* forests in particular, are described as zonal forest vegetation types or sub-types, *Platycladus orientalis* forests, on the other hand, are an additional element in the vegetation spectrum that needs to be considered in this context. More appropriately, *P. orientalis* forests can be characterized as an azonal forest vegetation type. This type is naturally distributed nearly all over China, including *Liaoning, Hebei, Shanxi, Shaanxi, Sichuan, Guangxi, Yunnan*, but does not exhibit a coherent distribution area that is confined to specific macro- or meso-climatic conditions. More typically, *P. orientalis* forests are generally restricted to relative extreme sites in terms of local moisture and temperature regimes. In *Shaanxi*, natural *P. orientalis* forests do not occur any more when annual precipitation decreases to less than 450 mm.

With regard to the *mixed xeric forest community* (Nan Niwan) and the *Amygdalus davidiana* community (Huangling), it appears that these communities represent a forest type in its own right that is distinctively different from the *Q. liaotungensis* and *P. orientalis* forests. In the Chinese literature, the mixed xeric/*Amygdalus davidiana* community is not further identified as an element of the oak forest zone nor as an azonal vegetation type, although it occupies an intermediary position between these forest types. However, the proposed classification more appropriately illustrates that oak forests are not simply accompanied by additional species. Instead, they gradually diverge into discernably different communities along continuous site-specific gradients. Changing site conditions from habitat to habitat are finally responsible for a change in the competition regime between species that leads to a characteristically different species assembly.

From the above findings, it seems to be justified to separate the *mixed xeric forests*, at least at the micro-level, from the *Q. liaotungensis* forests as this species is no longer indicative for the prevailing site conditions here. In addition, the numerical analysis clearly arranges the mixed xeric community closer to the *P. orientalis* community than to the mesic oak forests. Probably more accurately, the mixed xeric forests also take an intermediary position between zonal and azonal forest types. They represent a forest community that closely accompanies the mesic oak forests on sites of more xeric conditions but does not extend over a climatically defined region.

However arbitrary the discussion about delineating forest types and communities at different scales is, it indicates that it is important to thoroughly examine local site conditions as well as suited tree and shrub when planning revegetation activities. With such a detailed analysis, forest rehabilitation might be more often successful compared to rather plain approaches that do not differentiate properly between the different scales and ecological gradients at work.

6.5.2 The Natural Native Forest Communities and Matching Site Conditions

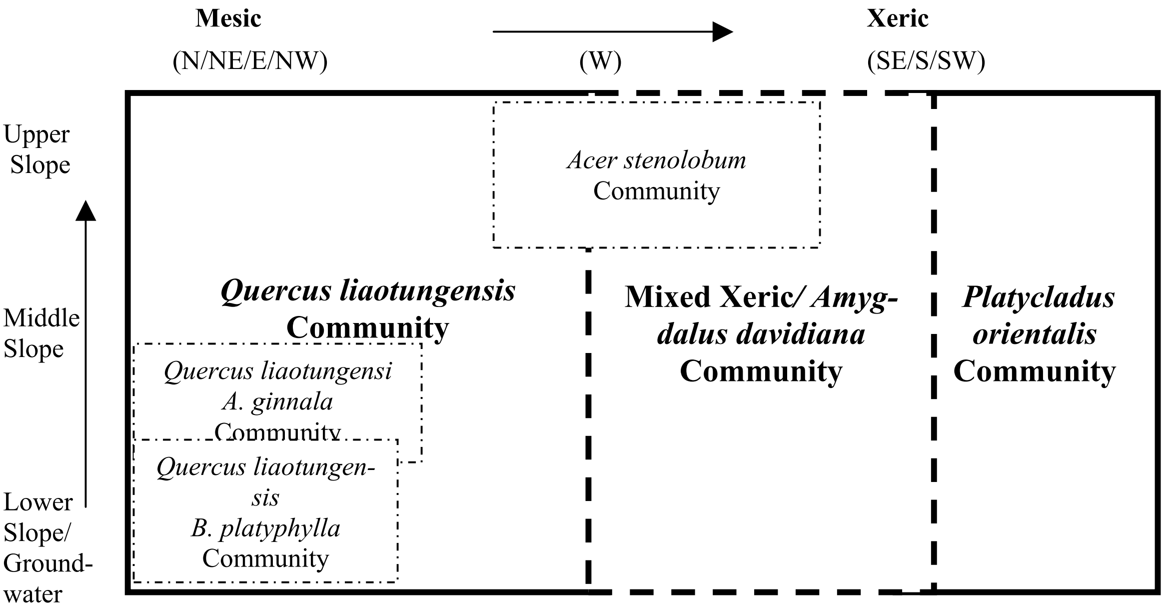
For *Yan'an*, several forest communities have been derived that despite human disturbances can be differentiated in their floristic composition along an ecological moisture gradient. This gradient consists of parameters such as slope aspect, elevation, relief, and slope degree. Basically, slope aspect is the major determinant of local moisture conditions in the two study locations, Nan Niwan and Huangling, whereas other parameters vary in their relevance for the vegetation differentiation between the locations. All parameters can easily be identified in the field and related to vegetation patterns.

Differences in the amount of data evaluated and in species composition between the two locations have resulted in slightly different arrangement and delineation of forest communities during the classification procedure. However, there is a strong analogy between the forest communities of Nan Niwan and those of Huangling, which confirms that both locations are part of the same forest vegetation zone. The close correlation between tree species, forest communities and site parameters provides a sound foundation for decision-making when sites and species are to be selected for ecological forest rehabilitation.

The important contribution of the analysis is that it enlarges the spectrum of species that are conventionally chosen for afforestation. More specifically, this study takes an approach to reforestation that is directed at rehabilitating forest ecosystems rather than solely planting trees.

By proposing naturally adapted plant communities as objectives of reforestation rather than mono-species plantations, it implicitly favors natural revegetation processes over artifical plantings in the first place. Where natural succession alone might not be able to achieve specific objectives sufficiently, reforestation planners can gain some orientation for species selection and mixed plantings along the ecological positioning of natural forest communities (fig.6-10) and the list of species representative for each of these communities (tab. 6-18).

Fig. 6-10: Schematic Distribution of Forest Communities in Yan'an Prefecture



Tab. 6-18: Site-adapted Woody Species as Guidance for Forest Rehabilitation in Yan'an

Yan'an Central Part	**Mesic Oak Forests**			**Xeric Mixed Boradlevaed and Coniferous Forests**	
	Quercus liaotungensis Acer ginnala	**Quercus lioatungensis**	**Acer stenolobum**	**Xeric Mixed**	**Platycladus orientalis**
Sites	**Lower Slope Valley Locations**	**N/NE/NW/E Lower to Middle Slopes**	**NW/W Middle to Upper Slopes**	**W/SW/SE All Locations**	**W/SW/S Steep Upper, to Middle Slopes**
Tree Species	*Quercus liaotungensis* *Acer ginnala* *Malus baccata* *Celtis bungeana* *Cladrastris wilsonii* *Populus adenopoda* *Populus cathayana* *Populus davidiana*	*Quercus liaotungensis* *(Acer ginnala)*	*Acer stenolobum* *Euonymus verrucosoides* *Armeniaca sibiricum* *Koelreuteria paniculata* *(Quercus liaotungensis)*	*Amygdalus davidiana* *Ace. stenolobum* *Ailanthus altissima* *Armeniaca sibiricum* *Celtis biondii* *Koelreuteria paniculata* *Pyrus betulafolia* *Ulmus macrocarpa* *Xanthoceras sorbifolia*	*Platycladus orientalis*
Shrub Species	*Cerasus polytricha,* *Cotoneaster ambiguous, C. multiflorus* *Lonicera stephanocarpa* *Ostryopsis davidiana* *Spiraea hirsute, S. mollifolia* *Syringa komarowi* *Ulmus pumila* *Viburnum sympodiale*			*Cotoneaster ambiguous, C. multiflorus* *Rhamnus rosthornii* *Sophora davidii* *Syringa komarowi* *Ulmus pumila*	
	Ligustrum mollicum *Lonicera maackii* *Syringa. vulgaris*	*Crataegus cunneata* *Lonicera maackii* *Syringa vulgaris*	*Caragana arborescens* *Rosa xanthina*	*Caragana arborescens* *Lonicera hispida* *Rosa xanthina* *Spiraea hirsuta* *S. mollifolia*	*Wikstroemia chamaedaphne*
Yan'an Southern Part	**Mesic Oak Forests**			**Xeric Mixed Boradlevaed and Coniferous Forests**	
	Quercus liaotungensis-Betula platyphylla	**Quercus liaotungensis -A. ginnala**	**Quercus liaotungensis**	**Amygdalus davidiana**	**Platycladus orientalis**
Sites	**Lower Slope Valley Locations**	**N/NE/NW/E Lower to Middle Slopes**	**NW/W Middle to Upper Slopes**	**W/SW/SE All Locations**	**W/SW/S Steep Upper, to Middle Slopes**
Tree Species	*Quercus liaotungensis* *Acer ginnala* *Betula platyphylla* *Quercus accutissima*	*Quercu. liaotungensis;* *Acer ginnala* *Rhus potaninii*	*Quercus liaotungensis* *Pinus tabulaeformis* *(Acer ginnala)*	*Amygdalus davidiana* *(Armeniaca sibirica;* *Ailanthus altissima;* *Ulmus bergmanniana)*	*Platycladus orientalis* *Ulmus bergmanniana*
Shrub Species	*Cornus macrocarpa* *Cotoneaster ambiguus, Cotoneaster multiflorus* *Eleagnus umbellata* *Cerasus polytricha* *Lonicera hispida* *Ostryopsis davidiana* *Spiraea hirsute, S. mollifolia* *Viburnum sympodiale*			*Cerasus polytricha* *Forsythia suspense* *Jasminum uniflora* *Lonicera hispida* *Picrasma japonica* *Sageretia pycnophylla* *Sophora davidii* *Spiraea hirsute, S. mollifolia* *Viburnum sympodiale* *Vitex negundo*	

6.5.3 Ecological Appropriateness – Transferring Forests to Degraded Steppes

6.5.3.1 Conceptual Issues

The analysis of degraded secondary steppe communities revealed that differences in species composition can be correlated to an ecological moisture gradient similar to the one apparent in natural forests. Whether degraded secondary steppes can ultimately be "returned" to natural secondary forests from an ecological point of view needs a broader perspective beyond a single study site. This question is examined by simultaneously placing sample plots of natural forests and secondary steppes into a single ordination diagram and investigating their relative positioning in the ecological space. As sample plots will be differentiated according to their species composition, forest communities and steppe communities will clearly be separated into two different clusters that reflect different geographical location and land management history. The important question, whether today's steppes are potential forest sites, then, needs to be evaluated from the analysis of ecological site parameters.

Firstly, an indication of forest suitability can possibly be gained from the relative spread of forest as compared to steppe plots along vectors that represent moisture conditions. With steppe plots further spread out than those of forests in the direction of such a vector, it can be concluded that steppe communities possibly extend over a larger spectrum of site conditions beyond the range of conditions forest communities are able to establish on. Alternatively, if forest plots are spread out more than steppe plots along a common gradient, it seems likely that all sites are potential forest sites.

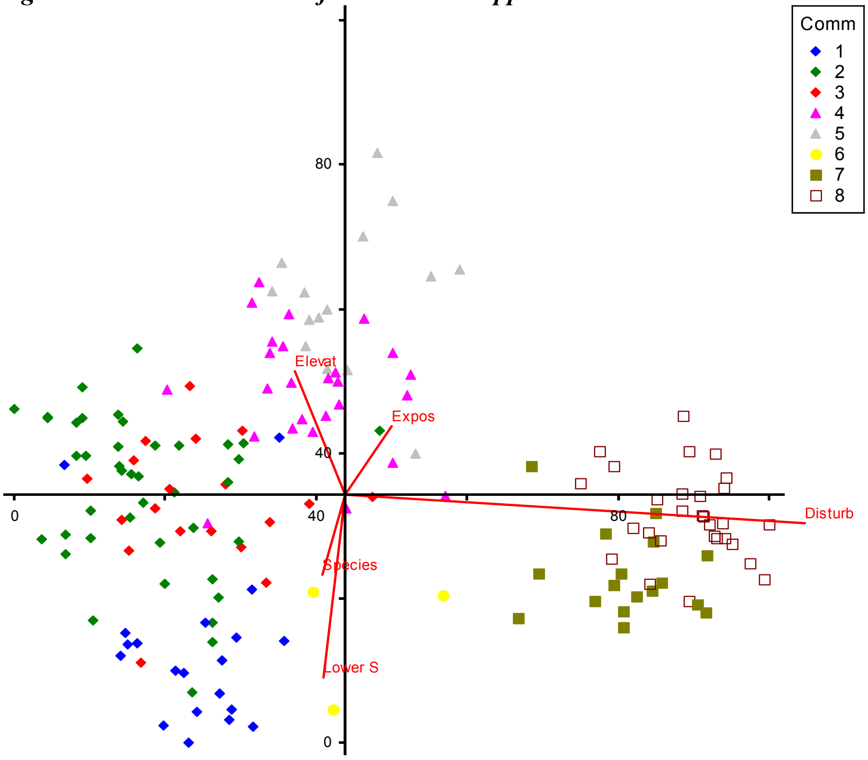
Secondly, there is also a possibility that additional gradients appear when synoptically examining forest and steppe communities. These might have not been detected when examining locations separately but, nevertheless, represent relevant humidity gradients and possibly preclude the existence or establishment of forests. In this case, approaches to ecological landscape rehabilitation need to consider the re-establishment of plant communities, i.e. natural steppes, that are suited to the respective site conditions here.

6.5.3.2 Forests and Steppes of Nan Niwan

For Nan Niwan, the joint ordination diagram illustrates that forest and steppe sample plots are clearly separated along the first ordination axis as they differ in species composition (fig. 6-11). Since forest and secondary steppe sites are located in close proximity (neighboring sites), the first axis gradient is basically a result of long-time human interference (disturbance) and its effects on the vegetation. Obviously, differentiation is not due to an environmental gradient in this case.

Along the second axis, sample scores of forests and steppes are both correlated with the parameters *slope aspect*, *elevation,* and *relief* as indicated by the direction of the corresponding vectors. Here, the already identified moisture gradient emerges again (fig. 6-11; tab. 6-19). As both sample sets cover the whole range of site conditions in this particluar location, i.e. plots of each set are equally distributed over all expositions, the more clustered positioning of steppe plots indicates that human disturbance has not only altered the species composition of sample plots but also resulted in a greater homogeneity (reduction of diversity and degradation) as compared to the secondary natural forest communities.

Fig. 6-11: Relative Position of Forest and Steppe Communities in Nan Niwan



Note: Synoptical ordination of forest and steppe communities. Community 1: A. ginnala-Q. liaotungensis; Community 2: Q. liaotungensis; Community 3: Q. lioatungensis-A. stenolobum; Community 4: Mixed Xeric Forest; Community 5: Platycladus orientalis; Community 6: Koelreuteria paniculata; Community 7: Forest Shrublands; Community 8: Artemisia-Sophora Steppe

Fig. 6-11 further confirms the parallel vegetation response of forests and steppes along the moisture gradient when including the classified forest and steppe communities into the diagram. Forests as well as steppes are both vertically separated into mesic and xeric communities indicating a corresponding response of the two different sets of plant communities along equivalent site conditions. Finally, the trend of increased species total per plot toward the moist site spectrum remains visible for both clusters.

Tab. 6-19: Gradients, Eigenvalues and Correlation Coefficients for Site Comparisons

	Nan Niwan-Nan Niwan		**Nan Niwan-He Zhuang**		**Huangling-Luochuan**	
	Axis 1	**Axis 2**	**Axis 1**	**Axis 2**	**Axis 1**	**Axis 2**
Gradient Length	3.3	2.7	3.9	2.6	3.4	2.3
Adjust. Eigenvalue (%)	45.3	13.0	51.9	15.8	67.8	5.0
Site Parameter						
Slope Aspect	0.288	0.358	0.097	0.694	0.274	0.542
Elevation	-0.300	0.477	-0.909	-0.019	-0.703	0.262
Slope Degree	-0.106	0.071	0.492	0.160	-.0.004	-0.252
Valley/Lower Slope	-0.193	-0.581	0.060	-0.079	-0.061	0.014
Middle Slope	0.102	0.207	0.137	0.041	0.301	-0.129
Upper Slope/Hilltop	0.049	0.306	-0.181	0.042	-0.296	0.169
Location (Dummy)	0.902	-0.230	0.965	0.069	0.956	-0.073
Stand/Plot Parameter						
Species Number/Plot	-0.205	-0.385	-0.516	-0.467	-0.521	0.095

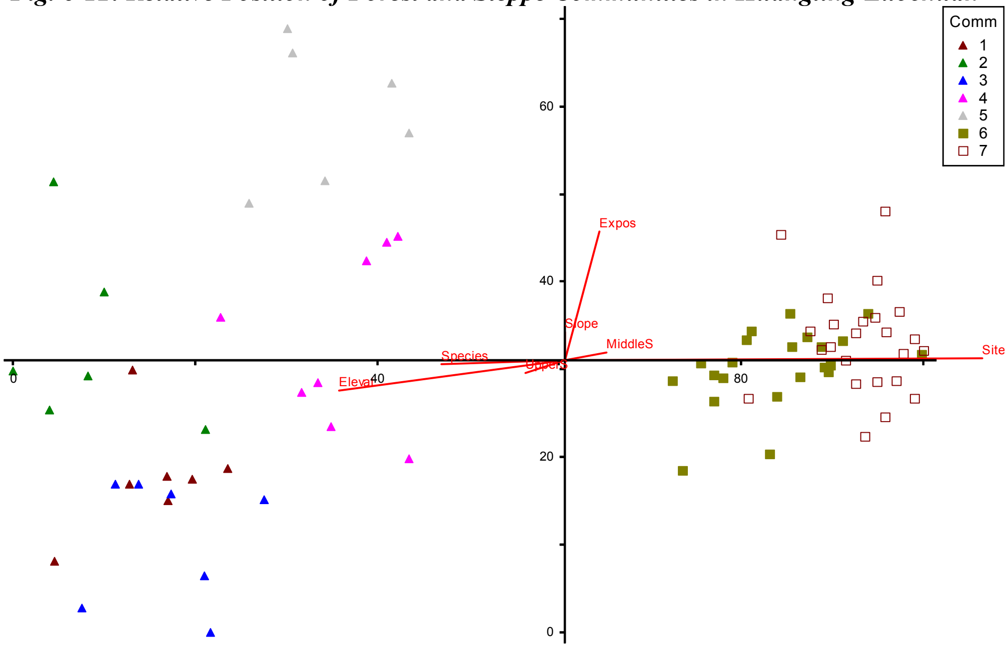
In terms of ecological rehabilitation, it seems reasonable from the results to adopt a scheme of site-specific forest communities as proposed above (tab. 6-18). The scheme can serve as guiding principle for all locations and sites in the proximity of Nan Niwan, i.e. the central part of Yan’an. There is no indication that the distribution of steppe communities is determined by environmental conditions distinctly different from those prevailing in the forests that would preclude the existence or re-establishment of forests here.

6.5.3.3 Forests of Huangling and Steppes of Luochuan

In the south of *Yan’an*, forest communities of *Huangling* and degraded secondary steppe communities of *Luochuan* are simultaneously examined. Both locations are located closely together in the south of the prefecture where annual precipitation (> 620 mm), temperature (> 9.2 °C) as well as soil conditions (tab. 6-21) are more favorable for forest growth than in the prefecture’s central and northern parts.

Similarly to *Nan Niwan*, forest and steppe communities are clearly separated along axis 1 with forests of *Huangling* positioned in the left and steppes of *Luochuan* in the right half (fig. 6-12). Although elevation is strongly correlated with first axis ordination scores, it seems unlikely that this vector is an indication of profound environmental differences that preclude the existence of natural forests in *Luochuan*. Again, the vegetation differentiation along axis 1 seems more to be an outcome of the different landuse history in these two sites.

Fig. 6-12: Relative Position of Forest and Steppe Communities in Huangling-Luochuan



Note: Synoptical ordination of forest and steppe communities *Community 1-3: Q. liaotungensis (Betula platyphylla, Acer ginnala); Community 4: Amygdalus davidiana Ccommunity 5: Platycladus orientalis; Community 6: Artemisia Steppe; Community 7: Artemisia-Sophora-Ziziphus Shrubs*

While the densely populated plains of *Luochuan*, easily accessible and highly productive agricultural areas, were intensively cultivated for many centuries, the mountaineous areas of *Huangling* were possibly better preserved because of less favorable geo-morphological conditions for agriculture, and hence, less population pressures.

More recently (after 1949) administrative protection in form of a state-owned forest farm might have contributed to the protection of forests as well.

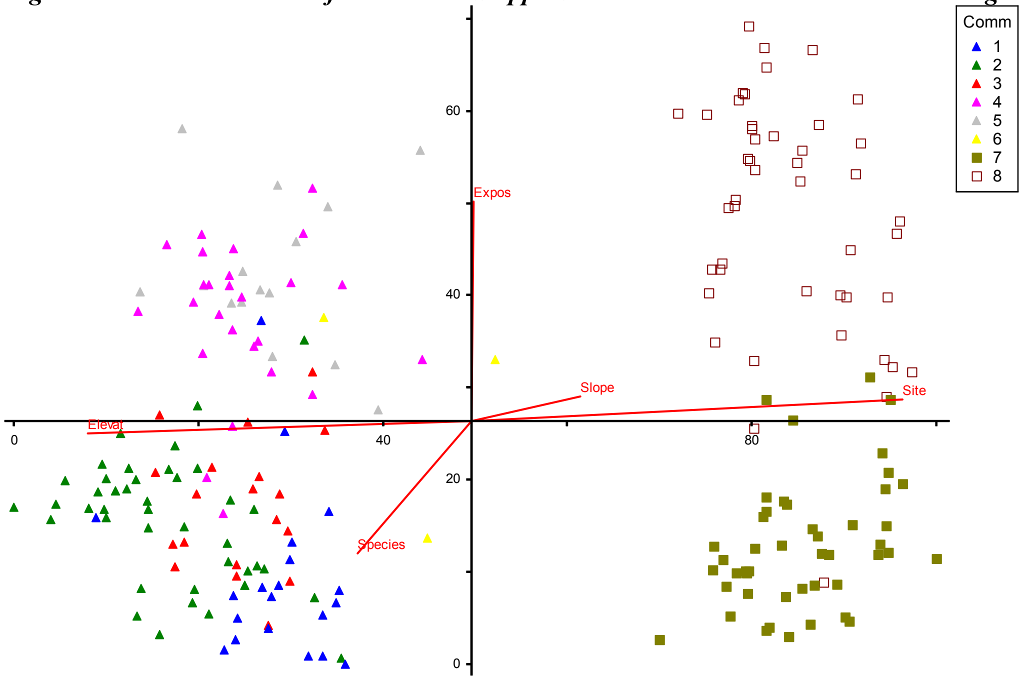
Similar to *Nan Niwan*, the relative concentration of sample plots in the right half of the diagram (steppes of *Luochuan*) indicates a greater species homogeneity over the plots than in the forests of *Huangling* (left). On the one hand, intensive disturbances of these areas, e.g. animal grazing, fodder harvesting, possibly fostered a selection of grazing tolerant species and led to the disappearance of many other species. Equally plausible, on the other hand, is that with a shift of human activties toward the plain areas, a natural succession process started on the investigated sites, which in its beginning is characterized by a large degree of species homogeneity. Again, species total per plot is higher in forests than in steppes.

The site-specific exposition-dependent moisture gradient is again shifted to the vertical axis with mesic communities (lower half) gradually diverging into more xeric communities (upper half), although this pattern is less apparent for the steppe communities of *Luochuan*. For rehabilitation efforts in *Luochuan* and adjacent areas, it seems, however, justified to follow the guiding scheme of communities and species set out in tab. 6-18.

6.5.3.4 Forests of Nan Niwan and Steppes of He Zhuang

The comparison of forest communities of *Nan Niwan* (*central Yan’an*) with the secondary steppes of *He Zhuang* (*northern Yan’an*) demands a cautious interpretation in terms of the latter’s suitability for forest vegetation (fig. 6-13).

Fig. 6-13: Relative Position of Forest and Steppe Communities in Nan Niwan-He Zhuang



Note: Synoptical ordination of forest and steppe communities. Community 1: A. ginnala-Q. liaotungensis; Community 2: Q. liaotungensis; Community 3: Q. lioatungensis-A. stenolobum; Community 4: Mixed Xeric Forest; Community 5: Platycladus orientalis; Community 6: Koelreuteria paniculata;Community 7: Artemisia Steppe; Community 8: Artemisia-Sophora Steppe

Possibly, the separation of sample sets along the first axis is not only due to differences in land management as proposed for *Nan Niwan* and *Huangling/Luochuan* but at least partly resulting from different environment conditions. It is important to note that the ordination diagram here captures two levels of scale, namely the horizontal distance of roughly 80 kilometers between *Nan Niwan* and *He Zhuang* (axis 1) and the local sites in each location (axis 2).

As shown in chapter 5.1.2, precipitation and temperature are less favorable in *He Zhuang* than in *Nan Niwan* with a decrease in annual rainfall of about 40 mm and annual temperature of 1.2 K. Besides climatic differences, the correlation with slope degree along the first axis points to differences in landscape features with potential relevance for forest growth (tab. 6-21). Generally, *Nan Niwan* is more gently sloped than the typical loess hills of *He Zhuang*.

Along the second axis, the exposition-dependent moisture gradient becomes apparent again with southern and southwesten expositions concentrated at the upper half of the diagram. Differently from the above diagrams (fig. 6-11; 6-12), plots sampled in degraded steppes are clearly further spread out toward the drier end of the moisture gradient, although both sample sets cover the same range of expositions.

However, it remains confusing from the below ordination diagram (fig. 6-13) whether profound differences in environment conditions or simply the human disturbances are responsible for the two-dimensional separation of sample plots in *He Zhuang*. Probably, the gradual change in soil conditions— clay and silt contents gradually decrease over the *Loess Plateau* from southeast to northwest while sand content increases—is an important additional factor that precludes the simple transfer of forest communities identified in *Nan Niwan* to the steppes of *He Zhuang*. Differences in particle composition possibly lead to an alteration in soil moisture conditions between the two locations.

JIANG (1997), for example, provides data on the changes in particle composition over the northen section of *Shaanxi* (tab. 6-20). The data supports the above proposition in that the increase in the sand fraction and decrease in clay and silt from south to north can be intepreted as a gradual reduction of the water storage capacity of loessial soils from south to north.

Tab. 6-20: Particle Composition of Upper Loess Strata in N-Shaanxi (JIANG, 1997)

Location (Counties in N-Shaanxi)	**Sand (0.5 ~ 0.05 mm)**	**Silt (0.05 mm ~ 0.002 mm)**	**Clay (< 0.002 mm)**
Yulin	74%	15%	11%
Mizhi	32	57	11
Suide	28	61	11
Qingjian	21	67	12
Yanchuan	8	70	22
Luochuan	7	71	22

Note: From its geographical position, Nan Niwan is roughly located between Luochuan and Yanchuan, while He Zhuang is located between Yanchuan and Qingjian.

Although plot-level data on soil moisture was not recorded during the field studies, secondary data on soil moisture conditions over the different vegetation zones and vegetation communities in northern Shaanxi further support this line of argument (tab. 6-21).

As can be seen below in tab. 6-21, there is a clear trend of decreasing soil moisture, soil water storage capacity and plant available soil water from the southern forest zone toward the northern forest-steppe and typical steppe zones. This trend becomes probably visible in the above ordination diagram when investigating sites across different sections of the study area.

Tab. 6-21: Soil Moisture Conditions in N-Shaanxi (Chen et al., 2002)

		Yichuan County (Forest Zone)	**Ansai County (Forest-Steppe Zone)**	**Wuqi County Typical Steppe Zone**	
Vegetation Community	**Annual Precipitation (mm)**	**574**	**524**	**364**	
Wasteland (Natural Succession)	Soil Moisture (%, 8 m depth)	15.2	12.6	8.02	
	Total Water Storage (mm, 8 m depth)	1496	1240	789	
	Total Plant Available Soil Water (mm)	1004	847	396	
Wood- and Grassland (Artifical Plantings)	Soil Moisture (%, 8 m depth)	11.4	6.3	4.7	5.3
	Total Water Storage (mm, 8 m depth)	1122	619	462	520
	Annual Water Consumption (mm)	590 (*Pinus tabulaeformis*)	549 (*Robinia pseudoacacia*)	375 (*Pyrus betulafolia*)	394 (*Astragalus adsurgens*)

With regard to potential revegetation in *He Zhuang* and hence in all parts, which are located north of *Yan'an city*, it needs to be carefully examined if site-specific moisture conditions are sufficient to carry and sustain forest ecosystems. It is likely that only moist sites in valley locations or on lower and middle shadowy northern slopes are suited for natural forest growth. On these sites, it appears from the above ordination diagram that there is a clearer overlap of forest sample plots of *Nan Niwan* and steppe plots of *He Zhuang* (fig. 6-13). Here moisture conditions will possibly suit *Quercus liaotungensis* and other species as set out in tab. 6-18.

6.6 Conclusion

The comparison of forest vegetation and steppe communities in an ecological space for the southern, central and northern parts of *Yan'an* leads to two major conclusions.

Firstly, rehabilitation of natural forests in the southern and central parts of *Yan'an Prefecture* appears to be uncritical from an ecological perspective. Basically, human disturbances led to an alteration and impoverishment of the local species pool, but overall climatic and other conditions are unlikely to preclude the natural revegetation process in these areas. There seems to be no major impediment that deforested areas can be returned to funcitioning forest ecosystems once pressure for agricultural land eases in the course of the development process.

Secondly, in the northern part of *Yan'an Prefecture*, the picture is less clear with regard to the suitability of sites for forest vegetation. Furthermore, the situtation is more critical as erosion is much more serious in terms of soil loss and sedimentation; and forests would fulfill even more important erosion protection functions (Wang et al., 2002). Possibly, human disturbances have resulted in a permanent change in environmental conditions that reduce the potential for reforestation and forest rehabilitation.

Li et al. (2002), for example, report of dense natural tree and shrub cover for *Zhifang Gou Watershed* in northern *Ansai County* of *Yan'an* in the 1940s and 50s, while today no tree and shrub vegetation is left. Similarly, personal interviews held with elder farmers revealed that, several decades ago, today's degraded areas were covered with dense woody vegetation.

Generally, in the northern part of *Yan'an* tree plantings should only be recommended on sites of appropriate water availability conditions. However, such areas are often used for agriculture; and revegetation, then, needs to be evaluated not only in terms of ecological feasibility and environmental benefit but also in terms of incurring agricultural opportunity costs. On upper slopes or hilltops, where agricultural productivity is reduced due to the lack of water and irrigation, economic trade-offs might be less prevalent but ecological conditions might as well not be suited anymore for forest growth.

These deliberations also include the establishment of artifical forests such as plantations of *Pinus tabulaeformis* and *Robinia pseudoacacia*. It is likely that potential environmental benefits of forests that are planted outside their natural distribution range will be offset by negative side effects. Evidence from several field studies in northwestern China suggests that such negative impacts are increased water consumption, competition for soil water with adjacent agricultural plots, salinization, and soil degradation (CCICED, 2002). Hence, ecological restoration efforts on sites identified as not suitable for forest growth should focus on the rehabilitation of natural shrub and steppe vegetation communities as well as integrated watershed management measures.

7. Socioeconomic Findings

7.1 Yan'an Prefecture - General Overview

7.1.1 Agricultural Sector

Yan'an Prefecture is part of the underdeveloped hinterland of Western China. More than 90% of the population is registered as rural population (chin.: *nong min*). Around 90% of all settlement areas are rural, while only 10% are urban settlements. With 52 people per sq. kilometer, *Yan'an's* population density is low as compared to other agricultural regions of China. Total land resources per capita amount to 1.9 hectares, more than twice the national average (ANONYMOUS, 2000b). When considering agricultural land only, per capita land resources are four times as big as the national average (tab. 7-1). Because of comparatively unfavorable climate conditions, overall agricultural productivity is low.

Tab. 7-1: Population and Land Resources – China and Yan'an Prefecture

	Total Area (sq. km)	Population	Population Density (pers./sq. km)	Land Area (ha/capita)	Agricultural Area (sq. km)	Agricultural Area / capita (ha)
China	**9 600 000**	**1 254 600 000**	**135**	**0.8**	**949 700**	**0.11**
Yan'an	**37 040**	**1 938 800**	**52**	**1.9**	**8 490**	**0.44**

(Source: ANONYMOUS (2000b): Yan'an Tudi Liyong Xiankuang – Landuse in Yan'an.)

About 96% of the land resources in *Yan'an* are administered by the agriculture and forestry administrations. Land is classified as (1) farmland (agricultural area); (2) fruit tree plantations (orchards); (3) wasteland; and (4) land for forestry. *Farmland* is further classified according to quality, e.g. high quality land on terraces, plain valley areas, and several categories of less productive sloping land.

Land for forestry is further classified into forest management categories, i.e. natural forest, artificial forest, air seeding areas, and silvicultural sub-categories, i.e. forested land, open forest, shrub forest, new planting area, nursery, cut-over area, non-forested land. There are also functional classes, i.e. timber, fuelwood, special purpose, protection, and economic forest. Regarding the status of fruit tree plantations, there is often considerable confusion as to whether these areas are under agricultural jurisdiction (as trees are planted on land formerly used for farming) or to be defined as *economic forest* and administered by the forestry bureau.

Farmland and orchards account for 25.4% of the total area of *Yan'an*. Only 20% (714 100 hectares) of the total land area is flat land. About 80% (3 001 860 hectares) are classified as sloping land with slopes above 15°. The overall composition of land resources in Yan'an is summarized in tab. 7-2.

Tab. 7-2: Composition of Land Resources in Yan'an Prefecture in 1996 (figures in ha)

Farmland	Fruit Tree Plantations	Land for Forestry	Wasteland	Settlement Areas	Infrastructure	Water Areas	Other
848 960	**92 070**	**1 509 160**	**1 104 590**	**53 660**	**15 210**	**30 300**	**49 080**
22.9%	**2.5%**	**40.8%**	**29.8%**	**1.4%**	**0.4%**	**0.8%**	**1.3%**

Source: ANONYMOUS (2000b): Yan'an Tudi Liyong Xiankuang – Landuse in Yan'an).

Examining farmland in more detail, reveals that *Yan'an* is characterized by dry-farming (rain-fed) systems while irrigation farming is nearly irrelevant (tab. 7-3). This is because of the semi-humid to semi-arid conditions, the lack of appropriate water resources, and underdeveloped irrigation infrastructure. Large parts of the rural population depend on subsistence farming. Generally, a three-year rotational production cycle is practized with periods where land, especially sloping farmland, is left fallow for one to two years to regenerate soil fertility.

Tab. 7-3: Composition of Farmland According to Farming Systems in Yan'an (hectares)

Agricultural Land (Total)	Irrigated Rice Cultivation	Irrigated Farmland	Dry Farming Area
848 960	**1 630**	**6 590**	**839 710**
100%	**0.21%**	**0.8%**	**98.9%**

(Source: ANONYMOUS (2000b): Yan'an Tudi Liyong Xiankuang – Landuse in Yan'an).

In 1999, per capita grain production amounted to 500 kg, which corresponds to the official annual per capita consumption demand (tab. 7-4). Cultivation area of potatoes was ca. 46 000 hectares with 655 000 tons harvested that year. Tobacco production reached 20 400 tons. Also in 1999, about 96 000 hectares of orchards existed of which about 40 000 hectares fruited with a total output of 397 000 tons. The fruit tree plantation area has been greatly increased since the initiation and implementation of the Sloping Land Conversion Program (SLCP) *(see below)*. Finally, a total livestock inventory of 2 900 000 of cattle and goats are reported for Yan'an in 1999 (ANONYMOUS, 2000a).

Tab. 7-4: Basic Characteristics of Yan'an's Agricultural Economy (1996)

Grain Production per capita	Average Rural Net Income	Average Urban Income	Average Productivity	Average Grain Harvest	Average Grass Harvest
500 kg	**1381 CNY/capita**	**4070 CNY/capita**	**23.3 CNY/mu**	**43 kg/mu**	**275 kg/mu**

Note: 1 mu = 0,0667 hectares; CNY = Chinese Yuan; US$ 1 = CNY 8.27

Source: ANONYMOUS (2000a): Yan'an Shi Guomin Jingji Fazhan Gaikuang – Yan'an Economic Development Overview

7.1.2 State Forestry Sector

Forest resources are mainly scattered in the south of Yan'an Prefecture where overall climate and precipitation conditions are better. Although around 1 850 000 hectares (42.6% of the total area) are officially classified as *land for forestry*[4] (ANONYMOUS, 2000b), the actual forest cover is much lower. Observations from the field surveys suggest that commercially exploitable timber resources have been largely exhausted.

Forest resources are state-owned. Forest farms (forest enterprises) are managed under the jurisdiction of state, provincial, county, and township governments. With the launch of the Natural Forest Protection Program (NFPP) and the imposition of a countrywide logging ban in 1999, commercial forestry stopped. Most of the forest farm staff, today, is unemployed with currently no restructuring underway.

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[4] Discrepancies in area figures of *land for forestry* mainly result from confusions regarding the definition of fruit tree plantations. As fruit tree plantations on agricultural land count as *economic forests*, area statistics of the forestry administration often differ from those of the agricultural administration.

The current status of forest management in Yan'an can exemplarily be summarized for *Nan Niwan Forest Farm*.

Nan Niwan Forest Farm is located about 30 kilometers southeast of *Yan'an City* and is administered by *Baota County*. It extends over an area of more than 36 000 hectares at elevations between 1060 to 1460 meters. Of this area, about 30 000 hectares are covered by trees or secondary shrub vegetation. Average stocking volume is reportedly 40.2 cubic meteres per hectare. For a detailed description of forest vegetation types see Chapter 6.

Nan Niwan Forest Farm was first established in 1956 by the provincial government of Shaanxi together with four other state forest farms in *Yan'an*. In 1974, *Nan Niwan* became economically independent. With the implementation of the NFPP in 1999, timber cutting stopped completely. Local timber processing enterprises around the farm went bankrupt because of lack of raw material. Prior to the logging ban, about 2000 cubic meters of timber were harvested annually and the forest farm received an overall income of ca. CNY 150 000. Out of originally 82 staff (18 personnel with specialized education, 64 workers), only a small number is still with the forest farm as the farm is no longer able to pay salaries or to provide pensions to retired staff. The only remaining activities carried out by the administration of the farm is some patrolling to prevent fire and illegal grazing of cattle and goats from the nearby villagers (ANONYMOUS, 2000d; personal interviews with farm management).

In general, Non-Timber Forest Products (NTFPs) are of no economic importance in the region. Mushrooms and some fruits are harvested occasionally for self consumption in some locations where villagers have direct access to the forest. Local administrations and farmers are, in general, aware that these forest fulfill some ecological functions but basically there is no involvement of the rural population in the management of these forest resources. Currently, some efforts are underway to develop the forest farms as tourism sites.

7.1.3 Industrial and Urban Sectors

Besides the importance of the agricultural sector, a significant industrial sector was developed in Yan'an after the foundation of the P. R. China (1949), especially during the 1950s and 60s. Yan'an's industrial base is comprised of large deposits of crude oil, natural gas and coal. Developing an industrial sector based on the exploitation of mineral resources is currently a focus of government development efforts. In 1999, 4 million tons of coal, 2.1 million tons of crude oil, and electricity of 360 million kilo watt hours (kWh) were produced in the district. The total value of all outputs and services from the state-owned and private enterprises, i.e. township and village enterprises (TVE) and collectives, amounted CNY 601 million. The most important industrial enterprises are coal mining, crude oil and tobacco processing (ANONYMOUS, 2000a).

Together with the accelerated industrialization, rapid urbanization trends are visible in *Yan'an Prefecture* and especially in *Yan'an City*, which is the administrative and economic center of the prefecture. Currently, *Yan'an City* extends over an area of 10 000 hectares but the city is growing in all directions. The officially registered population of *Yan'an City* is 135 000, but the administration acknowledges an additional number of 40 000 people in the city, so-called *floating population* from the countryside (ANONYMOUS, 2000c).

7.1.4 Rural Poverty Situation

In 1994, eight out of 12 counties in *Yan'an* with 56 townships and 1 429 administrative villages were officially classified as poverty districts (ANONYMOUS, 2000d). Altogether, more than 461 000 people were living below the official rural poverty line. This line is set according to the minimum subsistence level, i.e. annual cost of a basket of grain, vegetable oil, vegetables, pork, and eggs providing 2150 calories per day per person plus essential non-food items. Currently, the official Chinese poverty line is at CNY 635 (~ US$ 77) annual income per capita. As defined by international organizations, however, poverty thresholds are somewhat higher with the rural income-poverty line set at 1985-US$1.0/day purchasing power parity (PPP) and the rural expenditure-poverty line set as 1993 PPP US$1.08/day (YING, 2002).

Until today, *Yan'an* is one of the key areas for poverty relief programs of the Chinese government and international donor organizations whereby such efforts are mostly concentrated in the northern half of the prefecture. Since the economic reforms of the 1980s, Yan'an has received significant financial transfers under the umbrella of such programs. From 1994 to 2000, transfers of the provincial government of *Shaanxi* amounted nearly CNY 5 billion. In addition, *Yan'an* also received transfers from the central government and through development loans and grants financed through payments from local governments and the population (ANONYMOUS, 2000d).

In general, three major strategies have emerged to reduce rural poverty and to develop the economy in *Yan'an Prefecture* (see also chapter 3.2.4).

(1) New farmland is created by developing land previously not cultivated. In addition, existing farmland is improved through large-scale terracing. Farmland, then, is allocated to rural households to provide a production basis for subsistence needs as well as for improving market incomes from farming. Farmland development and improvement can be seen as core element of the Chinese rural poverty alleviation strategy. According to government statistics, about 41 300 hectares of new or improved (terraced) farmland were created during the past years in *Yan'an*. In addition, the construction of more than 660 kilometers of roads improved rural infrastructure conditions and market accessibility. Nearly all administrative villages in *Yan'an* are by now connected to the electricity network. Measures to improve living standards also include resettlements from remote and inaccessible areas closer to the centers in the prefecture (ANONYMOUS, 2000d).

(2) In order to increase agricultural productivity, farmers are encouraged to terminate farming on marginal sloping lands. Such lands are to be planted with fruit trees or other tree species, while on the remaining (high quality) land techniques, such as green house farming, intercropping systems and the use of high-yield and drought resistant cultivars, are promoted to increase production. Farmers with incomes below the poverty line receive direct financial subsidies or technical support from the local extension stations. In addition, grain and other agricultural products are distributed among the poorest household to ease transitional difficulties. For example, in 2000, 14 000 hectares of corn, 10 000 hectares of potatoes, and 10 000 hectares of wheat were cultivated by government for such purposes (ANONYMOUS, 2000d).

The most recent program in this regard has been the SLCP, which started in 1999 with a pilot phase in *Shaanxi* and other provinces, and was extended to the whole country in 2001.

Its objectives are to reduce soil erosion while at the same time restructuring the agricultural sector. The program aims at reclaiming sloping farmland and encouraging farmers to plant trees and grasses for ecological and economic purposes. To achieve these objectives, the SLCP compensates farmers in exchange for tree planting on unproductive farmland areas with cash and grain subsidies. To date, however, it is unclear to what extent economic and ecological objectives of the SLCP have been achieved (XU et al., 2002).

(3) Government programs also focus on the development of industrial and service sectors to create employment opportunities outside the agricultural sector for the large proportion of underemployed farmers. Township and household enterprises are subsidized; and farmers receive micro-credits for private businesses. Altogether, about CNY 94 million were allocated to micro-credit programs in 2000 in Yan'an where eligible households are entitled to a low interest loan of up to CNY 1500 (ANONYMOUS, 2000d).

7.2 Landuse Characteristics

7.2.1 Differentiation of Landuse Types Across Landscape Types

Characteristic differences in geo-morphological and ecological conditions divide *Yan'an* into a southern and northern sub-region. The boundary between these sub-regions can be roughly drawn from the south of Ansai county in the west, Lao Shan township in Ganquan county, and Nan Niwan township in Baota county in the east (fig.5-4). These townships are located in a loess mountain ridge which extends from western to eastern direction at elevations between 1000 to 1400 meters.

The northern *Yellow Hills and Valleys (loess hills)* account for 49.5% of the total land of Yan'an. Characteristic features, besides the generall geo-morphological characteristics described in Chapter 4, are the comparatively smaller portion of productive (plain) farmland and forestland and the higher proportion of grassland as compared to the southern sub-region. The southern *High Plains and Gullies (loess tableland)* account for 50.5% of the total land, where farmland productivity is higher. The *tableland* is the center of apple and oil plant production of this region (tab. 7-5).

Tab. 7-5: Land Resource Distribution Between Northern and Southern Sub-regions

	Total Land	Total Farmland	Grassland/ Shrubs	Forest Land
Northern Sub-region (Loess Hill Region)	49.55%	31.39%	72.58%	17.14%
Southern Sub-region (Loess Tableland)	51.45%	68.61%	27.42%	82.86%
Total	100.00%	100.00%	100.00%	100.00%

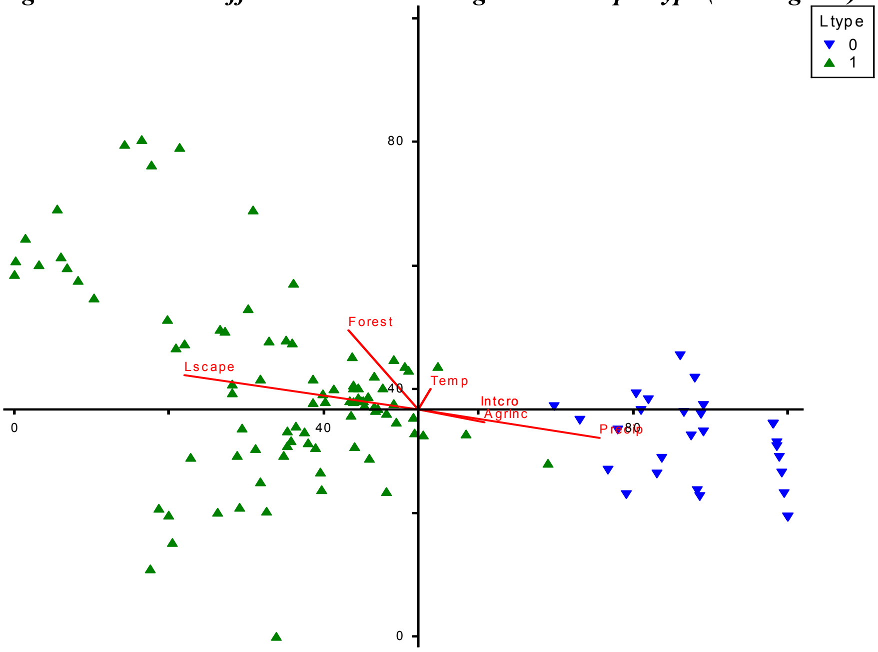
(Source: Anonymous (2000b) Yan'an Tudi Liyong Xiankuang – Landuse in Yan'an).

When numerically evaluating the primary data collected during the household surveys, the climatic and geo-morpholigical distinction between the two sub-regions and landscape types is also reflected in different agricultural landuse systems. The below ordination diagrams (fig. 7-1 and 7-2) illustrate different cultivation patterns in the *loess hill region* and the *loess tableand.*

The differences are calculated by DCA and based on overall crop composition (crop mix) and extent of cultivation of individual crops (specialization) at the household level.

Fig. 7-1 displays the spatial distribution of households across the two landscape types (sub-regions). The colored symbols represent individual households that are characterized and positioned according to the mix of crops they cultivate. While households located in the *tableland* are positioned in the right half of the diagram (blue), those located in the *hills* are situated on the left (green). Crops are weighted by their respective cropping areas per household. Only common crops cultivated by more than 5% of all household were considered. Corrected eigenvalues of the ordination calculation are 49.4% (axis 1), 6% (axis 2), and 5% (axis 3, not displayed).

Fig. 7-1: Landuse Differentiation According to Landscape Type (Sub-regions)

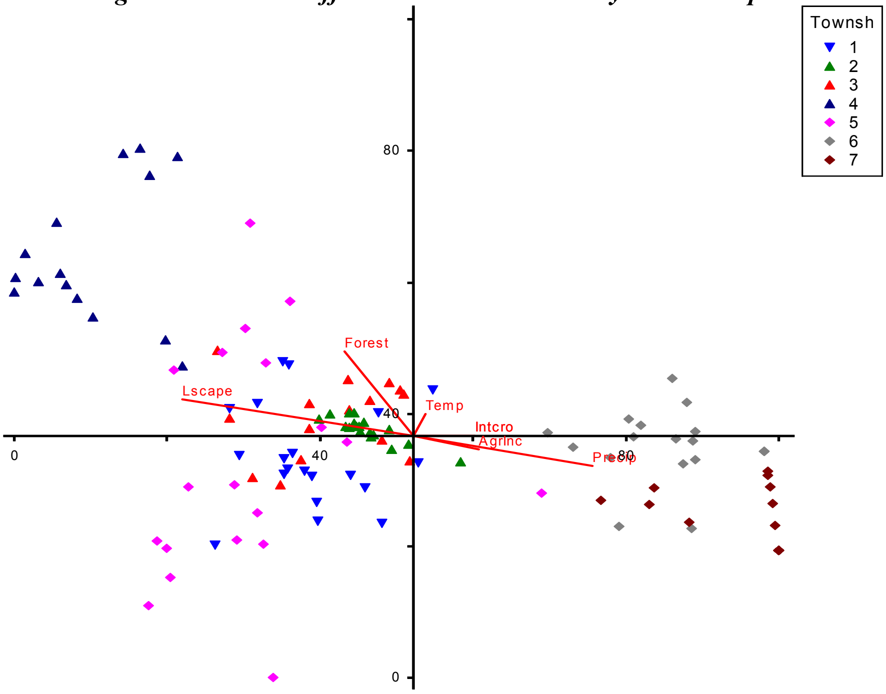


Note: Positioning of households in a two-dimensional abstract space along landscape types.
Ltype 0 (blue): tableland (southern sub-region); Ltype 1 (green): hills (northern sub-region).
Explanatory Variables (vectors): Lscape: Landcape type; Forest: access to natural forest; Temp: mean annual temperature; Precip: annual average precipitation; Agrinc: agricultural income; Intcro: intercopping systems.

Fig. 7-2 details the landuse differentiation across individual townships. Townships 1 to 5 (*Yanhe, He Zhuang, Liu Lin, Nan Niwan, Lao Shan*) are located in the *loess hills* whereas townships 6 and 7 (*Jiao Dao, Jing Zhao*) are part of the *tableland* in the south (fig. 5-4).

The correlation coefficients between household ordination scores and individual crops weighted by cultivation area per household can be used to further characterize the specific landuse systems in terms of crops and cultivation patterns across the landscape types (tab. 7-6). They are discussed in sections 7.2.2 and 7.2.3.

Fig. 7-2: Landuse Differentiation Across Surveyed Townships



Note: Hills (northern sub-region): townships 1- 5; Tableland (southern sub-region) townships 6- 7. Explanatory Variables: Lscape: Landscape type; Forest: Proximity to natural forest; Temp: mean annual temperature; Precip: annual average precipitation; Agrinc: agricultural income; Intcro: intercopping systems.

Tab. 7-6: Correlation Coefficients for Household Ordination Scores and Crops

	Axis 1	**Axis 2**
Cultivated Crop	**Correlation Coefficients**	
Apple (flatland/terraces)	0.878	-0.428
Corn	-0.687	0.435
Potato	-0.417	0.140
Rice (irrigation)	-0.414	0.395
Millets	-0.251	0.058
Alfalfa (*Medicago sativa*)	-0.225	0.536
Vegetable (greenhouse)	-0.166	-0.128
Soy beans	-0.190	-0.172

7.2.2 Farming in the Loess Hill Region

Farming in the *loess hills*, as represented by the households on the left side of the above scatter plots (fig. 7-1 to 7-2), displays two characteristic features. Firstly, the majority of farmers cultivate staple crops such as corn (*Zea mays*), potato (*Solanum tuberosum*), millets (*Panicum miliaceum, Sorghum vulgare, Setaria italica*), soy beans (*Phaseolus radiatus*), buckwheat (*Fagopyrum sagittatum*), wheat (*Triticum aestivum*), and rice (*Oryza sativa*). Terraces and high quality natural flatland, i.e. valley grounds and river plains are generally called *essential farmland resources* (chin.: *jiben nongtian*) and represent the economically most important resources of every household's land allocation. Among the common staple crops, corn is most important one in terms of number of cultivating households and average cultivation area followed by potato, millets and soy beans (fig. 7-3, tab. 7-6).

Staple crops, in general, are produced for self-consumption. Surplus harvests are often sold or exchanged in local markets. In general, farmers can be characterized as subsistence-level producers. One exception is corn that in many areas is produced as pig feed for sale or used to raise pigs in the household. A distinct corn economy has emerged during the last 15 years with changing market conditions and increasing meat consumption all over China (ROZELLE & CARTER, 1996). Several households in the *loess hills* have also constructed greenhouses for the commercial cultivation of melons and vegetables whereas greenhouse cultivation is rarely seen in the south in the *tableland*. According to information provided by farmers, most of the purchased fertilizer is applied to crops on terraces or productive flatlands and in greenhouses.

Secondly, on sloping farmland, the majority of farmers has greatly reduced labour input and other physical investments during the last couple of years and moved away from farming toward the management of so-called economic tree species. This development was also reinforced and accelerated with the implementation of the SLCP. Fruit trees, such as apple, apricot (*Armeniaca sibirica*: cultivars and wild forms), pear, walnut, and peach trees, are often planted. Other so-called economic species are Black Locust (*Robinia pseudoacacia*), *Caragana microphylla, C. korshinskii*, *Hippophae rhamnoides,* which are occasionally planted on marginal lands, i.e. steep and erosion prone wastelands of low economic value to the household. In several of the observed villages, tree plantings other than fruit trees remain under collective ownership and are not contracted out to individual households. Such plantations are often not regularly managed but instead provide an open access resource for farmers to obtain firewood, graze livestock, and harvest timber for construction purposes.

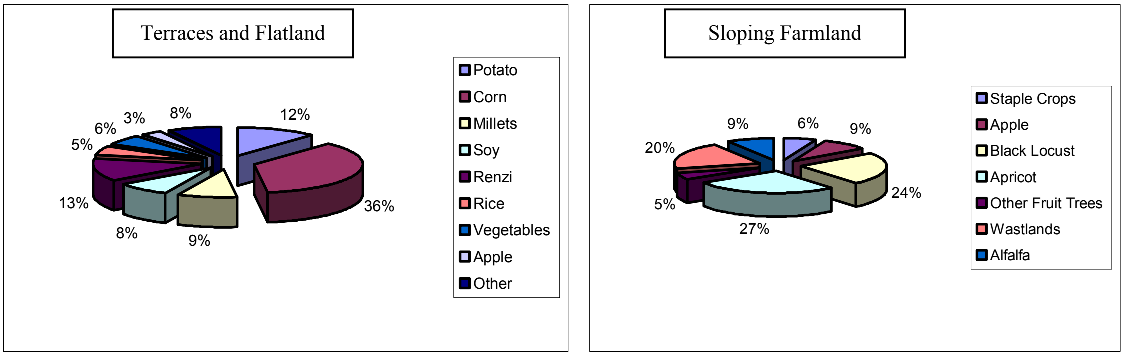
It is important to note that farmers rarely plant so-called ecological species, i.e. native species adapted to the local ecological conditions. Although planting of ecological species is encouraged under the SLCP in order to restore ecosystem health, it appears from the field surveys that this has not materialized. On one hand, knowledge on raising and planting of species other than the common plantation species is limited, while—more importantly—on the other hand, farmers strictly pursue short-term economic interests in the light of their already difficult living conditions.

Fruit harvests provide one important source of cash income to the household as harvested fruits are mostly sold in local and regional markets. With the increase of apple production and abandoning of price regulations and guarantees by the government, however, apple prices decreased in recent years, and farmers' cash income opportunities decreased as well (FU, 2001). Furthermore, as indicated by many farmers during the interviews, quality issues and less favorable growth conditions in the *loess hills* make orchards less competitive as compared to such orchards in the *tableland* where climate is more suited for productive and high quality apple cultivation.

The above described farming system—small areas of productive and intensively managed terraced land and less intensively managed sloping land—is the dominating landuse pattern in the townships of *Yan He* (1), *He Zhuang* (2), *Liu Lin* (3), and *Lao Shan* (5) (fig 7-2).

Fig. 7-3 provides an overview of the crop mix on flatlands and terraces (left) and sloping farmland (right) for the *loess hills* in terms of percentages of planting households. This proprotional distribution of planted crops explains why households of *loess hills* are separated from households of the tableland in the above ordination diagrams (fig. 7-1 to 7-2).

Fig. 7-3: Crop Cultivation in Percent of Farmer Households in the Loess Hill Region



Nan Niwan township (4), which is located in the far upper left of the ordination diagram (fig. 7-2), is the only area in Yan'an where rice is cultivated on permanently irrigated farmland plots. Furthermore, a plant locally known as *renzi* or *xiangzi* (*Fabaceae*) is cultivated here requiring improved moisture conditions as well. Its seeds are used to distill a plant oil, which is then sold to the cosmetics industry through a network of local traders. Many farmers in the villages around Nan Niwan specialized in the cultivation of this plant. Finally, Nan Niwan township is located nearby the forest farm of Nan Niwan and, thus, is connected to natural forest resources that cannot be found in any other part of the *loess hills* in Yan'an. Whether the existence of this forest is responsible for the characteristically different landuse patterns in that it provides a balanced water discharge from the area and a stable source of water for irrigation independently of drought periods during the summer, was difficult to explore. A direct link between the existence of natural forests and economic benefits in terms of higher agricultural productivity, however, could not be detected as is discussed below in section 7.4.1.

7.2.3 Farming in the Loess Tableland

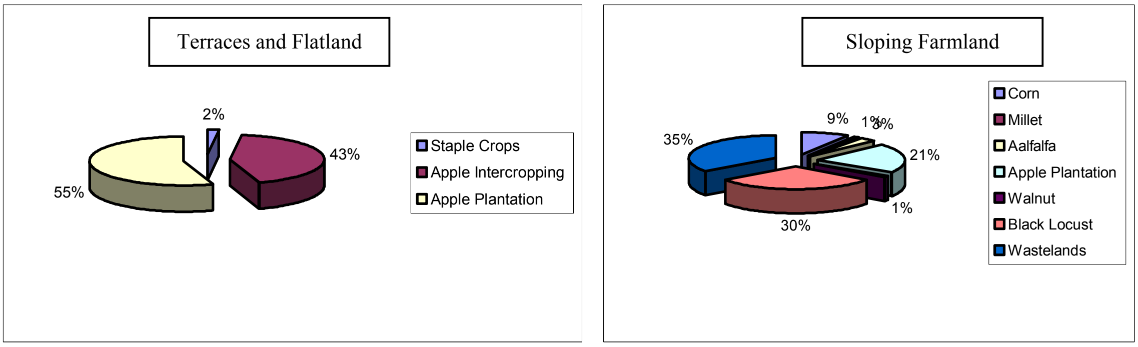
Farming in the *tableland* greatly differs from farming practized in the *loess hills* (fig. 7-4). Natural flat areas of the *tableland* are nearly exclusively used for apple cultivation either as pure plantations or as intercropping systems with staple crops planted between tree rows. Intercropping is generally practized only on newly established young apple plantations where trees are not fruiting yet. When canopies are still open, such plantations allow for the cultivation of additional crops. As soon as the canopy of orchards closes, intercropping ceases. Staple crops are mostly produced for household consumption or exchange in local markets.

Commercial plantations on the plateau began to emerge in the early 1980s with the introduction of the *Household Responsibility System (HRS)* and were largely extended in the 1990s. Under the HRS, collective-owned land resources (chin.: *jiti*) are contracted to farmers for a duration of between 30 to 50 years. Farmers are given overall responsibility to manage the land and encouraged to economically benefit from it. With the state allowing farmers to reallocate household labour resources and investments toward their contracted plots according to their economic needs, the government implicitly promoted agricultural specialization, with the result that farming on less productive sloping lands gradually disappeared in the *tableland*.

The *tableland*, especially *Luochuan* and *Fu* counties, is one of the best-known apple cultivation areas of China. From here, apples are exported to all over China. In *Fu* county, intercropping systems are still more common as apple cultivation has probably started somewhat later here than in *Luochuan*.

As illustrated in fig. 7-4, sloping farmland is mainly planted with economic species, such as apple, walnut, *Black Locust*. Slopeland that is not leased out by the village is basically left fallow and often not used at all with a natural vegetation succession process going on.

Fig. 7-4: Crop Cultivation in Percent of Farmer Households on the Loess Tableland



As can be seen from the ordination diagram (fig. 7-1 and 7-2) and table 7-7 below, the two identified major landuse systems of Yan'an along the first axis are closely correlated to landscape type (r=-0.890), precipitation (r=0.791) (with annual precipitation in the *tableland* being some 70 to 90 mm higher than in the *hills)*, and temperature (r=0.214) (with mean annual temperature in the south being around 1.4 K higher than in the north).

Tab. 7-7: Correlation Coefficients for Household Scores and Explanatory Variables

	Axis 1	**Axis 2**
Explanatory Variables	**Correlation Coefficients**	
Landscape Type	-0.898	0.385
Precipitation	0.791	-0.350
Temperature	0.214	0.297
Intercropping Systems	0.518	-0.040
Economic Forests (excluding orchards)	-0.198	-0.096
Agricultural Income	0.476	-0.240

Higher precipitation and temperature, combined with topographical features that can be utilized by the local farmers more efficiently and productively, largely explain the emergence of two different landuse patterns. Favorable climatic conditions together with the emerging HRS led to an agricultural specialization in high quality apple production in the *tableland* whereas this option does not exist to that extent under the less favorable semi-arid conditions in large parts of the *loess hills*. The predominant existence of intercropping systems on the *tableland* (r=0.518) is a further indication, that better climate conditions offer more options for agricultural specialization and more flexible resource allocation here.

Even after orchards begin to fruit and staple crops cannot be planted any more between the tree rows, farmers do not move toward the cultivation of sloping land to produce staple crops for household consumption. Obviously, when considering household labour constraints, it is economically still more attractive to focus on intensive apple plantation management and to buy needed grains from the outside.

According to information from government officials, similar specialization trends have taken place to more or less similar degrees in the counties of Ganquan (apricot), Huanglong (*Castanea mollissima*), and Qingjian (*Ziziphus jujuba*).

Household-level forest resources, i.e. economic forests (excluding orchards) and shrubland, appear to be of some greater economic value to households in the *hills* (r= -0.198). This is possibly due to the fact that animal husbandry is still an important supplementary economic activity of households in the *hills.* Often, fodder for pen feeding is obtained from such forestland or otherwise unused shrublands. Finally, there is a general trend of increasing agricultural incomes from the *hills* toward the *tableland* (r=0.476), which confirms the above interpretation of better production conditions and specialization in the south (tab. 7-9).

Recent government programs, such as the *SLCP* and the *Loess Plateau Watershed Rehabilitation Project*, for example, attempt to diversify the existing landuse patterns and improve land quality through large-scale terracing in the north. Although these programs have been successful in stabilizing and raising farmers' incomes in the *loess hills* (WORLD BANK, 2000), differences in landuse patterns and, thus, living standards between Yan'an's two sub-regions remain visible (fig. 7-8). Overall, natural conditions will possibly be major constrain to agricultural development in the future.

7.3 Composition and Distribution of Land Resources

With the introduction of the HRS in the 1980s, farmland was equally distributed among rural farmers to secure a minimum of household-level food production. Today, with the rapid development of productive farmland (terraces), this strictly regulated land allocation system continues. Depending quality and availability of land resources per township or village, each person is assigned between 1 to 2 mu of *high quality farmland*[5] from the collective. (fig. 7-5).

In most cases, farmland plots are allocated on a contract basis of up to 50 years duration and managed by the household for subsistence needs. In recent years, the transfer of landuse rights between households has been allowed by local governments so that households with a sufficient labour force can rent additional land from neighbours when land is not needed there. In terms of the surveyed townships, such landuse transfers between households, however, were observed only sporadically.

On average, high quality farmland amounts to 6.0 mu per household (1.49 mu/capita) in the *hills* and 7.5 mu (1.74 mu/capita) in the *tableland.* Differences in per capita land allocations partly reflect different topographical characteristics as well as different status of land development programs. Land allocations in *He Zhuang* and *Nan Niwan* townships, for example, show the largest median values (fig. 7-5). While in *He Zhuang* the implementation of a land development project recently created new wide-level terraces, *Nan Niwan* is characterized by a broad river valley with abundant natural flatland resources. In general, the amount of this essential farmland is roughly equal across Yan'an Prefecture without large differences between the different locations.

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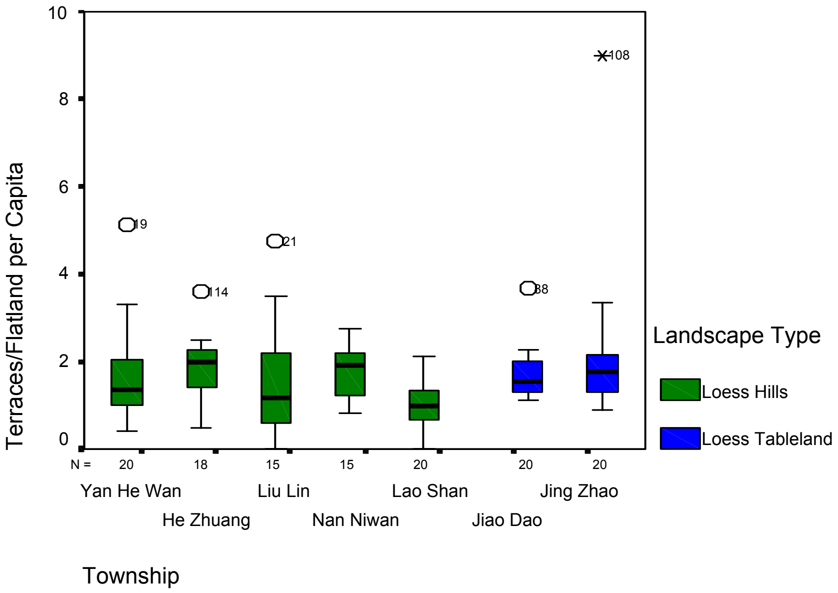
[5] Productive high quality farmland *(jiben nongtian)* includes several categories such as natural flatland (*zhuandi* or *pingdi*), terraces (*taidi* or *titiandi*) or irrigated plots in river valleys (*shuidi*).

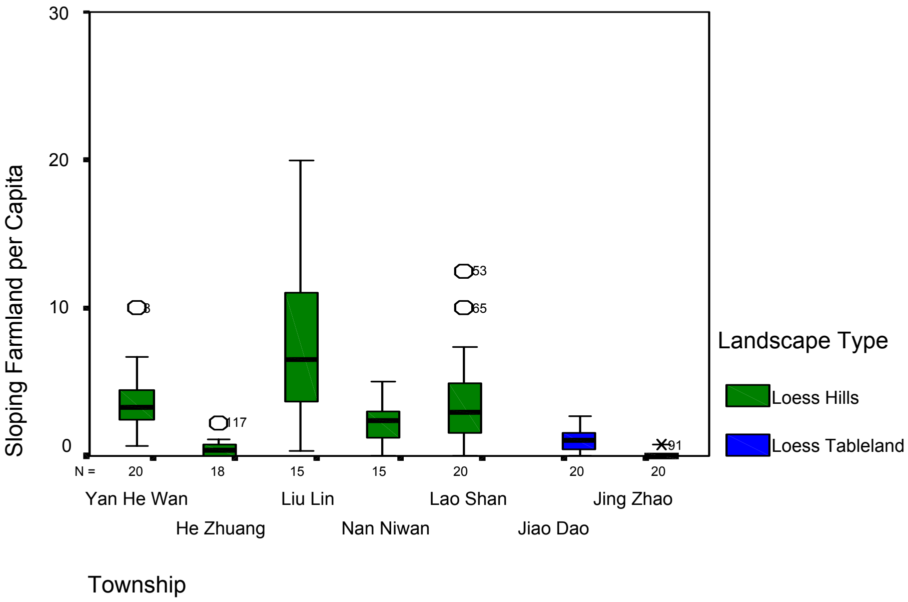
Fig. 7-5: Per Capita Land Resources – High Quality Farmland (figures in mu/capita)



Note: Boxes extend from 25th to 75th percentile, with the black line being the median. Whiskers extend to the largest and smallest observed values within 1.5 box lengths. Values beyond whiskers are extreme values.

Sloping farmland is, naturally, more abundant in all of the townships. Per capita distribution varies more widely depending on individual household needs, relative economic land value, labour constraints, and land allocation history (fig 7-6).

Fig. 7-6: Per Capita Land Resources – Sloping Farmland (figures in mu/capita)



Note: Boxes extend from 25th to 75th percentile, with the black line being the median. Whiskers extend to the largest and smallest observed values within 1.5 box lengths. Values beyond whiskers are extreme values.

For example, in terms of land allocation history, sloping land resources were largely contracted to households for free during the 1970s. In contrast, farmers that moved into these villages at later times often had to pay leases to the village or collective and were allocated smaller amounts of land.

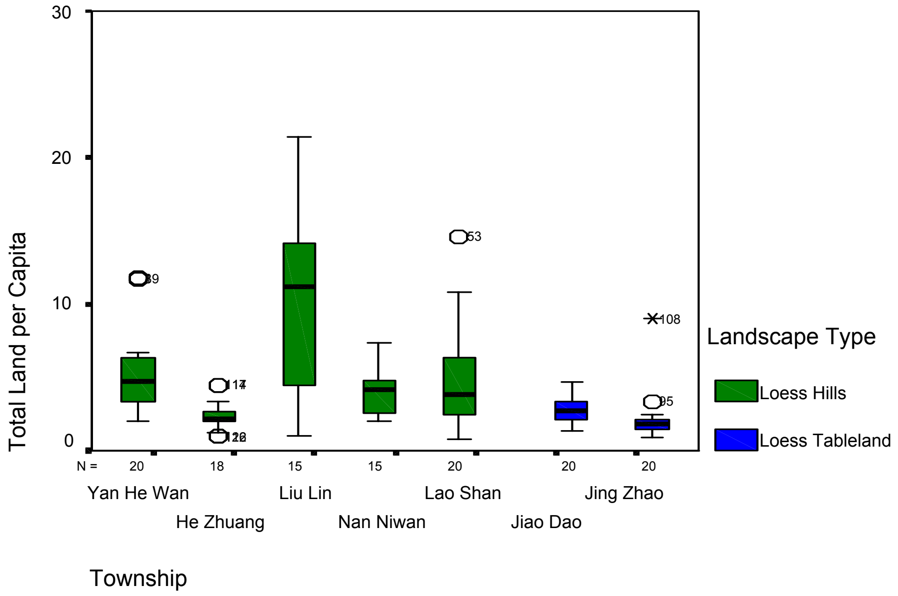
In some cases, migrating farmers were not part of the allocation process of high quality farmland at all and were completely restricted to slopeland farming.

On average, households in the *loess hills* cultivate 12.3 mu (3.03 mu/per capita) of sloping farmland while households on the *tableland* only manage about 2.7 mu (0.62/capita).

A noteworthy observation is that, in He Zhuang township of northern Yan'an, household allocations of sloping farmland are lower than in other townships of the *loess hills* and display a similar trend as on the *tableland*. Obviously, with the artificial construction of high quality terraced land, much less sloping farmland land is needed by the household in order to meet its subsistence needs. The refocusing away from land-intensive farming on sloping lands toward intensive terrace farming is one of the essential prerequisites to develop concepts for the ecological rehabilitation of large parts of the Loess Plateau. In other surveyed townships in the *hills,* such interventions are currently underway, but it remains to be seen to what extent farming on sloping land can be reduced permanently.

Finally, looking at the *total per capita land resources* currently managed in the surveyed townships, traditional farming in the *hills* is more land intensive in terms of per capita land cultivated than on the *tableland* (fig. 7.7). Only in cases where land construction program have been implemented, i.e. *He Zhuang* township, similar patterns as in the *tableland* emerge.

Fig. 7-7: Total Per Capita Land Resources (figures in mu/capita)



Note: Boxes extend from 25th to 75th percentile, with the black line being the median. Whiskers extend to the largest and smallest observed values within 1.5 box lengths. Values beyond whiskers are extreme values.

These findings suggest that, with such continued restructuring, considerable options for ecological restoration and natural revegetation exist as more and more land resources for replanting and revegetation become available. As these programs are still ongoing, it is not possible to quantify the total area that will not be needed any more for agricultural production. Also, the above proposition is made under the assumption that landuse changes are permanent and not to be reversed. Whether abandoned sloping farmland is reclaimed again when underlying macro-economic or demographic conditions change remains to be seen.

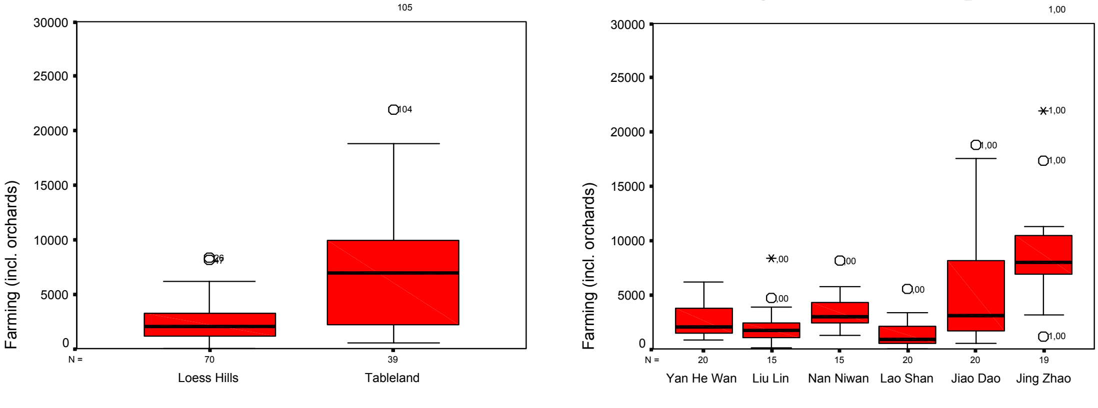
7.4 Household Income, Expenses and Living Standard

7.4.1 Agricultural Income

Farmers on the *Loess Plateau* belong to the poorest people in China. Most of the surveyed households can be classified as pure subsistence farmers with very small cash incomes and currently with only limited development options. The below figures on incomes and expenses are one-time observations and, hence, need to be interpreted carefully. Furthermore, findings from the field suggest that incomes and expenses vary considerably on a year-by-year basis. Farmers themselves are often not clear about the exact amount of annual cash income and expenses. Nevertheless, some trends in incomes between the townships and in aggregate terms for the two sub-regions can be detected as discussed below.

Most farmers in *Yan'an* produce staple crops for household consumption. Although crops are in general not sold in markets, annual farm yields often represent the major source of income for the household when estimated in terms of market prices. Fig. 7-8 (left side) indicates that agricultural incomes are lower in the *loess hills* with a median value of about CNY 2000 than in the *tableland* with a median value of about CNY 6000. An additional indication that farmers, especially in the *hills*, are only able to produce for subsistence needs is that agricultural income is little spread out here. On the other hand, with increasing specialization, the range of household incomes is larger in the *tableland* and more spread out for the middle 50% of incomes. Fig. 7.8 (right) confirms this observations when looking at the distribution and spread of agricultural incomes along six of the surveyed townships. (*He Zhuang* township is not included as no appropriate data on farming income was available from the survey.)

Fig. 7-8: Distribution of Agricultural Income between Sub-regions and Townships (CNY)



Note: Boxes extend from 25th to 75th percentile, with the black line being the median. Whiskers extend to the largest and smallest observed values within 1.5 box lengths. Values beyond whiskers are extreme values.

A linear multiple regression model shows that agricultural income per household (measured as natural logarithm Ln) is to a large extent determined by four factors, namely the amount of high quality farmland per household (*flatland*), the amount of *fertilizer* used (Ln), the extent of slopeland farming (slope), and landscape type (dummy variable: *ltype*). This last variable accounts for climatic conditions (precipitation, temperature) and better production conditions because of natural flatland. The estimated parameters of the model are:

$$\text{Ln (income)} = 6.09 + 0.139 \text{ flatland} + 0.158 \text{ Ln (fertilizer)} - 0.02 \text{ slope} + 0.346 \text{ ltype}$$

$R^2 = 0.489$, N = 108 households

For all included coefficients, *t*-statistics are significant at the 5% error level, i.e. linear relationships between the dependent variable (income) and the predictor variables exist. Non-significant variables of no additional explanatory value were *total workforce per household* and the potential *protection functions of nearby natural forests* (dummy). These were excluded by stepwise selection.

It can be argued that this simple model basically accounts for all natural production conditions in Yan'an; and the relatively small coefficient of determination $R^2=0.489$ indicates that possibly other factors, such as educational background, technological standard, landuse arrangements etc. need to be identified to explain parts of the relatively large residual variance of $(1-R^2)=0.511$. However, the model confirms that agricultural production increases with increasing availability of flatland/terrace resources, increased fertilizer use, increased precipitation etc. (as expressed in the landscape type), and by reducing farming on sloping land, i.e. reallocation of .household resources.

Generally, farming is characterized by low technical standards. Fieldwork is normally done manually or with the support of cattle or donkeys. Only in the *tableland*, better-off farmers are able to afford small tractors for field work and transportation of harvests to local markets. Vegetable cultivation in greenhouses seems to be economically attractive in the north, but according to farmers' responses, initial investments to construct greenhouses are high; and maintenance costs, fertilizer, pesticide expenses and taxes often eat up the modest profits.

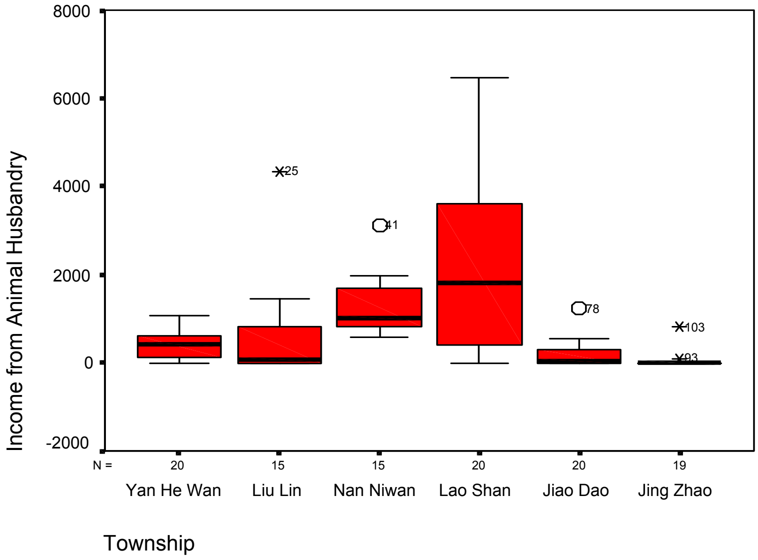
Furthermore, farmers face fierce competition as more and more villagers build such greenhouses and enter the markets with their products. Similarly, on the *tableland*, when apple orchards first became productive about 10 to 15 years ago in the *Luochuan* area, e.g. *Jing Zhao* township, farmers benefited from high prices and government subsidies. With rapidly increasing apple production and the lift of price controls and subsidies, average price per kg dropped from CNY 2.8 to 3.0 to only CNY 0.5 yuan, thus considerably reducing cash incomes of apple farmers. However, the income situation on the *tableland* is still more favorable than in the *loess hills*.

7.4.2 Animal Husbandry

Animal husbandry is practized in two different ways over the survey area. Often households raise one to two pigs and some poultry for self consumption. On the other hand, several households have specialized in cattle and goat raising for meat and wool production. The latter type is economically more important and particularly practiced in the townships of *Nan Niwan* and *Lao Shan*. As both townships are located close to the forests of Nan Niwan, animal husbandry is obviously related to the availability of relatively easily accessible grazing grounds nearby and within the secondary natural forests. Although grazing on sloping lands has become illegal in recent years, grazing bans are only loosely enforced. With the implementation of the SLCP, however, free grazing has been reduced somewhat and, as was observed during the fieldwork, many farmers have moved toward stable or pen feeding.

Median annual income from animal husbandry in these two townships is between CNY 1000 to 1800 whereas animal husbandry is irrelevant in *Jiao Dao* and *Jing Zhao* townships of the *tableland* (fig. 7-9). Farmers can receive between CNY 100 to 250 for the sale of a goat and around CNY 800 for cattle.

Fig. 7-9: Distribution of Income from Animal Husbandry between Townships (CNY)



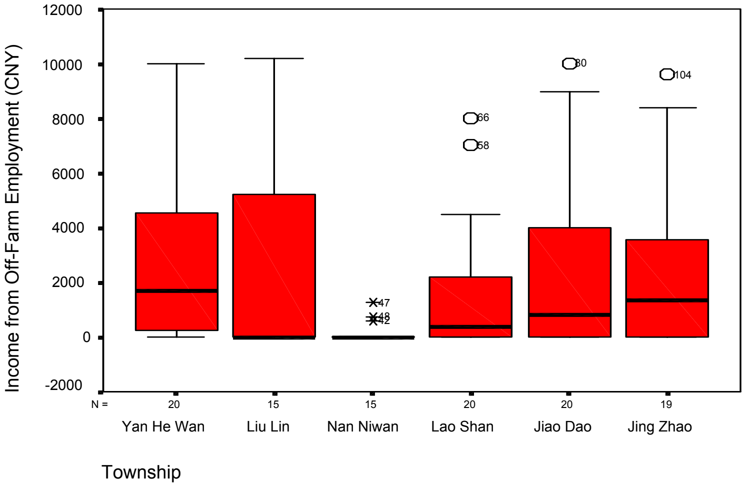
7.4.3 Off-Farm Employment

Off-farm employment is becoming more important to local farmers, and it represents one of the few opportunities to earn cash income. Cash income is essential to purchase fertilizer and pesticides, buy supplementary food grains as well as finance health care and children's education. Many households, therefore, practice a pattern of seasonal off-farm work outside the busy planting and harvesting seasons. In general, the family head and grown-up sons work outside for several weeks or months during the year. Opportunities are taken on as far as in Xi'an, the provincial capital, and range from work at construction sides, street construction, mining, work in stone mills to truck driving, carpentry or jobs in the service sector of the major cities, such as Yan'an. Jobs that require special skills, such as carpentry or driving, earn considerably higher weekly or monthly wages than unskilled labour. In some cases, the wife of the household head also takes on some work outside the household, mostly as seasonal laborer in greenhouses and in the apple business. Younger female members of the household are often sent for temporary or permanent work in restaurants or stores in bigger cities.

Annual incomes from off-farm work are roughly evenly spread with similar median values that do not differ considerably between the *loess hills*, e.g. *Yan He* Township, and the *tableland*, e.g. *Jiang Zhao* (fig. 7-10).

One important observation is that work opportunities are closely related to farmers' access to township and larger urban centers, such as the prefecture capital of Yan'an. In remote townships that are located comparatively far away from major roads or urban centers, i.e *Nan Niwan* and *Lao Shan*, off-farm opportunities are less frequently taken on by farmers and thus incomes are lower.

Fig. 7-10: Distribution of Off-farm Income between Townships (CNY)



To provide a statistical prove of the above described differences in income patterns, *agricultural income, incomes from animal husbandry* and *off-farm employment* were tested for statistical significance between the surveyed townships with *analysis of variance* (ANOVA). Results are as follows:

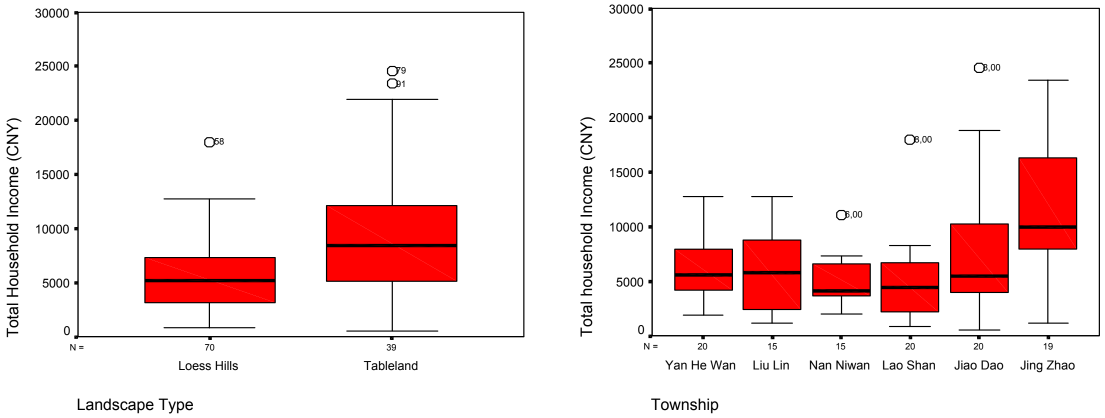
Jing Zhao township of *Luochuan* county—located on the tableland with the longest history of intensive apple cultivation—differs significantly in terms of higher average agricultural income per household from all other townships. At the same time, households of *Luochuan* also shows a significantly higher use of pesticides and fertilizer as compared to all other townships. On the other hand, incomes from animal husbandry are highest (discernable at the 5% error level) in the townships of *Nan Niwan* and *Laoshan*, the two townships with nearby natural forests. Finally, no statistical differences can be observed between the townships in terms of off-farm incomes. Off-farm employment appears to be of equal importance in both sub-regions and more dependent on transportation infrastructure and accessibility of urban centers with seasonal labour markets for farmers than other factors. Calculations are provided in Annex III.

7.4.4 General Patterns of Income and Expenses

Finally, looking at the distribution of total income between sub-regions (landscape types) and townships (fig. 7-11), *total household income* closely follows the pattern that has been discussed for *agricultural income*. Due to better climatic conditions and specialization in production, overall incomes in the *tableland* tend to be higher than in the *hills*. These differences are also not compensated for by more intense animal husbandry in the northern sub-region.

In terms of general living standard considerations, households in the surveyed area earn an average income of CNY 6143 per year. With an average family size of 4.1 persons, annual per capita income, including staple food production, is about CNY 1498 (US$ 181). This figure, estimated from the data collected during the field surveys, corresponds closely with the officially reported income figures provided in tab. 7-8.

Fig. 7-11: Distribution of Total Income between Sub-regions and Townships (CNY)



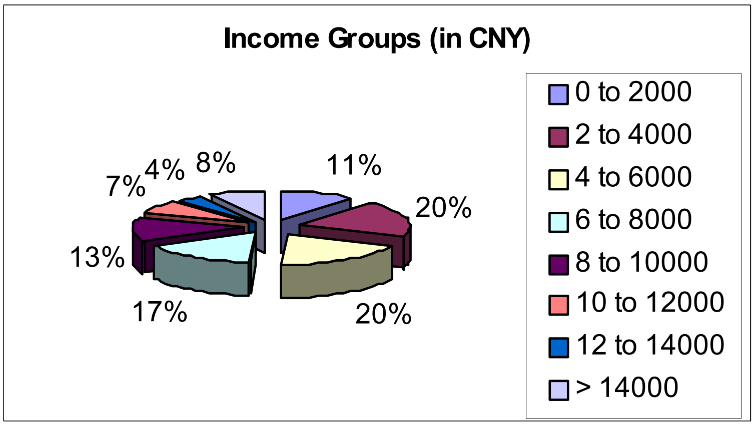
Tab. 7-8: Population and Income Figures for the Surveyed Townships (CNY)

	(1) Yanhe Wan	(2) He Zhuang	(3) Liu Lin	(4) Nan Ni-wan	(5) Lao Shan	(6) Jiao Dao	(7) Jing Zhao
Population	16 500	-	20172	-	5519	10484	5638
Rural Households	3474	2021	3363	1062	1056	2544	1347
Rural Population	16 037	8015	-	4155	4519	-	5391
Net per capita Income	1600	1688	1896	2000	1641	1855	2071

(Source: Secondary Data obtained from Township Officials 2001-2002)

When dividing the surveyed farm households into income groups (fig. 7-12) and applying a poverty line of CNY 1000—this line is somewhat higher than the official poverty line of CNY 635 and allows to account for quality of life measures beyond the pure subsistence level—it can be seen that roughly 30% of all surveyed households, namely households with incomes below CNY 4000 (with on average four household members), still live in absolute poverty. About 70% of all households are above this line.

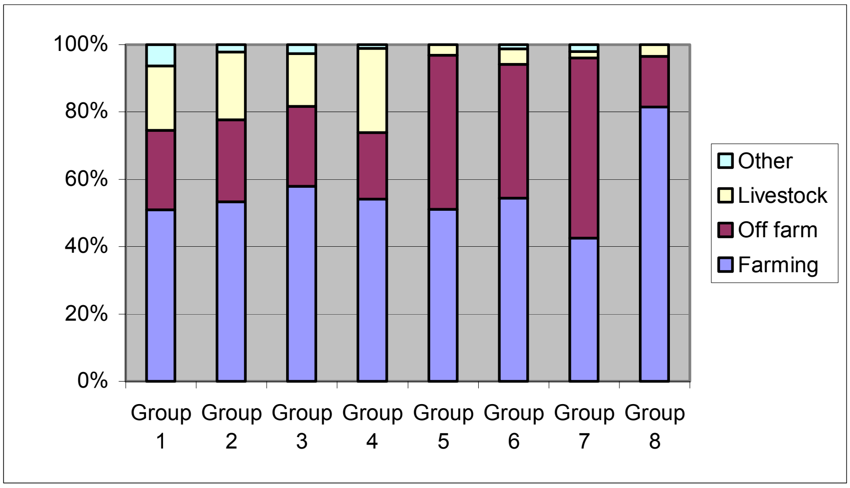
Fig. 7-12: Percentage of surveyed Households belonging to Different Income Groups



Note: Incomes are gross incomes; income figures in CNY

Income from farming (including staple food production) comprises about 50% of total income for income groups 1 to 6 (fig. 7-13). Off-farm work and animal husbandry each contribute between 20 to 25% to total income of the poorer households (group 1 to 4). Comparatively well-off households (groups 5 to 7) receive between 40 and 50% of their income from off-farm work while contributions from animal husbandry are negligible. Households of income group 8 with incomes higher than CNY 14 000 basically are households in the *tableland* specialized in apple cultivation. Here, again, income from agricultural activities represents the major income source with roughly 80% of the total income (fig. 7-13).

Fig. 7-13: Sources of Income in Percent of Total Income per Income Group



Note: Definition of income groups see fig. 7-12.

7.4.5 Household Expenses and Debt Situation

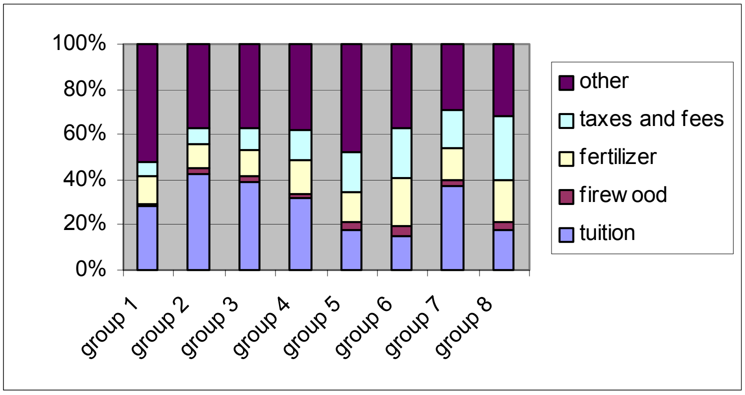
Annual household expenses are estimated at an average of CNY 6405 for the whole survey area. Expenses are comprised of food purchases (in addition to a household's own production) and essential non-food items such as clothing and health care (summarized as *others*), taxes and fees, fertilizer and pesticides, firewood and burning material, and tuition fees for children.

Purchasing food and other essential daily life items makes up around 40% of total expenses for income groups 1 to 6, i.e. 88% of all households. For the two highest income groups, the proportion of food purchases declines to around 30% (fig. 7-14).

Education expenses range between 20 to 40% over all income groups. Education, in general, is more difficult to finance for poorer households whereas richer households are able to spent more on tuition fees in absolute terms and, thus, provide better access to education for their children.

Regarding expenses for fertilizer and pesticides, there is a trend that these increase with total income. Whereas the poorest households spend about 10% on fertilizer and pesticides, the richest households spent up to 20% of total annual expenses. Tax expenses are difficult to estimate as they vary locally and from year to year. In general, they make up between 5 to more than 20% of households' expenditures. Finally, expenditures for fire and heating material make up only a small portion of all household expenses.

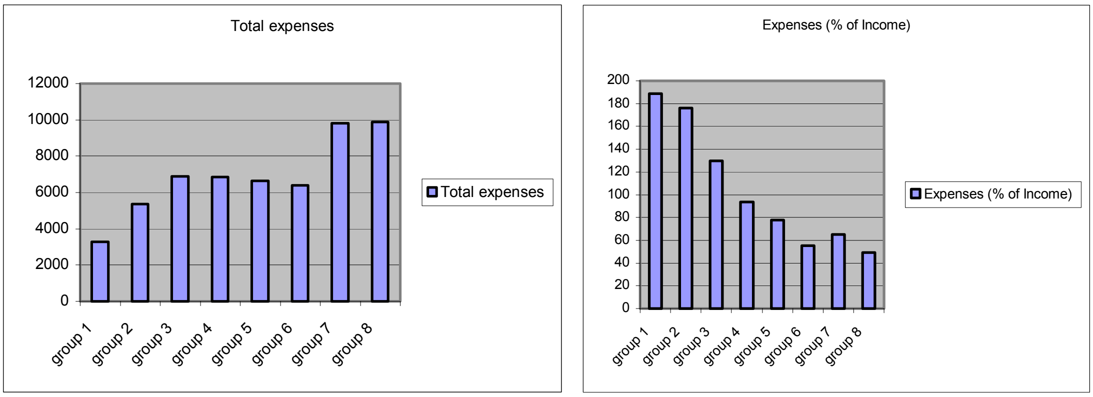
Fig. 7-14: Composition of Annual Expenses of Different Income Groups



Note: Annual expenses per category are expressed as percentage of total expenses per income group (fig 7-12).

More generally, total annual expenses range between about CNY 3000 to 5000 for the two lowest income groups, CNY 7000 for income groups 3 to 6, and to about CNY 10 000 for income groups 7 and 8 (fig. 7-15, left diagram). The findings of the fieldwork suggest that houesholds with an annual income less than CNY 6500, that is at least 50% of all households, are not able to cover necessary life expenditures from their annual income. This also suggests that the already more generous per capita poverty line of CNY1000 is still too low as a measure to adequately capture the current economic hardship in the survey area. Fig 7-15 (right diagram) indicates that the poorest households need about 180% of their annual income to cover their expenditures. Only when incomes exceed CNY 8 to 10 000 (income group 5), sufficient income is generated to cover the expenses and to initiate some savings for future investments.

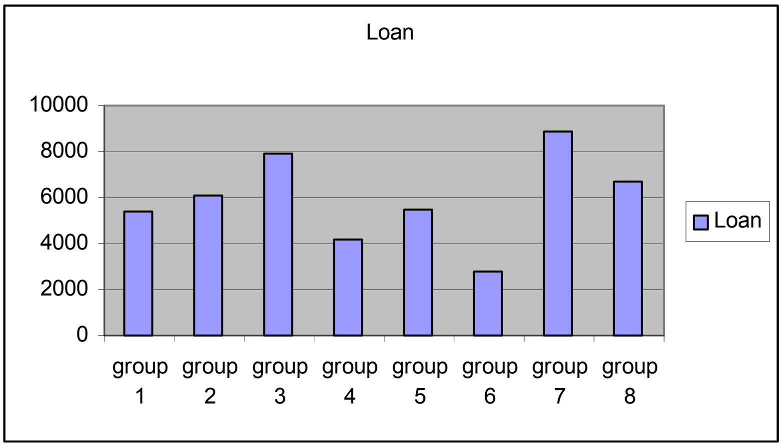
Fig. 7-15: Annual Total Expenses and in % of Total Income per Income Group (CNY)



Note: Expenses per income group expressed as absolute values in CNY (left) and in % of gross income (right).

Nearly all households, regardless to which income group they belong, are heavily indebted (fig. 7-16). According to field findings, loans are not only taken to finance special and costly events, e.g. weddings, funerals, hospital visits, which can easily exceed CNY 20 000, but are also taken on to cover basic living expenses. In some cases, loans are also taken to finance investments such as greenhouses, machinery, or children's education.

Fig. 7-16: Loans Taken by Households According to Income Group (CNY)



Note: Average amount of money borrowed per household according to inomce group; figures in CNY

Money is generally borrowed from local banks when villagers are eligible for government loans and participating in government development programs. Money is also borrowed privately from relatives or professional borrowers. In many cases, farmers reported an annual interest rate of more than 30%; and such interest payments are heavy burdens and likely to constrain future income options. When asked, finally, about future plans, farmers often responded that they are not planning and not even try to forecast the next years' harvests and income options. From this survey, it emerges that the rural financial sector is largely undeveloped constraining development and investment opportunities of households.

7.3 Conclusion

As stated above, it is difficult to generate detailed and comprehensive conclusions for the survey area based on the findings of this observational study. From the insights gained through the field work, it seems that agricultural landuse development is shaped and constrained by the prevailing natural and climate conditions. The further north one moves toward the drier and sandy areas of the Loess Plateau, the less favourable are agricultural production conditions and consequently the lower are incomes from farming. When other income opportunities do not exist, income and living standards decrease along these natural conditions.

It is well documented that China has made considerable achievements in reducing soil erosion since the 1980s, particularly in the Loess Plateau (JIANG, 1997; CHENG & WAN, 2002; WANG & LIU, 1993, WORLD BANK 2000). Among the measures implemented to reduce runoff and minimize sedimentation were large-scale terracing, tree and shrub planting on sloping farmland (often in monocultures), and dam building in gullies to retain sediments. Although these integrated soil conservation watershed management strategies have been largely successful to achieve the primary objective of erosion control, it is also acknowledged that efforts were not sufficiently directed at farmers' concerns and living conditions.

From the above findings, it seems that current land development efforts are well suited to provide rural farmer households with a minimum amount of high quality farmland that allows them to satisfy their basic food needs. Wide-level terrace construction and per capita land allocations can be interpreted as an important element in order to stabilize agricultural production and to provide basic food security. However, it needs to be critically discussed to what extent such land development can contribute to improving rural farmers' incomes beyond the basis subsistence level. Most possibly, options need to be found outside the agricultural sector with better employment and income opportunities in the emerging industrial and services sectors.

With regard to ecological landscape rehabilitation, the reduction of marginal agriculture and animal husbandry, i.e. on erosion-prone sloping lands, it is likely that more and more land resources become available for natural revegetation processes and forest rehabilitation. However, during this study it was difficult to establish a link between farmers' economic situation and accessibility of natural forest resources. It seems unlikely that natural forest rehabilitation—at least in the near and mid-term—will have large measurable economic impacts on the population. With regard to future timber production, it needs also to be considered, that natural forests in the border area to the steppe zone are unlikely to be productive timber resources. Consequently, arguments for natural forest rehabilitation in this particular border region should come from an environmental, i.e. erosion reduction, and ecological (biodiversity) but not from a socioeconomic perspective in the first place. The more general of socioeconomic role of natural forests and forest restoration over Yan'an is discussed in the last chapter.

8. Discussion

8.1 Overview

The major purpose of this study has been to offer a view on the ecological aspects of natural forest rehabilitation on the *Loess Plateau*, particularly in the Yan'an region of northern Shaanxi. The study was also an attempt to combine this primary ecological focus, namely the floristic-ecological research, with a general understanding of the underlying landuse and socioeconomic conditions in the research area based on a supplemental observational survey. In that, the study recognizes that its ecological findings and recommendations on natural forest rehabilitation are only relevant when a broader perspective on the interactions between the local population, people's socioeconomic needs and the natural environment is adopted.

The study also recognizes that an appropriate socioeconomic and institutional framework is a major prerequisite if improvements in overall environmental conditions are to take place and be sustainable. Environmental improvements through natural forest rehabilitation might be quickly reversed if socioeconomic needs put renewed pressure on the resources. Similarly, environmental improvement might not materialize if existing landuse arrangements and regulations encourage uncontrolled and unsustainable utilization of fragile sloping land.

Hence, the conclusions on natural forest rehabilitation of this study—in addition to the findings specifically discussed in the previous chapters—can be viewed from three different angles: the *community ecology perspective*, the *environmental perspective*, and the *socioeconomic and institutional perspective*.

8.2 Community Ecology Perspective

From the *community ecology perspective*, this study finds that distinct floristic differences in the secondary natural forest vegetation as well as in the degraded secondary steppe vegetation exist. The secondary natural forest vegetation of today can be described as a set of forest communities which significantly differ in their species composition at least at the level of dominant tree species (forest stands) and accompanying secondary tree and shrub species. To a similar but somewhat less obvious extent, distinct differences in floristic composition patterns can also be detected for heavily degraded secondary steppe communities.

Despite numerous human disturbances over different temporal and spatial scales, the occurrence of these plant communities is correlated to parameters such as slope aspect, relief, slope degree, and elevation that indicate differing environmental and ecological conditions at the site level. Although correlations do not provide an ultimate proof of the causal relationships, the observed vegetation patterns are interpreted as the result of naturally different habitat conditions. This interpretation is supported by the finding that relevant site parameters indicative for environmental conditions vary at the significance level between the plant communities.

For Yan'an Prefecture, the single most important environmental gradient detected at the site-level is related to moisture conditions and water availability. It is captured in the environmental parameters of slope aspect, relief and slope degree of a particular site. It is thus concluded that habitats are differentiated in each of the five selected study sites along a continuous water availability gradient from relatively moist to relatively dry sites.

The classification of forest communities, which was replicated in two representative study locations—the state forest farms of *Nan Niwan* and *Huangling*—captures the differences in overall ecological conditions well. Independently from human disturbances, the forest vegetation analysis results in a site-specific scheme of forest communities that can serve as guiding theory or benchmark of restoration efforts in different parts of Yan'an.

Despite some differences in the overall species composition, which are related to overall climatic and bio-geographical changes over the region, forest communities of *Nan Niwan* and *Huangling* show similar features and are distributed over the range of local sites conditions in nearly identical patterns. In both locations and hence all over Yan'an Prefecture where forests naturally occur, there is a transition from (1) communities dominated by *Quercus liaotungensis*, i.e. *Acer ginnala (Betula platyphylla)-Q. liaotungensis-, Q. liaotungensis-, Acer stenolobum*-community, toward (2) xero-thermal forests, i.e. mixed deciduous xeric/*Amygdalus davidiana*-community, and finally toward (3) pure *Platcladus orientalis* stands (*P. orientalis* community).

The differences in overall species composition between the plant communities imply that species not only respond differently to environmental conditions but—as species do not interact with the environment in isolation—are also accompanied by shifts in the competition regime between species along the gradient. For example, *Quercus liaotungensis*, the most visible species of this area, proves to be competitive against all other tree species only in the range of improved moisture conditions. With the decreasing moisture, competitiveness of *Quercus liaotungensis* decreases and there is a clear transition toward the predominance of more xerothermic species such as *Acer stenolobum*, *Amygdalus davidiana, Armeniaca sibirica*, *Pyrus betulafolia, Xanthoceras sorbifolia* and *Platycladus orientalis*.

This finding is made on the basis of relative cover degree changes of the dominant tree species along the gradient. The assumption is, however, that the change in cover degree over the forest communities is an appropriate indicator of the competition regime at a particular site and is not influenced by external factors such as selective cutting or selective grazing.

By moving away from the site level to a broader view of vegetation differentiation over Yan'an region, site-specific moisture gradients are complemented by regionally different precipitation, temperature and soil composition patterns. When examining these macro-patterns together with a synoptic ordination of forest and degraded steppe communities, one concludes that southern and central Yan'an is well suited for natural forest vegetation. In these areas, the species composition of steppe communities as compared to the forest communities appears to be mainly shaped by human disturbances, not by different environmental conditions.

On the other hand, the northernmost part of Yan'an Prefecture, i.e. all areas north of the city of Yan'an, appears to be already part of the natural grassland vegetation zone of the northern *Loess Plateau* and, hence, in large parts unsuited for natural forest growth. The synoptic investigation of forest and degraded steppe communities for this sub-region reveals that forest and steppe communities naturally occupy different sections of the moisture gradient in this region. In addition, toward the north of Yan'an Prefecture, there is a characteristic change in soil particle composition toward a larger fraction of sandy soil particles that further supports the assumption of decreasing moisture availability. Here, natural forests are likely to grow in small patches in moist valley grounds but are unlikely to form a continuous forest cover.

In conclusion, the floristic-ecological research results in two major findings. Firstly, the study broadly confirms the existing vegetation zonation system for the *Loess Plateau* as has been described, for example, by SONG (1983), HOU (1986), and CHEN (1992). Secondly, with its particular floristic-ecological perspective, the study further develops the general climate-based zonation system of the above authors. It identifies three characteristic forest types ranging from zonal (oak forests) to intermediary (mixed mesic forests) toward azonal forest types (*Platycladus orientalis* forests), which have not been described at that level of detail so far. The detection of site specific environmental and community level differences therefore suggests a refinement of the current vegetation zonation in this study area.

With regard to the original study objective to devise a species guide for natural forest rehabilitation in Yan'an Prefecture, this objective needs to be qualified somewhat. It can be argued that the simultaneous planting of different tree and shrub species in one site in order to mirror the existing natural forests is simply unrealistic. Local administrations and population in this underdeveloped region probably lack the capacity to carry out, monitor and manage such sophisticated plantings. With the above study results, however, a simple guidance on the ecological demands of common tree species is now available.

Furthermore, it is likely to be beyond the local means to provide the financial and technical resources required for collecting and breeding seeds, raising sufficient numbers of seedlings of many different species at the same time, appropriate transportation of plants and implementation of plantings. And finally, a high input into planting is no guarantee that reforestation or restoration will be successful. However, there are other options where the ecological findings can provide useful advice.

In large parts of the study area, natural forests are likely to quickly reappear in the course of natural succession. As farming becomes less land intensive under the current development programs, more and more areas become available for natural regeneration of forests. It was observed in the field that many species of the local species pool are able to quickly establish and form a closed vegetation cover in areas where farming has been abandoned.

Natural forest regeneration with low human input is a cost-efficient strategy to landscape rehabilitation, especially on marginal sloping lands, where previous farm yields have been very low and opportunity cost of a landuse change from farming to forest seem to be negligible. Supplemental tree planting into ongoing natural forest regeneration could be a low-cost, low-input strategy for farmers to meet individual household or community needs, e.g. production of high quality construction wood (*Quercus, Acer, Platycladus* etc.). Combining natural regeneration with modest social forestry objectives seems to be one option to handle today's marginal farmlands in the future and at a large scale. In that way, forest rehabilitation can be seen as one element of a more integrated approach to development.

Natural forest regeneration, finally, can benefit from today's remaining patches of natural forests as these serve as suppliers of species and seeds. In terms of biodiversity, natural forest regeneration, which occurs at different speeds and on different spatial scales, i.e. from small succession patches to large undisturbed areas, might also be an efficient strategy to protect single species as well as ecological processes at their different stages of development. This might be especially important in terms of the expected global climate change and the ability of individual species and ecosystems to adapt to a changing climate.

Future ecological research objectives should thus focus on ecological amplitudes of key species and ecosystems in the *Loess Plateau*, and on potential impacts of the expected climate change on the vegetation and the consequences for the region. Finally, a more detailed insight into natural and near-natural steppes is required to develop recommendations for steppe restoration and ecologically appropriate management of the northern areas of the *Loess Plateau*.

8.3 Environmental Perspective

From an *environmental perspective*, the reviewed literature as well as findings from other countries, by and large, offer strong arguments that natural forest vegetation compares favorable to other vegetation types in terms of soil and water protection functions. Considerations to reduce upstream soil erosion and prevent downstream sedimentation, therefore, need to include large-scale natural forest regeneration as a major strategy to alleviate these problems. Potentially, forest regeneration on unused farmland could also be an economic option for local farmers. Farmers would provide valuable environmental services to the society through forest management and in turn would need to receive compensation for their input.

It was beyond the scope of this study to identify and quantify the potential amount of reduced erosion through forest regeneration. Some studies are currently underway for the *Loess Plateau*, but it is difficult to distinguish between different scales and time periods of erosion and sedimentation phenomena. For example, is primary erosion through farming on small farmland plots directly leading to large-scale sedimentation downstream? What is the relative contribution of an upstream farming household to downstream sedimentation as compared to other land-related activities that induce erosion, i.e. infrastructure construction? How can environmental benefits and costs of upstream farming be quantified and valued in monetary terms? Such questions would need to be elaborated on before payment schemes for ecological services of forests can be developed and implemented.

8.4 Socioeconomic Perspective

The *socioeconomic perspective* of this study confirmed the initial expectation that collecting good data at sufficient level of detail is a difficult task. It is, however, felt that the household information gathered in this study provides an appropriate qualitative understanding of the living conditions of local communities. The findings also touch on the relationship between rural farmers and their socioeconomic strategies in relation to natural secondary forest as well as artificial tree plantings. This qualitative approach possibly needs to be complemented with more detailed and specific quantitative analysis in the future to evaluate and quantify the specific importance of the different types of forest and tree management.

With regard to the existing secondary natural forests in northern Shaanxi, there is basically no systematic or institutionalized interaction between the local population and natural forest resources. Today’s forests are managed under state-owned forest farms with forestry staff often coming from outside areas or other provinces. In general, neither local communities nor individual farmers participate in forest management and are excluded from the use of natural forest resources. The reasons for the exclusion of farmers from natural forest management are complex and rooted in the history of China, especially after 1949. Natural forest management in northern Shaanxi is not associated with social forestry objectives as compared to southern China with its long tradition of community forestry.

In the north, forestry is generally not part of any strategy to provide income opportunities or to reduce economic vulnerabilities of the farming population, for example, through ownership of land or contracting of (natural) forests to individual farmer households or communities. Hence, there is currently little opportunity for farmers to get involved into sustainable management of these forest resources.

In some cases, rural households living close to the forest farms combine their agricultural production with animal husbandry and utilize forests as open-access grazing grounds. Overall, this kind of utilization comprises only a small proportion of overall household income and is not based on any defined management arrangement. Similarly, the collection of non-timber forest products, such as fungi, game and medicinal plants appears to be negligible in terms household income.

As to distinguish from secondary natural forests, *artificial tree plantings* on private household plots, so-called *economic forests* such as fruit tree plantations, *Robinia pseudoacacia* or *Pinus tabulaeformis* stands, and shrub plantings for fodder harvesting are often comparatively well managed as they represent additional sources of income for the rural household. Similarly to farmland plots, such tree plots are contracted out long-term to individual farmers under the Household Responsibility System (HRS). Although, farmers primarily depend on the availability of high quality farmland for their subsistence and off-farm employment opportunities for cash income, these tree plots—depending on the climatic and socioeconomic conditions—represent economically relevant supplementary resources.

YIN & XU (2002) discuss the aggregate welfare effects of private forest land, i.e. contracted tree plots, in the context of China's rural agricultural reforms that started in the early 1980s. In the course of these reforms, the originally collective land ownership under the Soviet-style cooperative system, covering farmland in the beginning only, was transformed into household-level management, i.e. the Household Responsibility System. With the successful increase of agricultural production—farmers responded quickly to the incentive of private ownership of land by increasing investments and production—and the emergence of competitive markets, the HRS was later expanded to cover non-farming land as well. The purpose of this expansion was to replicate the good experiences with the HRS in the farming sector.

Generally, in northern China, the expansion of the HRS to land other than farmland led to a sharp increase of fruit tree plantings, the emergence of agro-forestry systems, and an overall increase in forest and shrub cover over the region (YIN & XU, 2002). These findings generally indicate that the delegation of management responsibilities to farmers with the right incentives in place can ensure long-term, productive and sustainable management of the respective resource.

These findings also seem to be of special relevance with regard to the current policy environment and future resource management arrangements in Yan'an.

Firstly, farmers are currently not involved in the management of natural forests. With the implementation of the Natural Forest Protection Program (NFPP) in 1999 and the imposition of a total logging ban on state-owned forest farms, there is no strategy on how to sustainably manage existing natural forests.

Involving farmers in the management of these forests, either at the community level or at the household level, potentially offers an opportunity to expand farmers' income opportunities in terms of timber and other forest products in the long run. At the same time, delegating management responsibilities might help creating necessary incentives to sustainably manage the existing forests.

Secondly, the inclusion of farmers into the management of existing forests could serve as a model for the future management of natural forest and shrub vegetation that is likely to appear on land that is no longer needed for agricultural production. Currently, it seems that through the implementation of the Sloping Land Conversion Program (SLCP), i.e. a general reduction of farming on sloping land, a large-scale natural re-vegetation process takes place in many areas of the *Loess Plateau*. Ultimately, large areas of southern and central *Yan'an Prefecture* could develop into natural forests if this process is not disturbed by renewed land reclamation.

A social forestry strategy to assist farmer in pursuing economic objectives in these natural succession areas, for example through targeted planting and management of appropriate species of economic value to farmers, could be another measure in integrating farmers' economic objectives with the environmental goal of landscape rehabilitation. However, low annual rainfall and unfavorable climate and soil conditions might be limiting factors in this context.

Reflecting critically on the above suggestions for long-term sustainable resource management in Yan'an, the relative change in land value, i.e. marginal sloping lands are abandoned while highly productive terraces are constructed for intensive farming, offers an excellent option that can be exploited for natural forest regeneration. As terrace construction raises the economic productivity of the land unit, opportunity cost of farming on sloping land will decrease far below the opportunity cost of terrace farming and off-farm labor. Consequently, farmers seek to allocate their labor resources to terrace farming and work outside the agricultural sector where they expect highest returns. In turn, slopeland farming will automatically decrease.

As most of the land in the northern *Loess Plateau* is sloping land and terraced areas comprise only a small portion of the total land, it can be argued that the land value for large parts of the plateau is relatively small. Natural vegetation will automatically emerge as this landuse change takes place. Natural vegetation and the associated environmental benefits can thus be interpreted as an unintended but positive impact of the induced economic land value changes.

Although, this hypothesis was not explicitly examined in this study, field observations provided some indication for this interpretation. In this case, natural vegetation rehabilitation would be mainly a side-effect in a complex development process in Yan'an but not be driven by expected direct economic benefits from forests. At this moment, natural forest restoration offers only very limited socioeconomic benefits for the rural population.

Beyond this short-term view, natural forests might however develop into economically important natural resources in the future. In any case, with the likely reemergence of natural vegetation in the region, a strategy and vision for sustainable forest management needs to be developed. Involving the local communities into the management of forest resources and creating incentives to sustainable forestry are probably promising and important steps to sustainable development in the Loess Plateau.

Summary

The *Central Loess Plateau* of Northwestern China comprises the world's largest continuous geological deposits of wind-blown loess and is characterized by massive soil erosion and serious land degradation. Annual erosion rates amount to 4300 tons/sq. kilometer under farmland and up to 6100 tons/sq. kilometer in the most heavily degraded locations. In addition, the *Loess Plateau* is one of the least developed and poorest regions in China. The Chinese government has long given priority to soil erosion prevention, improvement of farming techniques and the ecological rehabilitation of the plateau.

This study is concerned with two different aspects of natural forest rehabilitation in the context of environmental and economic development in the *Loess Plateau*. Firstly, the study aims at documenting the floristic composition of remaining secondary natural forests as well as degraded secondary steppe communities, relating floristic differences among plant communities to environmentally different site conditions, and analyzing the ecological suitability of today's degraded steppe areas for natural forest vegetation. Secondly, the study also aims at examining the current socioeconomic conditions of rural households in the plateau. It discusses the potential implications that current landuse patterns might have on natural forest rehabilitation.

This research was implemented during 2000 to 2003 in Yan'an Prefecture of Shaanxi Province, P.R. China. In terms of data collection and analysis, vegetation samples were collected in five different locations in Yan'an covering forest and degraded steppe vegetation in the south, center, and north of the prefecture. Adopting a floristic-sociological approach, vascular plants species were recorded based on individual cover degrees on marked-out quadrats of 100 sq. meters size. Altogether, 354 relevés were generated that equally covered all main expositions. Vegetation data was then processed and evaluated using multivariate methods.

In the first step, *detrended correspondence analysis (DCA)* was applied to explore the distribution of sample plots in an abstract low-dimensional floristic space. In the second step, environmental parameters, such as slope aspect, elevation, slope degree, precipitation, temperature, were correlated with the results of the ordination. The originally constructed floristic space was then interpreted as an ecological space. In the third step, vegetation data was hierarchically classified with *two-way indicator species analysis (TWINSPAN)*. Based on these classification results, different sets of plant communities for the study locations were derived and interpreted along characteristic site conditions. Finally, *analysis of variance (ANOVA*) was performed for a selected sub-set of the forest vegetation data to provide a statistical prove for the ordination and classification results and their proposed ecological interpretation.

Simultaneously, socioeconomic surveys were carried out in form of an observational study in 22 villages of three counties of Yan'an. In total, 154 households and 10 county/township governments were surveyed. The main methods used were informal discussions with government officials of functional departments and semi-structured interviews at the household level. Interviews with government officials focused on a general understanding of the economic situation in different areas of Yan'an.

At the household level, interviews covered land resource distribution, farming patterns, annual yields and market prices of major agricultural crops, labor and capital investments of households, off-farm employment opportunities, education level, and farmers' perspectives on forests and reforestation.

Household data was then evaluated with correspondence analysis to detect and describe different landuse systems within the study area. Variables to distinguish these systems were crop mix at the household level, cultivation centers of individual crops over the region, geomorphological and climatic characteristics. A *multiple regression model* was developed to explain major determinants of agricultural income. Furthermore, *analysis of variance (ANOVA)* was applied to the data to discern income differences between different townships and landscape types at the statistical significance level.

Results of the ecological study are as follows. Although the selected survey area has long been under intensive agricultural use and in large parts is heavily degraded, the region still contains diverse and species-rich secondary natural forests. The analysis of forest vegetation revealed that a characteristic set of forest communities exists throughout the region. The spatially relevant forest types and communities are: (1) mesic mixed oak forests: *Acer ginnala-Quercus liaotungensis* community, *Quercus liaotungensis* community, *Acer stenolobum* community; (2) xeric broadleaved deciduous forests: *Amygdalus davidiana* community; (3) azonal xeric coniferous forests: *Platycladus orientalis* community.

These forest communities are distributed along a site-specific humidity gradient and, in the field, can be easily related to slope aspect and other topographical features. For example, while the mesic oak forests are mainly distributed on northwestern to northeastern slopes and valley locations of relatively better moisture conditions, the xeric broadleaved deciduous forests are distributed on southwestern to southeastern drier slopes. Finally, the *Platycladus orientalis* community is restricted to steep (> 25º) southern and southwestern slopes. These slopes mark the most unfavorable sites in the ecological spectrum in terms of local moisture conditions.

Regarding its practical relevance, the proposed site-specific classification of forest communities and the documentation of their major tree and shrub species can serve as an orientation and guideline for ecologically oriented afforestation or natural forest rehabilitation. The comparatively large species pool (altogether about 40 tree and shrub species) of this temperate semi-humid to semi-arid region offers a variety of options to move away from mono-species afforestation such as plantations of *Robinia pseudoacacia* or *Pinus tabulaeformi*s.

The analysis of degraded secondary vegetation showed similar distributional patterns as the forest vegetation along site-specific humidity gradients. Despite the heavy degradation, steppe communities better adapted and communities less well adapted to drought conditions could be identified for all sites. Human disturbances, i.e. landuse systems, play a major role in shaping the species composition of these communities. Hence, the proposed classification can only be interpreted as a temporary delineation of currently existing plant communities but not as the natural vegetation potential of these sites.

When finally synoptically evaluating the distribution of natural forest communities and degraded secondary steppe communities, two major patterns emerge.

In the southern and central part of Yan’an Prefecture, degraded steppe communities are positioned within the range of environmental site conditions forest communities are distributed in. Basically, human disturbances have resulted in an alteration of the species composition as well as in a reduction of species diversity per sample plot. Both sets of plant communities (forests and steppes), however, show a clearly parallel response along equivalent site conditions. From an ecologicl perspective, then, rehabilitation (reforestation) of natural forests appears to be uncritical in these areas.

Contrastingly, in northern Yan’an, degraded secondary steppe communities are much further spread out toward the drier end of the site-specific moisture gradient. This indicates, that these drier sites here are possibly not suited for natural forest vegetation any more. Instead, these areas can be interpreted as natural steppe areas. Possible explanations for the unsuitability of sites for closed natural forests—besides the overall drier climate in the north of the prefecture—are a change in the soil particle composition toward a larger proportion of sandy fractions and, hence, a reduced water retention capacity of soils as described in the literature.

With regard to the socioeconomic study results, *Yan’an Prefecture* can be divided into two climatically and geo-morphologically sub-regions with distinctly different landuse systems. These two sub-regions mirror the above distinction between areas suited for natural forest vegetation and those not suited for natural forest growth. The northern part of the prefecture, i.e. forest steppe and natural grassland areas, can be characterized as subsistence farming area. The southern part, i.e. the natural forest area, comprises a center of intensive farming and high-yielding apple production.

Overall, agricultural incomes of household appear to be significantly dependent on the availability of high quality (terraced) farmland and the amount of fertilizer and pesticides used, but also on overall climate conditions as well as landscape features. Furthermore, there is an indication that agricultural income increases as farming on sloping farmland decreases, i.e. overall agricultural productivity per land unit increases.

Income from animal husbandry is the highest in areas, which are nearby natural forest and shrub vegetation areas. Here, the local population uses these areas as open-access grazing grounds. However, there is a tendency, that households of forest-rich areas that focus on animal husbandry are the poorest in the whole prefecture. Off-farm employment is equally important to all households over the region, but mainly depends on the villagers’ connection to the urban centers. Generally, the proportion of the rural households still living in poverty is between 40 to 50%.

With regard to natural forest rehabilitation, current land development efforts to create small patches of high-quality farmland in the form of wide-level terraces and abandoning slopeland farming in large parts of the loess plateau have the effect that less land per capita is needed to fulfill basic subsistence needs. With the reduction of farming on sloping land, potentially more and more land becomes available that can be devoted to natural vegetation rehabilitation at comparatively low opportunity cost for rural households. In large parts of the study area, this rehabilitation could take place along the classified forest communities and site conditions. However, it remains to be seen if current landuse changes are permanent and are not being reversed when macro-economic or demographic conditions change.

When finally looking at the socioeconomic importance of ecological landscape rehabilitation through natural forest restoration, only cautious judgments should be made. During the field work, it was hardly possible to identify or even quantify potential near-term socioeconomic benefits of forest rehabilitation at the household level. This study, therefore, concludes that natural forest rehabilitation should be viewed from ecological and environmental perspectives instead of expecting significant and measurable socioeconomic benefits from such plantings in the near future.

Zusammenfassung

Das *zentralchinesische Lößplateau* ist die größte zusammenhängende Lößablagerungsstätte der Welt und ist durch massive Bodenerosion und großflächige Landdegradation gekennzeichnet. Jährliche Erosionsraten können unter landwirtschaftlicher Nutzung bis zu 4300 t/km² und in den am stärksten degradierten Bereichen bis zu 6100 t/km² betragen. Lößplateau zählt zudem zu den wirtschaftlich rückständigsten und ärmsten Regionen in China. Die chinesische Regierung implementiert daher schon seit vielen Jahren Programme zur Eindämmung und Reduzierung der Erosion, zur Verbesserung der landwirtschaftlichen Anbaumethoden sowie zur ökologischen Landschaftsrehabilitierung.

Die vorliegende Studie befaßt sich mit verschiedenen Aspekten der ökologischen Landschaftsrehabilitierung im Lößplateau. Zum einen hat die Studie zum Ziel, das floristische Inventar der heute vorhandenen sekundären naturnahen Wälder sowie der sekundären Steppenvegetation der stark degradierten Bereiche zu dokumentieren, die Beziehungen zwischen Vegetationsverteilung und wesentlichen Standortfaktoren offenzulegen und schließlich die Waldfähigkeit heute waldfreier Teilregionen aus standörtlicher Sicht zu analysieren. Zum anderen befaßt sich die Studie mit den sozioökonomischen Rahmenbedingungen der ländlichen Haushalte im Untersuchungsgebiet. Es werden dabei neben der allgemeinen Einkommenssituation auch die Auswirkungen gegenwärtiger Veränderungen in den bestehenden Landnutzungssystemen auf eine zukünftige naturnahe Wiederbewaldung diskutiert.

Die Forschungsarbeiten wurden während der Jahre 2000 bis 2003 in der Präfektur Yan'an (Shaanxi) in China durchgeführt. Im Rahmen der Feldarbeiten wurden in fünf verschiedenen Untersuchungsgebieten Daten zur naturnahen Waldvegetation sowie degradierten Sekundärsteppenformationen erhoben. Die Untersuchungsgebiete waren von Nord nach Süd über die gesamte Präfektur Yan'an verteilt. Gemäß des floristisch-soziologischen Ansatzes der klassischen Vegetationskunde wurden auf repräsentativ im Gelände verteilten Untersuchungsflächen (100 m²) alle Gefäßpflanzen mit ihren individuellen Deckungsgraden aufgenommen. Insgesamt wurden 354 pflanzensoziologische Aufnahmen erarbeitet und aufbereitet, die die acht Hauptexpositionsrichtungen in allen Gebieten gleichermaßen abdecken.

Die multivariate Analyse umfaßte folgende Schritte: Mit Hilfe einer Korrespondenzanalyse durch Ordination *(DCA)* wurde die Verteilung der Aufnahmeflächen in einem abstrakten zwei- bis dreidimensionalen floristischen Raum erarbeitet. Zusammen mit den gewonnenen Standortdaten wurde der floristische zu einem ökologischen Raum erweitert und die Beziehungen zwischen Vegetation und Standort dargestellt. In einer formalen Klassifikation *(TWINSPAN)* ausgeschiedene Vegetationseinheiten wurden mit Hilfe der Ordinationsergebnisse verifiziert und entlang ökologischer Standortgradienten interpretiert. Auf der Basis einer Varianzanalyse (ANOVA) wurden schließlich standörtliche Unterschiede zwischen den ausgeschiedenen Vegetationseinheiten und Verteilungszentren einzelner wichtiger Baumarten statistisch abgesichert.

Sozioökonomische Befragungen wurden in Form einer beobachtenden Studie in 22 Dörfern in drei Landkreisen in Yan'an durchgeführt. Insgesamt wurden 154 ländliche Haushalte befragt sowie 10 Landkreis- und Gemeindeverwaltungen besucht. Wesentliche Methoden der Datenerhebung waren informelle Diskussionen mit Personal verschiedener Funktionsabteilungen der Kreis- und Gemeindeverwaltungen sowie Interviews auf der Haushaltsebene.

Gespräche mit Verwaltungspersonal hatten vorwiegend zum Ziel, eine allgemeine Einsicht in die lokalen wirtschaftlichen und organisatorischen Gegebenheiten in Yan'an zu erhalten. Haushaltsinterviews deckten Aspekte der Landverteilung und der Landnutzungssysteme ab und befaßten sich mit durchschnittlichen jährlichen Erntemengen wichtiger Feldfrüchte, Markterlöse, Arbeits- und Kapitalinvestitionen der Haushalte, Einkommen aus außerlandwirtschaftlicher Tätigkeit, Ausbildungsstandard sowie allgemeinen Fragen zu Waldnutzung und Wiederbewaldung.

Haushaltsdaten wurden mit Hilfe einer Korrespondenzanalyse ausgewertet, um die regionalen Landnutzungssysteme zu erfassen und zu interpretieren. Externe Variablen zu Erklärung von Unterschieden in der Landnutzung zwischen verschiedenen Gemeinden in Yan'an waren die Zusammensetzung der Umfang der angebauten Feldfrüchte (Erfassung von Anbauzentren) sowie geo-morphologische und klimatische Charakteristika. Ein Regressionsmodell half, die wichtigsten Einflußgrößen auf das landwirtschaftliche Einkommen zu erklären, während mit einer Varianzanalyse die aufgedeckten Unterschiede verschiedener Einkommensarten aus Landwirtschaft, Viehzucht und außerlandwirtschaftlicher Tätigkeit zwischen den betrachteten Gemeinden statistisch abgesichert werden konnten.

Die Ergebnisse der vegetationskundlichen Teilstudie können wie folgt zusammen gefaßt werden: Obgleich das ausgewählte Untersuchungsgebiete im zentralen Lößplateau seit langem intensiver menschlicher Nutzung ausgesetzt und in weiten Teilbereichen stark degradiert ist, hat sich in Teilbereichen von Yan'an eine artenreiche und standörtlich differenzierte naturnahe Waldvegetation erhalten. Charakteristische Waldvegetationstypen und Waldgesellschaften in Yan'an sind (1) mesische Eichenmischwälder: *Acer ginnala-Quercus liaotungensis* Gesellschaft, *Quercus liaotungensis* Gesellschaft, *Acer stenolobum* Gesellschaft, (2) xerische sommergrüne Laubmischwälder: *Amygdalus davidiana* Gesellschaft und (3) azonale xerische Nadelwälder: *Platycladus orientalis* Gesellschaft.

Diese Waldgesellschaften differenzieren sich entlang eines standörtlichen Feuchtegradienten und können in ihrer räumlichen Verteilung im Gelände leicht mit der jeweiligen Exposition sowie anderen topographischen Gegebenheiten in Beziehung gesetzt werden. So besiedeln beispielsweise die mesischen Eichenwälder überwiegend feuchtebegünstigte nord-west- bis nordost-exponierte Hanglagen sowie Tallagen, während die xerischen Laubmischwälder vor allem an Südwest- und Südosthängen zu finden sind. Die *P. orientalis* Gesellschaft schließlich ist beschränkt auf die steilen und südexponierten Hanglagen, die die relativ ungünstigsten Feuchteverhältnisse im lokalen Standortspektrum aufweisen.

Im Hinblick auf ihre Anwendungsrelevanz können die ausgeschiedenen standortspezifischen Waldgesellschaften und die Dokumentation der wichtigsten, d. h. bestandesbildenden, Gehölzarten dieser Gesellschaften als Orientierung und Richtlinie für eine ökologisch orientierte Wiederbewaldung (Wiederaufforstung degradierter Bereiche) dienen. Der vergleichsweise große natürliche Artenpool (mehr als 40 Baum- und Straucharten) dieser temperierten semi-humiden bis semi-ariden Region bietet damit viele Möglichkeiten von den bisher praktizierten Aufforstungen von Monokulturen, überwiegend *Robinia pseudoacacia* oder *Pinus tabulaeformis*, abzugehen.

Die Analyse der degradierten Sekundärsteppen zeigt eine im Grundzug ähnliche Vegetationsverteilung entlang eines standort-spezifischen Feuchtegradienten wie die Waldvegetation. Trotz einer weitgehenden Degradierung konnten in allen Untersuchungsgebieten eine Differenzierung in eine Gesellschaft mit geringeren Ansprüchen und eine mit höheren Ansprüchen an die lokalen Feuchteverhältnisse identifiziert werden. Da menschliche Nutzungseinflüsse ein wesentlicher Faktor in der Vegetationsentwicklung und –verteilung in diesen Bereichen darstellen, können die ausgeschiedenen Pflanzengesellschaften jedoch nur als eine Momentaufnahme im lokalen Nutzungsumfeld interpretiert werden.

In der die Vegetationsanalyse abschließenden synoptischen Betrachtung von naturnaher Waldvegetation und degradierte Sekundärsteppenvegetation stechen zwei Beobachtungen hervor, die bei der Planung von Wiederaufforstungen berücksichtigt werden müssen:

Im südlichen und zentralen Teil der Präfektur Yan'an befinden sich die ausgeschiedenen degradierten Steppengesellschaften ausschließlich innerhalb des von den Waldgesellschaften besetzten Standortspektrums. Im wesentlichen hat hier die menschliche Bewirtschaftung im Vergleich zu den umgebenden Wäldern zu einer Veränderung der Artenzusammensetzung, aber auch zu einer Reduzierung der Artenvielfalt pro Aufnahmefläche geführt. Beide Aufnahmekollektive (Wälder und Sekundärsteppen) zeigen jedoch ein klare und parallele Differenzierung entlang äquivalenter Standortbedingungen. Aus standörtlich-ökologischer Sicht erscheint die naturnahe Wiederbewaldung mit heimischen Baumarten hier unproblematisch.

Im Gegensatz dazu zeigen sich im nördlichen Teil von Yan'an die degradierten Sekundärsteppen weit über den von den naturnahen Wäldern besiedelten Standortbereich hinaus in trockenere Bereiche verschoben. Diese Beobachtung deutet darauf hin, daß diese trockeneren Bereiche weniger gut oder aber überhaupt nicht mehr für Aufforstungen geeignet sein könnten. Statt dessen können diese Teilbereiche als natürliche Steppenstandorte charakterisiert werden. Als mögliche Erklärungen für die Grenze der Waldfähigkeit, neben dem allgemeinen regionalen Klimagradienten, können die in der Literatur beschriebenen Verschiebungen in der Korngrößenverteilung der Lößböden hin zu sandigeren Böden und damit eine reduzierte Bodenwasserverfügbarkeit angeführt werden.

Auf der Basis der gewonnenen sozioökonomischen Daten, kann Yan'an entlang klimatischer und geomorphologischer Merkmale in zwei Teilregionen mit distinkt verschiedenen Landnutzungssystemen gegliedert werden. Diese beiden Teilregionen spiegeln dabei auch den oben beschriebenen Wechsel von waldtragenden bzw. waldfähigen Bereichen hin zu natürlichen, nicht waldfähigen Steppenbereichen wieder. Der nördliche Teil der Präfektur, die Waldsteppen- und Steppenzone, kann als Teilregion der Subsistenzlandwirtschaft charakterisiert werden. Die südliche Teilregion, die Waldzone, dagegen ist ein Zentrum der produktiven Landwirtschaft und des großflächigen Apfelanbaus.

Das landwirtschaftliche Einkommen der betrachteten Haushalte hängt im allgemeinen von der Verfügbarkeit von qualitativ gutem Ackerland und dem Einsatz von Düngern und Pestiziden ab, ist aber auch wesentlich bestimmt von den allgemeinen klimatischen und geomorphologischen Rahmenbedingungen. Die Auswertung hat auch gezeigt, daß (mit der Verfügbarkeit von Terrassen) das landwirtschaftliche Einkommen steigt, sobald die Landwirtschaft auf Hanglagen reduziert wird und damit die Produktivität pro Flächeneinheit ansteigt.

Einkommen aus Viehzucht ist in denjenigen Gemeinden am höchsten, die nahegelegene Wald- und Strauchgebiete, teilweise unter Umgehung des Beweidungsverbots, als Weidegründe nutzen. Gleichzeitig hat sich gezeigt, daß Haushalte der Gemeinden, in denen Viehzucht eine besondere wirtschaftliche Bedeutung hat (waldnahe Gebiete), tendenziell die ärmsten in der ganzen Präfektur sind. Einkommen aus außerlandwirtschaftlicher Produktion schließlich ist für alle Haushalte gleichermaßen wichtig, ist aber in besonderem Maße von der Zugänglichkeit zu städtischen Zentren abhängig. Generell leben ca. 40 bis 50 % aller betrachteten Haushalte in Armut.

Im Hinblick auf die Wiederbewaldung haben die gegenwärtigen Landentwicklungsbemühungen, die Schaffung hochproduktiver Terrassen sowie Reduzierung des Ackerbaus auf Hanglagen, den Effekt, daß in Zukunft weniger pro Kopf benötigt wird, um die Grundnahrungsbedürfnisse zu befriedigen. Mit der Reduzierung relativ unproduktiver Landwirtschaft auf steilen Hanglagen steht in Zukunft mehr Land zur Verfügung, welches bei geringen Opportunitätskosten für die ländlichen Haushalte potentiell für die Wiederbewaldung genutzt werden könnte. In weiten Bereichen des Untersuchungsgebietes könnte eine solche Wiederbewaldung entlag der besprochenen Waldgesellschaften stattfinden. Trotzdem bleibt abzuwarten, ob die gegenwärtigen Veränderungen in der Landnutzung dauerhaft sind oder bei sich verändernden makroökonomischen oder demographischen Veränderungen wieder umkehren.

In der abschließenden Betrachtung der sozioökonomischen Bedeutung der Wiederbewaldung bleibt festzuhalten, daß ein direkter ökonomischer Zusammenhang zwischen der Existenz von Wäldern und dem Haushaltseinkommen nicht festzustellen war. Ökologisch orientierte Wiederbewaldung sollte daher anstatt in Erwartungen kurz- oder mittelfristiger ökonomischen Verbesserungen für die ländliche Bevölkerung aus ökologischen und umweltrelevanten Aspekten erfolgen und begründet werden.

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Literature

Anonymous, 2000a. “Yan’an Shi Guomin Jingji Fazhan Gaikuang 2000 (Yan’an Prefecture- Economic Development Overview)”; unpublished government document.

Anonymous, 2000b. “Yan’an Tudi Liyong Xiankuang (Landuse in Yan’an Prefecture)”; unpublished government document.

Anonymous, 2000c. “Yan’an Laoqu Jianshi Fupin Fazhan Gongzuo Qinkuang Huibao 2000 (Report on Poverty Alleviation and Development in Yan’an)”; unpublished government document.

Anonymous, 2000d. “Yan’an Nongye Shengchan Qingkuang Huibao 2000 (Report on the Situation of the Agricultural Sector in Yan’an)”; unpublished government document.

Bo Yinsheng, Han Enxian, Luo Weixiang, 1998: “A Preliminary Study on the Seasonal Growth Dynamics of *Platycladus orientalis* and its Relationship with Water and Thermal Conditions.” Scientia Silvae Sinicae, Vol. 34, No. 5: 120-126 (in Chinese).

Cai Yunlong, Fu Zeqiang, Dai Erfu, 2002: “The Minimum Area per Capita of Cultivated Land and its Implication for the Optimization of Land Resource Allocation.” Acta Geographica Sinica, Vol. 57, No. 2: 128-134 (in Chinese).

CCPH, 1998. Map of China. China Cartographic Publishing House.

Chambers, R., 1994. “The Origins and Practice of Participatory Rural Appraisal”. World Development, Vol. 22, No. 7: 953-969.

Che Kejun, Fu Huien, He Hongyuan, 1994. “A Study on Mechanisms of Water Resource Conservation of Forests on Northern Slopes of the Qilian Mountains.” in: Long-term Research on China’s Forest Ecosystems, China Forestry Publishing House, : 280-287 (in Chinese).

Chen Cungen, 1997. “Standörtliche, vegetationskundliche und waldbauliche Analyse chinesischer Gebirgsnadelwälder und Anwendung alpiner Gebirgswaldbaumethoden im chinesischen fichtenreichen Gebirgsnadelswald”. Dissertation Universität für Bodenkultur in Wien, VWGOE Wien, 314 pages.

Chen Lingzhi, 1992. “The Oak Forests in North China.” Braun Blanquetia, Vol. 8: 33-39.

Chen Yunming, 2002, Liang Yimin, Cheng Jimin. “The Zonal Character of Vegetation Construction on the Loess Plateau.” Acta Phytoecologica Sinica, Vol. 26, No. 3: 339-345 (in Chinese).

Cheng Jimin, Wan Hui’e, 2002. “Zhongguo Huangtu Gaoyuan – Zhibei Jianshi Yu Shuitu Baochi (The China Loess Plateau–Vegetation Construction and Water and Soil Conservation)”. China Forestry Publishing House, 426 pages.

Chinese Academy of Engineering (CAE) - Western China Water Resources Project Of Fice, 2002. “Xibei Diqu Shui Ziyuan Peizhi, Shengtai Huanjing Jianshi Fazhan He Kezhixu Fazhan Zhanlü Yanjiu” (Western China – Strategy Research Paper on Water Resources Allocation, Ecological Environment Construction and Sustainable Development. Newsletter No. 28.

Chinese Academy of Sciences (CAS), 1995. “Huangtu Gaoyuan Zonghe Kaocha Dui” (Loess Plateau Comprehensive Scientific Survey Series in 16 volumes). China Environmental Science Publishing House.

CSY, 1997. China Statistical Yearbook. China Statistical Publishing House.

Dai Xiaobing, 1993. “Changes in Composition and Structure of *Vitex*-Shrubland in Northern China in Relation to Human Disturbance.” Journal of Vegetation Science 4: 109-114.

Dai Xiaobing, Chen Lingzhi, Huang Jianhui, 1990. “The Restoration of the Destroyed Forest Vegetation in Yunmeng Mountain, Beijing.” Vegetatio 87: 145-150.

Dang Kunliang, 1994. “Studies on Soil Runoff Characteristics of Different Forest Lands at Huo Di Tang Forest Region in Qinling Mountains.” in: Long-term Research on China’s Forest Ecosystems, China Forestry Publishing House: 252-260 (in Chinese).

Dierschke, H., 1994. “Pflanzensoziologie.” Ulmer Stuttgart, 683 pages.

Fischer, A., 2002. “Forstliche Vegetationskunde.” Parey Buchverlag, Berlin, Wien, 421 pages.

Fu Jun, 2001. “Farming Systems Research for Integrated Sloping Landuse into the existing Farming System in the Loess Plateau Gully Region of Shaanxi Province, northwest China.” unpublished master thesis, Dresden University of Technology, 120 pages.

Fu Kuntsun (ed.), 2000. “Flora Loess Plateau Sinicae” – Vol. 1. Science Press (in Chinese).

Fu Kuntsun (ed.), 1992. “Flora Loess Plateau Sinicae” – Vol. 2. China Forestry Publishing House (in Chinese).

Fu Kuntsun (ed.), 1989. “Flora Loess Plateau Sinicae” – Vol. 5. Scientific and Technical Documents Publishing House (in Chinese).

“Flora Loess Plateau Sinica”. Unpublished manuscript versions 3 and 4 (...)(in Chinese).

Gan Zhimao, Sang Guangshu, 2002. “Discussion on the Cultivated Land Reduction and Forest and Grass on the Loess Plateau.” Journal of Arid Land Resources and Environ ment, Vol. 16, No. 1: 63-65 (in Chinese).

Gauch, Hugh G., 1982. “Multivariate Analysis in Community Ecology.” Cambridge University Press, 298 pages.

Hair, J., Anderson, R., Tatham, R., Black, W., 1995. “Multivariate Data Analysis-4th Edition.” Prentice Hall, 745 pages.

Hou Xueyu, 1996: “Vegetation Map of China.” in: The Soil Atlas of China, Cartographic Publishing House, Beijing.

Hou Xueyu, Chang Xinshi, 1992. “The Principal Types of Montane Vegetational Belts in China And Eco-Geographical Characteristics.” Braun-Blanquetia, Vol. 8: 11-17.

Huang Jikun, 2000. “Land Degradation in China: Erosion and Salinity.” unpublished report to the World Bank, Center for Chinese Agricultural Policy, 34 pages.

Huo Bing, Xue Zhide, Han Liming, Li Tingrui, 2002. “Comparison Study on Growth of Artificial *Platycladus orientalis* Forest of Different Sites in the Loess Hilly-Gully Region.” Journal of Northwest Forestry University, 17 (1): 5-7 (in Chinese).

Jiang Dingsheng, 1997. “Huangtu Gaoyuan Shuitu Liushi Yu Taili Moshi” (Soil Erosion and Control Models in the Loess Plateau).” China Water Conservation and Water Power Publishing House, 464 pages.

Jongman R., Ter Braak, C., Van Tongeren, O., 1995 “Data Analysis in Community Ecology.” Cambridge University Press, 300 pages.

Li Jiancun (ed.), 1998. “Propagation and Utilization of Plants in the Three-North Area of China.” State Forestry Administration Three North Shelterbelt Bureau; China Forestry Publishing House, 1238 pages (in Chinese).

Li Rui, Liu Guobin, Xie Yongsheng, Yang Qingke, Liang Yinli, 2002. “Ecosystem Rehabilitation on the Loess Plateau.” in: Regional Water and Soil Assessment for Managing Sustainable Agriculture in China and Australia, Australian Center for International Agricultural Research.

Li Shidong, 2002. “Study on the Models of Conversion of Cropland to Forest and Grassland in Dry Hot and Arid River Valley Sub-regions and Hill Ravine Sub-regions of the Loess Plateau.” Journal of Beijing Forestry University, Vol. 24, No. 3: 35-38 (in Chinese).

Li Zhongkui, 1996. “Small Watershed Integrated Planning and Evaluation.” Northwestern Agriculture University; Xi’an Mapping Publishing House, 216 pages (in Chinese).

Lin Zhiguang, 1986. “Climatic Map of China.” in: The Soil Atlas of China, Cartographic Publishing House, Beijing.

Liu Guobin, Xu Mingxiang, Li Rui, Joe Walker, Hu Weiyin, 2002: “Assessment of a Small Catchment on the Loess Plateau.” in: Regional Water and Soil Assessment for Managing Sustainable Agriculture in China and Australia, Australian Center for International Agricultural Research: 139-154.

Liu Jian, Lu Qi (ed.), 1999. “CCICED – Sustainable Agricultural Working Group (SWAG)- Landuse and Sustainable Development on Loess Plateau, Northwest China – Proceedings.” Environmental Science Press, 200 pages.

Liu Tungsheng, 1985. “Loess and the Environment.” China Ocean Press, Beijing, 250 pages.

Luo Weixiang, 1995a. “A study on Construction Models for Eco-Economical Protection Forests In Weibei of the Loess Plateau.” in: Study on Construction Model of Eco-Economical Type Protection Forest System on Weibei Of Loess Plateau, China Forestry Publishing House: 1-21.

Luo Weixiang, 1995b. “A Preliminary Report on Balancing Soil Erosion of Protection Forest System by Measuring Needles at Huocun Watershed.” in: Study on Construction Model of Eco-Economical Type Protection Forest System on Weibei Of Loess Plateau, China Forestry Publishing House: 200-205.

Mackinnon, J.; Meng S., Cheung, C., Carey, G., Zhu X., Melville, D., 1996 “A Biodiversity Review of China.” WWF China Programme, Hong Kong, 524 pages.

McCune, B., Mefford, M. J., 1999 “PC-ORD-Multivariate Analysis of Ecological Data, Version 4.17.” MjM Software, Gleneden Beach, Oregon , U.S.A.

Meng, Xinmin, Derbyshire, E., 1998: “Landslides and Their Control in the Chinese Loess Plateau: Models and Case Studies From Gansu Province, China.” Geohazards in Engineering Geology 15.1, 1998: 141-153.

Mucina, L., 1997. “Classification of Vegetation: Past, Present and Future.” Journal of Vegetation Science 8: 751-760.

Müller-Dombois, D, Ellenberg, H., 1974 “Aims and Methods of Vegetation Ecology.” Wiley&Sons, New York, London, Sydney, Toronto, 547 pages.

Norusis, M., 1998. “SPSS 8.0 Guide to Data Analysis, Prentice Hall, 563 pages.

Pécsi, M., Richter G., 1996 “Löss: Herkunft – Gliederung – Landschaften; Zeitschrift für Geomorphologie” Neue Folge Supplementband 98, Gebrüder Borntraeger, Berlin, Stuttgart, 391 pages.

Peng Wenying, Zhang Keli, Li Shuangcai, 2002. “Studies of the Regional Classification about Returning Farmland to Forests or Grassland on the Loess Plateau.” Journal of Natural Resources (Ziran Ziyuan Xuebao) Vol. 17, No. 4, 438-443 (in Chinese).

Qin Dahe, Ding Yihui, Wang Shaowu, Wang Sumin, Dong Guangrong, Lin Erda, Liu Chunzhen, She Zhixiang, Sun Huinan, Wang Shourong, Wu Guanghe, 2002. “A study of Environment Change and its Impacts in Western China.” Earth Science Frontiers, Vol. 9, No. 2: 321-328 (in Chinese).

Rao, V., Woolcock, M., 2002 "Integrating Qualitative and Quantitative Approaches in Program Evaluation." in: Tool Kit – Tools and Techniques for Evaluating the Poverty Impacts of Economic Policies, World Bank, 268 pages.

Rozelle, S., Carter, C., (…) "China's Corn Economy – A Report to the National Research Initiative Committee", 1996. http://www.primal.ucdavis.edu.faculty.

Shan Shengdao, 2002. "Impact Assessment of Forest Resources." Territorial Development and Management, Vol. 12, No. 1: 51-54 (in Chinese).

Smalley, I. J., (ed.), 1975: "Loess: Lithology and Genesis." Stroudsburg: Dowden.

Song Yongchang, 1983. "Die Räumliche Ordnung der Vegetation Chinas." Tuexenia 3: 131-157.

SSQT, 1995. Shaanxi Sheng Qihou Tuji (Climate Maps of Shaanxi Province), Shaanxi Meteorological Bureau.

SSDC, 2001. Shaanxi Sheng Ditu Ci, Maps of Shaanxi Province, China Cartographic Publishing House.

Sun, C.Y., Feoli, E., 1992 "Trajectory Analysis of Chinese Vegetation Types in a Multidimensional Climatic Space." Journal of Vegetation Science 3: 587-594.

Tang Keli, (1987?). "Soil Erosion and Soil Conservation in China." Science Press Beijing.

Van Groonewood, C.,1992. " The Robustness of Correspondence, Detrended Correspondence, and TWINSPAN Analysis." Journal of Vegetation Science 3: 239 – 246.

Wang Shuyuan, Lin Shengshou, 1994. "Advance in Long-term Research on Forest Ecosystems in China" in: Long-term Research on China's Forest Ecosystems, China Forestry Publishing House: 1-27 (in Chinese).

Wang Wanzhong, Jiao Juying, 2002. "Temporal and Spatial Variation Features of Sediment Yield Intensity on the Loess Plateau." Acta Geographica Sinica, Vol. 57, No. 2: 211-217 (in Chinese).

Wang Youmin, Liu Bingzheng, 1993. "Huangtu Gaoyuan Fanghulin Shengtai Tezheng (The Loess Plateau-Ecological Characteristics of Shelterbelt Plantations)." China Forestry Publishing House, 262 pages.

World Bank, 2000. "China Loess Plateau Watershed Rehabilitation Project II." unpublished project document.

Wu Qinxiao, Liu Xiangdong, Zhao Hongyan, 1995. "Ways and Measures of Restoring Vegetaion for Controlling Soil and Water Loss on the Loess Plateau of China." Indian Forester: 194-200 (in Chinese).

Wu Zhonglun (ed.), 2000: Zhongguo Senlin (Forests of China), Volume 1-4 , China Forestry Publishing House.

Xu Jintao, Eugenia K., Thomas A. W. (ed.), 2002. "Implementing the Natural Forest Protection Program and the Sloping Land Conversion Program – Lessons and Recommendations." China Forestry Publishing House, 98 pages.

Xu Yong, Tian Junliang, Shen Hongquan, 2002. "Eco-environmental Rehabilitation and Spatial Differentation based on Enlarging Terrace and Defarming in the Loess Hilly-Gully Region." Journal of Natural Resources (Ziran Ziyuan Xuebao) Vol. 17, No. 2: 430-437 (in Chinese).

Yang Chen, 1998. "An Analysis on the Diversity and Ecological Niche of Oak Forests in the Qiaoshan Area." Journal of Northwest Forestry College, 13 (4): 28-32 (in Chinese).

Yang Qingke, Li Rui, Zhang Xiaoping, Hu Liangjun, 2002: "Regional Evaluation of Soil Erosion by Water: A Case Study on the Loess Plateau of China in: Regional Water and Soil Assessment for Managing Sustainable Agriculture in China and Australia, Australian Center for International Agricultural Research: 304-310.

Yin Guokang, 2002. "Sustainability of the Yellow River Basin Environment to Development of Water Resources." Acta Geographica Sinica, Vol. 57, No. 2, March: 224-231 (in Chinese).

Yin Runsheng, Xu Jintao, 2002. "A Welfare Measurement of China's Rural Forestry Reform during the 1980s." World Development Vol. 30, No. 10: 1755-1767.

Ying, Y., 2002. "Income, Poverty and Inequality in China During a Transition to a Market Economy." Transition Newsletter, World Bank: http://www.worldbank.org/html/prddr/trans.

Yu Guirui, Xie Gaodi, Wand Qiufend, Niu Dong, 2002. "Considerations to Some Issues on Vegetation Rehabilitation in Western China." Journal of Natural Resources (Ziran Ziyuan Xuebao) Vol. 17, No. 2: 216-220 (in Chinese).

Zavalo-Hurtadao, J.A, Valverde, P., Diaz-Solis, A, Vite F., Portilla, E, 1995. "Vegetation-environment relationships based on a life-forms classification in a semi-arid region of Tropical Mexico.": http://www.ots.duke.edu/tropibiojnl/

Zhang Jianjun, Zhu Jinzhao, Zhan Tonggang, Yang Yuxing, 1998. "Soil Retention of Soil and Water Conservation Forest in the Loess Plateau of Western Shanxi Province." Journal of Beijing Forestry University, Vol. 20, No. 6, Nov.:20-24 (in Chinese).

Zhang Sifeng, Zhang Wenke, Yuan, Xiaoling, Ma Xinwen, 2002. "The Exploitation, Utilization and Protection of the Land Resources in Shanxi in China's Western Development." Territorial Development and Management, Vol. 12, No. 1: 46-50 (in Chinese).

Zheng Wangou (ed.), 1998. "Zhongguo Shumuzhi (Sylva Sinica)." Volume 1-3, China Forestry Publishing House.

Zhou Gangyu, Ye Zhengfeng, 1992: “The Role of Vegetation in Water-Soil Conservation in Mountainous Areas of Shandong Province.” Braun-Blanquetia, vol. 8: 221-222.

Zhou Xiaofeng, Deng Zhu, 1998. “Forest Ecology – Functions and Management – The China Forest Ecology Research Network”, China Forestry Publishing House.

Zhou Xiaofeng, Li Qingxia, Jin Yongyan, 1994. “Studies on Forest Water Cycling” in: Long-term Research on China’s Forest Ecosystems, China Forestry Publishing House: 213-222 (in Chinese).

Zhou Xingmin, 1992. “Vegetation Types and their Geographical Distribution on the Southern Slope of Qilian Mountains”. Braun-Blanquetia, Vol. 8: 38-39.

Zhou Yunan, Fan Shengcai, 1997: “A Preliminary Study on Forest Depleting in Ancient Shaanxi on Building Timber.” Journal of Northwest Forestry College, 12 (1), 104-107 (in Chinese).

Zhou Yunan, Liu Zhilian, Fan Shengcai, 1996. “A brief review of tree planting history in Ancient China.” Journal of NW Forestry College, 11 (3): 70-77 (in Chinese).

Zhu Zhicheng, 1997. “Recovering Succession of Vegetation in Forest Region of North Shaanxi Loess Plateau.” Journal of Northwest Forestry College, 8 (1): 89-94 (in Chinese).

Zou Niangen, Luo Weixiang, Zhu Bian, 1997. “Huangtu Gaoyuan Zaolinxue (Afforestation Studies on the Loess Plateau).” China Forestry Publishing House, 517 pages.

Zuo Zhangda, Zhang Hongjian, 1992. “A Study of the Montane Vegetation of the Liu Pan Mountains.” Braun-Blanquetia, Vol 8: 66-62.

Annex I: Documentation Vegetation Data (Sorted Tables)

1. Nan Niwan Forests 2000-2002

Forest Communities:	*Acer ginnala-Quercus liaotungensis*	1
	Quercus liaotungensis:	2
	Acer stenolobum:	3
	Mixed Xeric Forests:	4
	Platycladus orientalis:	5
	Koelreuteria paniculata:	6

T: Tree Layer (> 3m); S: Shrub Layer (1-3m); G: Ground Vegetation (<1m)

Steadiness: Superscripts denote range of cover from minimu to maximum.

I:	0-20% (of total plots),
II:	20-40%
III:	40-60;
IV:	60-80%;
V:	80-100%

			1	2	3	4	5	6
			n=19	n=41	N=19	n=26	n=15	n=3
	Species	*Abbreviation*						
1	**Acanthopanax obovatus**	*Acaobo*	**I**^{1b}	.	.	.	.	.
2	**Acanthopanax spec**	*AcaspS*	**I**$^{+}$	.	.	.	.	.
	Acanthopanax spec	*AcaspG*	**I**$^{+-1a}$	.	.	.	.	.
3	**Celtis bungeana**	*CelbuT*	**I**$^{+-1b}$	.	.	.	.	.
	Celtis bungeana	*CelbuS*	**I**$^{1b-2a}$	.	.	.	.	.
	Celtis bungeana	*CelbuG*	**II**$^{+-1a}$	**I**$^{+}$	.	.	.	.
4	**Cladrastis wilsonii**	*ClawiT*	**I**^{2b}	.	.	.	.	.
5	**Crataegus spec**	*CraspS*	**II**$^{+-1b}$	.	.	.	.	.
	Crataegus spec	*CraspG*	.	.	**I**$^{+}$	.	.	.
6	**Ligustrum molliculum**	*LigmoT*	**I**^{1b}	.	.	.	.	.
	Ligustrum molliculum	*LigmoS*	.	.	**I**$^{+}$	.	.	.
	Ligustrum molliculum	*LigmoG*	**II**$^{+}$	.	.	.	.	.
7	**Populus adenopoda**	*PopadS*	**I**$^{+-1b}$	.	.	.	.	.
	Populus adenopoda	*PopadG*	**I**$^{+-1a}$	.	**I**$^{+}$	.	.	.
8	**Ribes spec**	*RibspS*	**II**$^{+}$	.	**I**$^{+}$	.	.	.
	Ribes spec	*RibspG*	**II**$^{+}$	.	.	.	.	.
9	**Cacalia delphiniphylla**	*Cacdel*	**II**$^{+}$	.	.	.	.	.
10	**Campylotropis marcocarpa**	*Cammac*	**II**$^{+}$	.	.	.	.	.
11	**Fragraria ananassa**	*Fraana*	**II**$^{+}$	.	.	.	.	.
12	**Galium bungei**	*Galbun*	**II**$^{+}$	.	.	.	.	.
13	**Menispermum dauricum**	*Mendau*	**II**$^{+}$	.	.	.	.	.
14	**Euonymus alatus**	*EuoalS*	**I**$^{+}$	**I**$^{+}$	.	.	.	.
	Euonymus alatus	*EuoalG*	**II**$^{+}$	**I**$^{+}$	**I**$^{+}$	.	.	.
15	**Malus baccata**	*MalbaT*	**III**$^{1b-2b}$	**I**^{2a}	.	.	.	.
	Malus baccata	*MalbaS*	**I**^{1b}	.	.	.	.	.
	Malus baccata	*MalbaG*	**I**$^{+}$	**I**$^{+}$	.	.	**I**$^{+}$	.
16	**Populus cathayana**	*PopcaT*	**I**$^{+}$	**I**^{1a}	.	.	.	.
17	**Elaeagnus umbellata**	*EleumS*	**I**$^{+-1b}$	**I**$^{+}$	.	.	.	**II**^{1a}
	Elaeagnus umbellata	*EleumG*	**I**$^{+}$	**I**$^{+}$	**I**$^{+}$	.	.	.
18	**Adenophora wawreana**	*Adewan*	**I**$^{+}$	**I**$^{+}$	.	.	.	.
19	**Agrimonia pilosa**	*Agrpil*	**I**$^{+}$	**I**$^{+}$	.	.	.	.
20	**Apiaceae div spec**	*Apidsp*	**III**$^{+-1a}$	**I**$^{+}$	.	.	.	.
21	**Carpesium spec**	*Carspe*	**III**$^{+}$	**II**$^{+}$	.	.	.	.

22	**Chenopodium glaucum**	*Chegla*	II^{+}	I^{+}	.	.	.	.
23	**Cirsium segetum**	*Cirseg*	I^{+}	I^{+}	.	.	.	.
24	**Setaria glauca**	*Setgla*	I^{+}	I^{+}	.	.	.	II^{1a}
25	**Leonurus japonicus**	*Leojap*	I^{+}	I^{+}	.	.	.	.
26	**Lysimachia spec**	*Lysspe*	I^{+}	I^{+}	.	.	.	.
27	**Youngia spec**	*Youspe*	I^{+}	I^{+}	.	.	.	.
28	**Aristolochia contorta**	*Aricon*	III^{+}	I^{+}	.	.	.	II^{+}
29	**Celastrus orbiculatus**	*CelorS*	I^{1b}	.	I^{+}	.	.	.
	Celastrus orbiculatus	*CelorG*	IV^{+-1a}	II^{+}	II^{+}	.	.	.
30	**Populus davidiana**	*PopdaT*	I^{1a-2a}	.	I^{1b}	.	.	.
	Populus davidiana	*PopdaS*	I^{+-1a}	I^{+}	I^{1a}	.	.	.
	Populus davidiana	*PopdaG*	I^{+}	.	I^{+}	.	.	.
31	**Vitis spec**	*Vitspe*	I^{+}	I^{+-1a}	I^{+}	.	.	.
32	**Bothriospermum chinense**	*Botchi*	II^{+}	I^{+}	I^{+}	.	.	.
33	**Asparagus densiflorus**	*Aspden*	I^{+}	I^{+}	I^{+}	.	.	II^{+}
34	**Artemisia annua**	*Artann*	III^{+-1b}	I^{+}	I^{+}	.	.	.
35	**Bidens bipinnata**	*Bidpin*	I^{+}	I^{+}	I^{+}	.	.	IV^{+}
36	**Bidens parviflora**	*Bidpar*	I^{+}	.	I^{+}	.	.	II^{+}
37	**Carpesium abrotanoides**	*Carabr*	II^{+-1a}	I^{+}	I^{+-1a}	.	.	.
38	**Carpesium cernuum**	*Carcer*	I^{+}	I^{+}	I^{+}	.	.	.
39	**Cynanchum chinense**	*Cynchi*	II^{+}	.	II^{+}	.	.	.
40	**Epilobium cephalostigma**	*Epicep*	I^{+}	I^{+}	I^{+}	.	.	.
41	**Epipactis helleborine**	*Epihel*	II^{+}	.	I^{+}	.	.	.
42	**Ixeris polycephala**	*Ixepol*	III^{+}	II^{+}	I^{+}	.	.	.
43	**Neottianthe pseudo-diphylax**	*Neopse*	II^{+}	I^{+}	I^{+}	.	.	.
44	**Rubia cordifolia**	*Rubcor*	II^{+}	I^{+}	.	.	.	.
45	**Vicia spec**	*Vicspe*	I^{+}	I^{+}	I^{+}	.	.	.
46	**Senecio spec**	*Senspe*	II^{+-1a}	.	II^{+}	.	.	.
47	**Sonchus oleraceus**	*Sonole*	III^{+}	I^{+}	I^{+}	.	.	II^{+}
48	**Thladiantha dubia**	*Thldub*	II^{+-1a}	.	I^{+}	.	.	.
49	**Crataegus cunneata**	*CracuS*	.	I^{+-1a}	.	.	.	.
	Crataegus cunneata	*CracuG*	.	II^{+-1a}	.	I^{+}	.	.
50	**Duchesnea indica**	*Ducind*	.	I^{+}	.	.	.	II^{+}
51	**Fagopyrum tataricum**	*Fagtat*	.	I^{+}	.	.	.	II^{+}
52	**Lespedeza floribunda**	*Lesflo*	.	I^{+}	.	.	.	II^{+}
53	**Aster tataricus**	*Asttat*	.	I^{2a}	.	.	.	.
54	**Ixeris denticulate**	*Ixeden*	.	I^{+}	I^{+}	.	.	.
55	**Ixeris chinensis**	*Ixechi*	.	I^{+}	I^{+}	.	.	.
56	**Roegneri kamoji**	*Roekam*	.	I^{+}	I^{+}	.	.	.
57	**Cannabis sativa**	*Cansat*	.	I^{+}	II^{+}	.	.	IV^{+-1a}
58	**Rubis membranacea**	*Rubmem*	.	I^{+}	I^{+}	.	.	.
59	**Pedicularis spec**	*Pedspe*	.	.	I^{+}	.	.	.
60	**Acer ginnala**	*AcegiT*	IV^{2a-3}	I^{1a-2b}	.	I^{1a}	.	.
	Acer ginnala	*AcegiS*	II^{1a-2a}	II^{+-2a}	I^{+}	I^{+-1a}	.	.
	Acer ginnala	*AcegiG*	III^{+}	IV^{+-1a}	III^{+}	I^{+-1a}	.	.
61	**Ailanthus altissima**	*AilalT*	.	.	I^{2a}	I^{1a}	.	II^{2a}
	Ailanthus altissima	*AilalG*	II^{+-1b}	I^{+}	I^{+}	I^{+}	.	.
62	**Berberis reticulata**	*BerreS*	.	I^{+}	I^{1a}	I^{+}	.	.
	Berberis reticulata	*BerreG*	.	III^{+}	I^{+}	I^{+}	.	.
63	**Clematis fruticosa**	*Clefru*	III^{+}	I^{+}	.	I^{+}	.	II^{+}
64	**Cerasus polytricha**	*CerpoT*	.	.	I^{2a}	.	.	.
	Cerasus polytricha	*CerpoS*	III^{+-2a}	III^{+-2a}	III^{+-2a}	I^{+-1a}	.	.
	Cerasus polytricha	*CerpoG*	I^{+-1a}	III^{+-1a}	I^{+}	I^{+}	II^{+}	.
65	**Euonymus verrucosoides**	*EuoveT*	II^{1b-3a}	I^{1a-2b}	II^{2a-3}	I^{2a}	.	IV^{2a}
	Euonymus verrucosoides	*EuoveS*	I^{1a-1b}	I^{+-1a}	.	I^{1a}	.	II^{1b}
	Euonymus verrucosoides	*EuoveG*	III^{+}	II^{+}	II^{+}	I^{+}	.	.

66	**Koelreuteria paniculata**	*KoepaT*	I^{2a-3}	I^{2a}	.	I^{2a}	.	IV^{3}
	Koelreuteria paniculata	*KoepaS*	I^{+-2b}	.	I^{+}	I^{+-1a}	.	IV^{1b-2a}
	Koelreuteria paniculata	*KoepaG*	II^{+-1a}	II^{+-1a}	I^{+}	I^{+}	I^{+}	V^{+-1a}
67	**Lonicera maackii**	*LonmT*	I^{1a-1b}	.	.	.	.	.
	Lonicera maackii	*LonmS*	III^{+-2b}	I^{+}	I^{1a-1b}	I^{+}	.	II^{1a}
	Lonicera maackii	*LonmG*	III^{+-1a}	I^{+}	I^{+}	I^{+}	I^{+}	II^{+}
68	**Lonicera stephanocarpa**	*LonstT*	.	.	I^{1b-2a}	I^{+-1b}	.	.
	Lonicera stephanocarpa	*LonstS*	II^{1a-2a}	I^{1a}	II^{+-1b}	I^{+-2a}	.	II^{1b}
	Lonicera stephanocarpa	*LonstG*	III^{+-1b}	I^{+-1a}	II^{+-1a}	I^{+}	I^{+}	.
69	**Syringa vulgaris**	*SyrvuT*	II^{1a-2b}	I^{1a}	I^{1b-2a}	.	.	II^{3}
	Syringa vulgaris	*SyrvuS*	I^{1a-2a}	I^{+}	I^{+-1b}	I^{1a-1b}	.	II^{1b}
	Syringa vulgaris	*SyrvuG*	I^{+-1a}	II^{+-1a}	I^{+-1a}	.	I^{+}	IV^{+-1a}
70	**Ribes grossularia**	*RibgrS*	I^{1a}	I^{1a}	.	I^{+}	.	.
	Ribes grossularia	*RibgrG*	I^{+}	I^{+-1a}	.	.	I^{+}	.
71	**Hemistepta lyrata**	*Hemlyr*	I^{+}	I^{+}	.	I^{+}	.	II^{+}
72	**Ixeris sonchifolia**	*Ixesen*	I^{+}	I^{+}	I^{+}	I^{+}	.	.
73	**Euphorbia spec**	*Eupspe*	I^{+}	I^{+}	.	I^{+}	.	.
74	**Fagopyrum sagittatum**	*Fagsag*	I^{+}	I^{+}	.	I^{+}	.	IV^{+}
75	**Oxytropis div spec**	*Oxydsp*	I^{+}	I^{+}	.	I^{+}	.	.
76	**Periploca sepium**	*PerseK*	III^{+}	II^{+}	II^{+-1a}	I^{+}	.	IV^{+}
77	**Polygonatum odoratum**	*Polodo*	I^{+}	IV^{+-1a}	I^{+}	I^{+}	.	.
78	**Acer stenolobum**	*AcestT*	II^{+-3}	II^{1b-4}	IV^{+-4}	IV^{+-2b}	I^{1b-2a}	II^{1b}
	Acer stenolobum	*AcestS*	I^{+-1b}	II^{+-1b}	III^{+-2b}	IV^{+-1b}	II^{+}	.
	Acer stenolobum	*AcestG*	II^{+}	III^{+-1a}	IV^{+-1a}	II^{+}	III^{+-1a}	.
79	**Caragana arborescens**	*CararT*	.	.	I^{+-1a}	I^{1a-1b}	I^{1a-1b}	.
	Caragana arborescens	*CararS*	I^{+}	V^{+-2b}	.	II^{+-1a}	I^{1a-1b}	II^{1a}
	Caragana arborescens	*CararG*	II^{+}	V^{+-1b}	IV^{+-1a}	II^{+-1a}	III^{+}	.
80	**Corylus heterophylla**	*CorheS*	.	I^{+}	I^{1a}	.	I^{+}	.
	Corylus heterophylla	*CorheG*	I^{1b}	I^{+}	.	.	I^{+}	.
81	**Cotoneaster ambiguus/multiflorus**	*CotamS*	IV^{+-2a}	V^{+-3}	V^{+-2b}	V^{+-2a}	IV^{+-1b}	.
	Cotoneaster ambiguus/multiflorus	*CotamG*	I^{+}	III^{+-1b}	III^{+-1b}	II^{+-1a}	III^{+-1a}	.
82	**Lonicera hispida**	*LonhiS*	I^{+}	I^{+-2a}	.	IV^{+-2b}	I^{+-1a}	.
	Lonicera hispida	*LonhiG*	I^{+}	IV^{+-1b}	II^{+}	IV^{+-1a}	IV^{+-1a}	.
83	**Quercus liaotungensis**	*QueliT*	V^{1b-4}	V^{1b-5}	III^{1a-4}	I^{1b-2b}	I^{1b}	.
	Quercus liaotungensis	*QueliS*	II^{+-2a}	II^{+-1b}	II^{+-1a}	I^{+-1b}	I^{+}	.
	Quercus liaotungensis	*QueliG*	V^{+-1a}	V^{+-1a}	V^{+}	II^{+}	I^{+}	.
84	**Rubus mesogaeus**	*Rubmae*	IV^{+}	II^{+}	III^{+}	III^{+}	I^{+}	IV^{+}
85	**Spiraea hirsuta/mollifolia**	*SpihmS*	IV^{+-2b}	V^{+-2b}	III^{+-2b}	II^{1a-2b}	I^{+-1a}	II^{1a}
	Spiraea hirsuta/mollifolia	*SpihmG*	II^{1a-2b}	III^{+-1b}	II^{+-1a}	II^{+-1a}	II^{+}	.
86	**Syringa komarowi**	*SyrkoT*	II^{1b-2b}	I^{1a}	I^{+-2a}	IV^{+-2a}	.	II^{2a}
	Syringa komarowi	*SyrkoS*	I^{+-1a}	II^{+-1b}	II^{+-2a}	IV^{+-2b}	IV^{+-2a}	II^{1a}
	Syringa komarowi	*SyrkoG*	III^{+-1a}	V^{+-1b}	IV^{+-1b}	V^{+-1a}	IV^{+-1a}	.
87	**Ulmus pumila**	*UlmpuT*	II^{1b-3}	.	I^{2a}	I^{1a}	I^{1a}	.
	Ulmus pumila	*UlmpuS*	I^{1a-1b}	.	.	.	I^{+}	.
	Ulmus pumila	*UlmpuG*	I^{+-1a}	.	I^{+}	I^{+}	I^{+}	.
88	**Viburnum sympodiale**	*VibsyS*	III^{1a-2a}	V^{+-2a}	IV^{1a-2b}	III^{+-2a}	II^{+-1a}	.
	Viburnum sympodiale	*VibsyG*	III^{+-2a}	IV^{+-1b}	III^{+-1a}	III^{+}	III^{+}	.
89	**Adenophora potaninii**	*Adepot*	I^{+}	II^{+-1a}	III^{+}	I^{+}	II^{+}	.
90	**Anemone tomentosa**	*Anetom*	II^{+}	I^{+}	I^{+}	I^{+}	I^{+}	.
91	**Allium spec**	*Allspe*	I^{+}	.	.	.	I^{+}	.
92	**Artemisia lavandulaefolia/giraldii**	*Artlag*	III^{1a-2a}	I^{+-1b}	III^{+-1a}	IV^{+-1b}	III^{+}	V^{1a-2a}
93	**Artemisia mongolica**	*Artmon*	I^{+-1b}	I^{+-1b}	III^{+-2a}	V^{+-2a}	V^{+-1b}	V^{1a-2a}
94	**Artmesia div spec**	*Artdsp*	II^{+-1b}	III^{+-1b}	III^{+-1b}	III^{+-2b}	III^{+-1b}	.
95	**Aspidistra elatior**	*Aspela*	II^{+}	III^{+}	I^{+}	I^{+}	II^{+}	.
96	**Aster div spec**	*Astdsp*	V^{+-2a}	IV^{+-1b}	V^{+-1b}	IV^{+-1b}	V^{+-1a}	V^{+-1a}

97	**Carex lanceolata c.f.**	*Carlan*	V^{1b-4}	V^{+-4}	V^{1b-4}	V^{1a-4}	V^{1b-4}	V^{1b-3}
98	**Patrinia scabiosaefolia**	*Patsca*	IV^{+-1a}	IV^{+-1a}	III^{+}	II^{+}	II^{+}	II^{+}
99	**Poaceae div spec**	*Poacds*	III^{+-1b}	II^{+}	II^{+-1a}	III^{+-1a}	II^{+}	.
100	**Polygonatum verticillatum**	*Polver*	II^{+}	III^{+}	II^{+}	III^{+}	III^{+}	II^{+}
101	**Gentiana zollingeri**	*Genzol*	I^{+}	.	I^{+}	I^{+}	I^{+}	.
102	**Leibnitzia anandria**	*Leiana*	I^{+}	.	I^{+}	.	I^{+}	.
103	**Rubia lanceolata**	*Rublan*	II^{+}	II^{+}	III^{+}	II^{+}	I^{+}	IV^{+}
104	**Ranunculus spec**	*Ranspe*	II^{+}	.	III^{+}	I^{+}	I^{+}	.
105	**Leontopodium spec**	*Leospe*	I^{+}	I^{+}	.	.	I^{+}	.
106	**Lilium spec**	*Lilspe*	I^{+}	I^{+}	.	I^{+}	I^{+}	.
107	**Cynanchum sibiricum**	*Cynsib*	I^{+}	II^{+}	I^{+}	III^{+}	II^{+}	.
108	**Dioscorea opposita**	*Dioopp*	IV^{+}	V^{+-1a}	IV^{+}	II^{+}	I^{+}	.
109	**Lespedeza juncea**	*Lesjun*	IV^{+}	III^{+}	III^{+}	III^{+}	IV^{+-1a}	V^{+}
110	**Viola dissecta**	*Viodis*	IV^{+-1a}	III^{+}	I^{+}	II^{+}	II^{+}	.
111	**Vitis piasezkii**	*Vitpia*	V^{+-1a}	IV^{+}	V^{+-1a}	I^{+}	I^{+}	II^{+}
112	**Armeniaca sibirca**	*ArmsibT*	.	I^{1b}	II^{1a-2b}	II^{1a-2a}	I^{1b-2a}	II^{1a}
	Armeniaca sibirica	*ArmsibS*	.	I^{+-1b}	I^{1a}	I^{+-2a}	I^{1a}	.
	Armeniaca sibirica	*ArmsibG*	I^{+}	II^{+}	I^{+}	III^{+}	I^{+}	.
113	**Ostryopsis davidiana**	*OstdaS*	.	II^{+-2a}	II^{+-1a}	I^{+}	I^{+}	.
	Ostryopsis davidiana	*OstdaG*	I^{+}	II^{+-1a}	I^{+}	I^{+}	II^{+}	.
114	**Platycladus orientalis**	*PlaorT*	I^{1a}	I^{1b}	I^{2b-3}	I^{1b-3}	V^{2a-4}	.
	Platycladus orientalis	*PlaorS*	I^{1a}	.	I^{1a-1b}	II^{+-1b}	V^{+-2a}	II^{1b}
	Platylcadus orientalis	*PlaorG*	I^{+}	.	II^{+}	I^{+}	V^{+}	II^{+}
115	**Pyrus betulafolia**	*PyrbeT*	.	I^{1a-1b}	I^{1b-3}	II^{1a-2a}	.	II^{2a}
	Pyrus betulafolia	*PyrbeS*	.	.	.	I^{+-1a}	.	.
	Pyrus betulafolia	*PyrbeG*	.	I^{+}	.	II^{+}	I^{+}	.
116	**Amygdalus davidiana**	*AmydaT*	.	I^{2a}	I^{1b-2b}	IV^{+-2b}	II^{1a-1b}	IV^{2a}
	Amygdalus davidiana	*AmydaS*	.	I^{1a}	.	III^{+-2b}	II^{+-1a}	II^{1a}
	Amygdalus davidiana	*AmydaG*	.	I^{+}	I^{+}	III^{+-1a}	III^{+}	.
117	**Buddleija alternifolia**	*BudalS*	I^{+}	.	I^{1a}	I^{+-1b}	I^{1a}	II^{1b}
	Buddleija alternifolia	*BudalG*	.	.	.	.	I^{+}	.
118	**Crataegus hupehensis**	*Crahup*	.	I^{+}	I^{+}	.	I^{+}	.
119	**Rhamnus rosthornii**	*RharoT*	.	.	I^{2a}	I^{1a}	.	.
	Rhamnus rosthornii	*RharoS*	.	I^{1a}	I^{1a}	IV^{+-2a}	I^{1a}	II^{1a}
	Rhamnus rosthornii	*RharoG*	.	I^{+}	I^{+}	II^{+}	II^{+}	.
120	**Rosa xanthina**	*RosxaS*	.	III^{+-1a}	II^{+-1a}	V^{+-1b}	III^{+-2b}	.
	Rosa xanthina	*RosxaG*	I^{+}	III^{+}	IV^{+-1a}	IV^{+-1b}	IV^{+-1a}	.
121	**Ulmus macrocarpa**	*UlmmT*	I^{2a}	I^{2a}	I^{2a}	I^{1a-1b}	I^{1b}	.
	Ulmus macrocarpa	*UlmmS*	.	I^{+-1a}	I^{+}	I^{+-1a}	I^{+}	.
	Ulmus macrocarpa	*UlmmG*	.	I^{+}	.	II^{+-1a}	II^{+}	.
122	**Xanthoceras sorbifolia**	*XansoT*	I^{1b}	.	I^{1a}	II^{1a-2a}	.	.
	Xanthoceras sorbifolia	*XansoS*	I^{+-1b}	.	.	II^{+-2a}	I^{1a}	IV^{+-1b}
	Xanthoceras sorbifolia	*XansoG*	I^{+}	.	.	III^{+-1a}	I^{+}	II^{1a}
123	**Lespedeza bicolor**	*LesbiS*	.	I^{+}	.	I^{+}	.	.
	Lespedeza bicolor	*LesbiG*	.	I^{+}	.	.	.	.
124	**Thalictrum acquilegifolium**	*Thaaqu*	.	I^{+}	.	I^{+}	.	.
125	**Potentilla multifida**	*Potmul*	.	I^{+}	.	I^{+}	.	.
126	**Lamicaceae spec**	*Lamspe*	.	I^{+}	I^{+}	I^{+}	.	.
127	**Polygonatum cirrhifolium**	*Polcir*	.	I^{+}	I^{+}	I^{+}	.	.
128	**Anaphalis spec**	*Anaspe*	.	I^{+}	I^{+}	I^{+}	.	.
129	**Bupleurum scorzonerifolium**	*Bupscor*	.	.	I^{+}	I^{+}	.	II^{+}
130	**Glycyrrhiza uralensis**	*Glyura*	.	.	II^{+}	II^{+-1a}	.	.
131	**Potentilla spec**	*Potspe*	.	.	I^{+}	I^{+}	.	.
132	**Rhamnus spec**	*Rhaspe*	.	.	I^{+}	I^{+-1a}	.	.
133	**Setaria italica**	*Setital*	.	.	I^{+}	I^{+}	.	.
134	**Setaria viridis**	*Setvir*	.	.	I^{+}	I^{+}	.	IV^{+-1a}

135	**Speranskia tuberculata**	*Spetub*	.	.	**I**$^{+}$	**I**$^{+}$	.	.
136	**Prinsepia uniflora**	*Priuni*	.	.	.	**I**$^{+}$	.	**II**^{1a}
137	**Rhamnus erythroxylon**	*RhaerK*	.	.	.	**I**$^{+-1a}$	.	.
138	**Asparagus cochinchinensis**	*Aspcoc*	.	**II**$^{+}$	.	**I**$^{+}$	**II**$^{+}$	.
139	**Kengia spec**	*Kenspe*	.	**I**$^{+}$	.	.	**I**^{1a}	.
140	**Lysimachia stenosepala**	*Lysste*	.	**I**$^{+}$	.	**I**$^{+}$	.	.
141	**Lespedeza caraganae**	*Lescar*	.	**I**$^{+}$	**I**$^{+-1a}$	**II**$^{+}$	**III**$^{+-1a}$	.
142	**Ligularia spec**	*Ligspe*	.	**I**$^{+}$	**I**$^{+}$	**I**$^{+}$	**I**$^{+}$	.
143	**Miscanthus sacchariflorus**	*Missac*	.	**I**$^{+}$	**I**$^{+}$	**I**$^{+}$	**I**$^{+}$	.
144	**Poa div spec**	*Poadsp*	.	**I**$^{+}$	**I**$^{+}$	**I**$^{+}$	**IV**$^{+-1a}$	.
145	**Polygonatum spec**	*Polspe*	.	**I**$^{+}$	.	**I**$^{+}$	**I**$^{+}$	.
146	**Sophora davidii**	*SopdaS*	.	**I**^{1a}	.	**V**$^{1a-2b}$	**IV**$^{+-2a}$	**IV**$^{1a-1b}$
	Sophora davidii	*SopdaG*	.	**I**$^{+}$	**I**$^{+}$	**IV**$^{+-1a}$	**III**$^{+-1b}$	**IV**$^{+}$
147	**Bupleurum longiradiatum**	*Buplon*	.	.	**I**$^{+}$	**II**$^{+}$	**II**$^{+}$	.
148	**Cynanchum spec**	*Cynspe*	.	.	**I**$^{+}$	.	**I**$^{+}$	.
149	**Polygala sibiricum**	*Polsib*	.	.	**I**$^{+}$	**II**$^{+}$	**III**$^{+}$	.
150	**Bothriochloa ischaemum**	*Botisc*	.	.	.	**I**$^{1a-2b}$	**II**$^{+-2b}$	.
151	**Lilium pumilum**	*Lilpum*	.	.	.	**I**$^{+}$	**I**$^{+}$	.
152	**Potentilla parvifolia**	*Potpar*	.	.	.	**I**$^{+}$	**I**$^{+}$	.
153	**Siphinostegia chinense**	*Sipchi*	.	.	.	**I**$^{+}$	**I**$^{+}$	.
154	**Ulmus bergmanniana**	*UlmbeT*	.	.	.	**I**^{1a}	**I**^{2a}	.
	Ulmus bergmanniana	*UlmbeG*	.	.	.	**I**$^{+}$	.	.
155	**Wikstroemia chamaedaphne**	*WikchS*	.	.	.	.	**II**$^{+}$	.
	Wikstroemia chamaedaphne	*WikchG*	.	.	.	**I**$^{+}$	**II**$^{+}$	.
156	**Celtis biondii**	*CelbiT*	.	.	.	.	.	**II**^{1a}
	Celtis biondii	*CelbiS*	.	.	.	**I**^{1a}	.	**II**$^{+}$
	Celtis biondii	*CelbiG*	**I**$^{+-1a}$	.	.	.	.	**II**$^{+}$
157	**Xanthium sibiricum**	*Xansib*	.	.	.	.	.	**II**$^{+}$
158	**Artemisia capillaris**	*Artcap*	.	.	.	.	.	**II**^{1a}
	Speccies in < 6% of plots							
159	Acanthopanax setchuenensis	*Acaset*	I^{+}					
160	Anethum graveolens	*Anegra*	I^{+}					
161	Arctium lappa	*Arclap*	I^{+}					
162	Artemisia hedinii	*Arthed*	I^{+}					
163	Asteraceae div spec	*Asteds*	I^{+}					
164	Berberis giraldii	*BergiS*	I^{+}					
165	Berberis spec	*BerspS*	I^{+}					
166	Berberis spec	*BerspK*	I^{+}					
167	Campylotropis spec	*Camspe*	I^{+}					
168	Chenopodium hybridum	*Chehyb*	I^{+}					
169	Coreopsis spec	*Corspe*	I^{+}					
170	Cucubalus baccifer	*Cucbac*	I^{+}					
171	Galium soongoricum	*Galson*	I^{+}					
172	Geranium henryi	*Gerhen*	I^{+}					
173	Geranium wilfordii	*Gerwil*	I^{+}					
174	Geum aleppicum	*Geuale*	I^{+}					
175	Humulus lupulus	*Humlup*	I^{+}					
176	Lactua sativa	*Lacsat*	I^{+}					
177	Ludwigia prostata	*Luwpro*	I^{+}					
178	Melilotus suaveolens	*Melsua*	I^{+}					
179	Phlomis umbrosa	*Phlumb*	I^{+}					
180	Plantago major	*Plamaj*	I^{+}					
181	Prunella vulgaris	*Pruvul*	I^{+}					
182	Siegesbeckia pubescens	*Siegpub*	I^{+}					
183	Silene spec	*Silspe*	I^{+}					
184	Solanum nigrum	*Solnig*	I^{+}					

185	Torilis spec	*Torspe*	I$^+$			
186	Viola grypoceras	*Viogry*	I$^+$			
187	Cerastium fontanum	*Cerfon*		I$^+$		
188	Incarvillea sinensis	*Incsin*		I$^+$		
189	Kalimeris spec	*Kalspe*		I$^+$		
190	Ledeboriella seseloides	*Ledses*		I$^+$		
191	Picris japonica	*Picjap*		I$^+$		
192	Stellaria dichofoma	*Stedic*		I$^+$		
193	Viola yedoensis	*Vioyed*		I$^+$		
194	Viscum cobratum	*Viscob*		I$^+$		
195	Tilia panicortata	*TilpaK*		I$^+$		
196	Belamcanda chinensis	*Belchi*			I$^+$	
197	Bupleurum commelynoidem	*Bupcom*			I$^+$	
198	Cerasus spec	*Cerspe*			I$^+$	
199	Euphorbia helioscolia	*Euphel*			I$^+$	
200	Euphorbia lathyris	*Euplat*			I$^+$	
201	Physalis alkekengi	*Phyalk*			I$^+$	
202	Ranunculus japonicus	*Ranjap*			I$^+$	
203	Ribes pulchellum	*Ribpul*			I$^+$	
204	Sonchus spec	*Sonspe*			I$^+$	
205	Syringa villosa	*Syrvil*			I$^+$	
206	Allium tenuissimum	*Allten*				I$^+$
207	Linaria vulgaris	*Linvul*				I$^+$

2. Huangling Forests 2000-2002

Forest Communities:	Quercus liaotungensis.-Betuala platyphylla	1
	Quercu. liaotungensis	2
	Quercus liaotungensis-Acer ginnala	3
	Amygdalus davidiana	4
	Platycladus orientalis	5

Other explanations as above.

		1	2	3	4	5
		n=7	n=6	n=7	n=8	n=6
	Species					
1	**Betula platyphylla T**	III^{1a-2a}	.	I^{1a}	.	.
	Betula platyphylla S	II^{+-1b}	.	.	.	.
	Betula platyphylla G	I^{+}	.	.	I^{+}	.
2	**Caragana arborescens S**	II^{+}	.	.	.	.
	Caragana arborescens G	III^{+}	.	.	.	.
3	**Smilax discotis**	I^{1a}	.	.	.	.
4	**Smilax stans**	III^{+}	.	.	.	.
5	**Lespedeza spec.**	III^{+}	.	.	.	.
6	**Neotthianthe pseudo-diphylax**	II^{+}	.	.	.	.
7	**Rhus potaninii T**	I^{2a}	II^{2a}	.	.	.
	Rhus potaninii S	I^{1b}	I^{+-1b}	.	.	.
	Rhus potaninii G	I^{1a}	V^{+}	III^{+}	.	.
8	**Toxicodendron vernicifluum T**	I^{1a}	.	.	.	.
	Toxicodendron vernicifluum S	II^{+-2a}	.	I^{+}	.	.
	Toxicodendron vernicifluum G	III^{+}	II^{+}	III^{+}	.	.
9	**Euonymus alatus T**	.	I^{2a}	.	.	.
	Euonymus alatus S	II^{+-1a}	V^{+-1b}	.	.	.
	Euonymus alatus G	III^{+}	V^{+-1b}	III^{+}	I^{+}	.
10	**Cornus macrocarpa S**	II^{1a-2a}	II^{1b-2a}	II^{+-1a}	.	.
	Cornus macrocarpa G	I^{1a}	III^{+-1a}	I^{+}	.	.
11	**Dioscora opposita**	V^{+}	III^{+}	II^{+}	.	.
12	**Polygonatum odoratum**	V^{+-4}	V^{+}	III^{+}	.	.
13	**Crataegus kansuensis S**	.	III^{+-1b}	III^{+-2a}	.	.
	Crataegus kansuensis G	.	I^{1a}	II^{+}	I^{+}	.
14	**Lonicera tragophylla S**	.	I^{1a}	.	.	.
	Lonicera tragophylla G	.	II^{1a-1b}	I^{+}	.	.
15	**Malus baccata T**	.	.	II^{2a}	.	.
	Malus baccata S	.	II^{+-1b}	.	.	.
16	**Melampyrum roseum**	.	I^{+}	I^{+}	.	.
17	**Tripulaira szechuanica**	.	II^{+-1a}	II^{+}	.	.
18	**Epipactis hellborine**	.	IV^{+}	V^{+}	.	.
19	**Glechoma longituba**	.	III^{+-1a}	IV^{+-1b}	I^{1a}	.
20	**Periploca sepium**	.	II^{+}	.	.	.
21	**Veronica ciliata**	.	II^{+}	.	.	.
22	**Populus adenopoda S**	.	I^{1a}	.	.	.
	Populus adenopoda G	.	I^{+}	.	.	.
23	**Rhamnus davurica S**	.	I^{1a}	.	.	.
24	**Acer ginnala T**	II ^{1b}	IV^{1b-4}	.	II^{1b-3}	.
	Acer ginnala S	IV^{+-2a}	III^{+-1b}	IV^{1a-1b}	II^{+-2a}	.
	Acer ginnala G	III^{+}	V^{+-1a}	V^{+-1a}	II^{+-1a}	.

25	**Eleagnus umbellata S**	II^{+}	I^{1a}	IV^{+-1a}	I^{+}	.
	Eleagnus umbellata G	II^{+-1a}	.	I^{+}	I^{+}	.
26	**Lonicera maackii S**	II^{+-1a}	II^{+-1b}	II^{+-2a}	I^{1a}	.
	Lonicera maackii G	.	I^{+}	I^{+}	II^{+}	.
27	**Pyrus betulafolia T**	III^{1a-2a}	.	I^{1b}	III^{1b-2a}	.
	Pyrus betulafolia S	.	I^{1a}	II^{+-1b}	II^{+-1b}	.
	Pyrus betulafolia G	II^{+}	.	I^{+}	II^{+}	.
28	**Agrimonia pillosa**	II^{+}	II^{+}	III^{+}	I^{+}	.
29	**Clematis pogonandria**	III^{+}	II^{+}	I^{+}	II^{+}	.
30	**Rubus mesogaeus**	III^{+}	III^{+}	II^{+}	IV^{+}	.
31	**Viola yedoensis**	III^{+}	.	I^{+}	III^{+}	.
32	**Lotus corniculatus**	II^{+}	I^{+}	IV^{+}	I^{+}	.
33	**Rubia cordifolia**	I^{+}	III^{+}	I^{+}	I^{+}	.
34	**Sanguisorba officinalis**	IV^{+}	II^{+}	IV^{+-1a}	II^{+}	.
35	**Sophora alopecuroides**	II^{+}	III^{+}	III^{+-1a}	II^{+-1a}	.
36	**Vitis piasezkii**	III^{+-1a}	V^{+}	II^{+-1a}	II^{+}	.
37	**Pinus tabulaeformis T**	I^{1b}	.	.	II^{+-2a}	.
	Pinus tabulaeformis S	I^{+}	.	.	I^{1a}	.
38	**Syringa komarowi S**	.	.	.	I^{+}	.
	Syringa komarowi G	II^{+}	.	.	II^{+}	.
39	**Crateagus cunneata G**	I+	.	.	I^{+}	.
40	**Potentilla multifida**	I^{+}	.	.	IV^{+-1a}	.
41	**Denthranthima spec**	I^{+}	I^{+}	.	I^{+}	.
42	**Scutellaria baicalensis**	.	.	.	II^{+}	.
43	**Scorzonera austriaca**	.	.	II^{+}	II^{+}	.
44	**Lespedeza floribunda**	V^{+-1a}	.	.	II^{+}	.
45	**Pedicularis spec**	III^{+}	.	.	II^{+}	.
46	**Potentilla flagellaris**	I^{+}	.	.	II^{+}	.
46	**Campylotropis macrocarpa S**	.	.	I^{2a}	.	.
	Campylotropis macrocarpa G	II^{+}	.	II^{+-2a}	.	.
47	**Rhamnus utilis S**	I^{1a}	.	I^{1a}	.	.
	Rhamnus utilis G	.	.	I^{+}	I^{+}	.
	Rhamnus spec G	.	.	II^{+}	I^{+}	.
48	**Ulmus claucescens T**	.	.	I^{1a}	.	.
	Ulmus claucescens G	.	.	I^{+}	.	.
49	**Cephalanthera longifolia**	.	.	IV^{+}	.	.
50	**Clematis hexapetala**	.	.	II^{+}	.	.
51	**Populus davidiana T**	.	.	I^{1a}	.	.
	Populus davidiana S	.	I^{1b}	I^{+}	I^{+}	.
	Populus davidiana G	I^{+}				
52	**Koelreuteria paniculata T**	.	.	.	II^{2a}	.
	Koelreuteria paniculata S	.	I^{+}	.	.	.
	Koelreuteria paniculata G	.	II^{+-1a}	.	II^{+}	.
53	**Rhamnus globosa S**	.	I^{1a}	.	.	.
	Rhamnus globosa G	.	.	.	I^{+}	.
54	**Cerasus polytricha S**	III^{1a}	I^{1a}	II^{+-1b}	II^{+-1a}	II^{+-1a}
	Cerasus polytricha G	I^{+}	II^{+-1a}	.	.	II^{+}
55	**Celtis bungeana S**	I^{+}	I^{1a}	I^{+}	I^{+}	I^{1a}
	Celtis bungeana G	.	.	.	I^{+}	I^{+}
56	**Lonicera hispida S**	I^{+}	III^{1a-2a}	II^{+-1a}	II^{1a-2a}	V^{+-1a}
	Lonicera hispida G	III^{+-1a}	V^{+-1b}	III^{+}	V^{+-1a}	V^{+-1a}
57	**Ostryopsis davidiana S**	III^{1b-2a}	II^{+-2a}	III^{+-3}	II^{+-1a}	II^{+-1b}
	Ostryopsis davidiana G	II^{+-1b}	I^{1a}	I^{2a}	II^{+}	II^{+}
58	**Quercus liaotungensis T**	V^{2a-4}	IV^{2a-4}	V$^{3-4}$	III^{1a-2a}	.
	Quercus liaotungensis S	III^{+-4}	III^{1a-1b}	V^{+-1b}	III^{1a-2a}	II^{+-1b}
	Quercus liaotungensis G	IV^{+}	V^{+-1a}	IV^{+-1a}	IV^{+}	IV^{+}

59	**Rosa xanthina S**	**II^{+}**	**IV^{+-1a}**	**III^{+-1a}**	**IV^{+-2a}**	.
	Rosa xanthina G	**III^{+}**	**IV^{+}**	**IV^{+}**	**II^{+}**	**II^{+}**
60	**Spiraea hirsuta / mollifolia S**	**III^{+-1a}**	**I^{1a}**	**III^{+-2a}**	**I^{+}**	**II^{1a}**
	Spiraea hirsuta G	**IV^{+-1a}**	**II^{+}**	**III^{+-2a}**	**II^{+}**	**I^{+}**
61	**Viburnum sympodiale S**	**IV^{+-1b}**	**V^{1a-2b}**	**V^{+-2a}**	**IV^{1a-3}**	**V^{1a-2a}**
	Viburnum sympodiale G	**IV^{+-1a}**	**IV^{+-1a}**	**III^{+-1b}**	**II^{+}**	**V^{+-1a}**
62	**Anemone tomentosa**	**IV^{+}**	**III^{+}**	**V^{+-1a}**	**IV^{+}**	**I^{+}**
63	**Artemisia mongolica**	**I^{+}**	**I^{+}**	**III^{+-1a}**	**V^{+-1a}**	**V^{+-1a}**
64	**Artemisia div spec.**	**III^{+}**	**III^{+}**	**IV^{+}**	**IV^{+-1b}**	**IV^{+-1a}**
65	**Bupleurum longiradiatum**	**I^{+}**	**I^{+}**	**I^{+}**	**V^{+}**	**V^{+}**
66	**Carex lanceolata**	**V^{2a-4}**	**V^{1b-4}**	**V^{2a-4}**	**V^{2a-4}**	**V^{+-4}**
67	**Carpesium abrotanoides**	**V^{+}**	**V^{+}**	**III^{+}**	**II^{+}**	**I^{+}**
68	**Celastrus orbiculatus**	**III^{+}**	**IV^{+-1a}**	**III^{+}**	**II^{+-1a}**	**I^{+}**
69	**Hemistepta lyrata**	**III^{+}**	**II^{+}**	**III^{+}**	**V^{+}**	**III^{+}**
70	**Leibnitzia anandria**	**IV^{+}**	**II^{+}**	**III^{+}**	**II^{+}**	**V^{+}**
71	**Lespedeza juncea**	**II^{+}**	**V^{+}**	**V^{+-1a}**	**IV^{+}**	**IV^{+}**
72	**Miscanthus sacchariflorus**	**II^{+}**	**I^{1a}**	**V^{+-1a}**	**V^{+-1a}**	**V^{+-1a}**
73	**Patrinia scabiosaefolia**	**V^{+-1a}**	**V^{+}**	**III^{+}**	**II^{+}**	**I^{+}**
74	**Polygonatum cirrhifolium**	**I^{+}**	**V^{+}**	**I^{+}**	**III^{+}**	**IV^{+}**
75	**Poa div spec.**	**I^{+}**	**I^{+}**	**I^{+}**	**IV^{+-2a}**	**V^{+-1a}**
76	**Poaceae div spec**	**III^{+}**	**V^{+}**	**II^{+}**	**III^{+}**	**I^{+}**
77	**Rubia lanceolata**	**III^{+}**	**IV^{+}**	**III^{+}**	**V^{+}**	**V^{+}**
78	**Vicia villosa**	**II^{+}**	**I^{+}**	**II^{+}**	.	**I^{+}**
79	**Viola collina**	**III^{+}**	**III^{+-1a}**	**III^{+}**	**I^{+}**	**V^{+}**
80	**Cotoneaster ambiguous / multiflorus S**	**III^{+-1a}**	.	**I^{1a}**	**II^{1a-1b}**	**I^{1a}**
	Cotoneaster ambiguous / multiflorus G	**I+**	.	.	.	.
81	**Anaphalis spec.**	**II^{+}**	.	**I^{+}**	**II^{+}**	**III^{+}**
82	**Adenophora potaninii**	**III^{+}**	.	**III^{+}**	**II^{+}**	**I^{+}**
83	**Aster div spec**	**V^{+}**	.	**IV^{+}**	**IV^{+}**	**V^{+}**
84	**Oxytropis div spec.**	**I^{+}**	.	**III^{+}**	**II^{+}**	**II^{+}**
85	**Quercus accutissima G**	**II^{+}**	.	.	**I^{+}**	**II^{+}**
86	**Asparagus densiflorus**	**I^{+}**	.	.	**II^{+}**	**I^{+}**
87	**Polygonatum verticillatum**	**I+**	.	.	**II^{+}**	**I^{+}**
88	**Ixeris polycephala**	**III^{+}**	.	.	**IV^{+}**	**II^{+}**
89	**Lilium pumilum**	**I^{+}**	.	.	**I^{+}**	**I^{+}**
90	**Clematis fruticosa**	**II^{+}**	.	.	.	**I^{+}**
91	**Amygdalus davidiana T**	.	**I^{2a}**	.	**IV^{1a-3}**	.
	Amygdalus davidiana S	.	**I^{1a}**	**I^{+}**	**IV^{+-2a}**	**IV^{+-1a}**
	Amygdalus davidiana G	.	**I^{+}**	.	**II^{+-1a}**	**V^{+}**
92	**Sophora davidii S**	.	**II^{1a-1b}**	**I^{2b}**	**V^{+-2a}**	**V^{1a-2a}**
	Sophora davidii G	.	**II^{+}**	**I^{+}**	**IV^{+-2a}**	**V^{+-1a}**
93	**Ledebouriella seseloides**	.	.	**III^{+}**	**IV^{+}**	**III^{+}**
	Lespedeza caraganae	.	**II^{+}**	**I^{+}**	**V^{+}**	**V^{+}**
94	**Rhamnus rosthornii S**	.	**II^{+-1a}**	.	**I^{1b}**	**I^{1b}**
	Rhamnus rosthornii G	.	.	.	**I^{+}**	**I^{+}**
95	**Vitex negundo S**	.	**III^{1a-1b}**	**I^{+}**	**II^{1a-2a}**	**V^{1b-2b}**
	Vitex negundo G	.	**I^{+}**	.	.	**V^{+-2a}**
96	**Forsythia suspensa S**	.	**I^{1b}**	.	.	**II^{+-1a}**
	Forsythia suspensa G	.	**I^{1b}**	.	.	**I^{+}**
97	**Atractylodes lancea**	.	**I^{+}**	**I^{+}**	.	**I^{+}**
98	**Brachypodium spec**	.	.	**I^{+}**	**I^{+}**	.
99	**Heteropappus hispidus**	.	**II^{+-1a}**	**I^{+}**	.	**III^{+}**
100	**Cynanchum sibiriorum**	.	**III^{+}**	.	.	**V^{+}**
101	**Clematis aethusifolia**	.	**IV^{+}**	**I^{+}**	.	**I^{+}**
102	**Picrasma quassioides G**	.	**II^{+}**	.	.	**II^{+}**
103	**Lespedeza tomentosa**	.	**I^{+}**	**III^{+-1b}**	**I^{+}**	**II^{+-1a}**

104	**Polygala japonica**	.	I^{+}	.	.	I^{+}
105	**Viola dissecta**	.	I^{+}	.	I^{+}	III^{+}
106	**Youngia spec**	.	I^{+}	.	.	III^{+}
107	**Ailanthus altissima S**	.	.	.	II^{+-1b}	I^{+}
	Ailanthus altissima G	.	.	I^{+}	I^{+}	I^{+}
108	**Indigoferae potaninii**	.	.	I^{+}	.	V^{+-1a}
109	**Zisiphus jujuba S**	.	.	.	I^{1a}	II^{+}
	Zisiphus jujuba G	.	I^{+}	.	II^{+}	IV^{+}
110	**Armeniaca sibirica T**	.	.	.	II^{1b-2a}	.
	Armeniaca sibirica S	.	.	.	I^{+}	.
	Armeniaca sibirica G	.	.	.	.	I^{+}
110	**Platycladus orientalis T**	.	.	.	I^{3}	V^{2b-3}
	Platycladus orientalis S	.	.	.	I^{+}	IV^{+-1a}
	Platycladus orientalis G	.	.	.	II^{+}	III^{+}
112	**Sageretic pycnophylla S**	.	.	.	I^{1a}	III^{1a-1b}
	Sageretic pycnophylla G	.	.	.	.	IV^{+-1a}
113	**Artemisia giradii / lavandulaefolia**	.	.	I^{1a}	III^{+}	I^{+}
114	**Siphonostegia chinensis**	.	.	.	IV^{+}	III^{+}
115	**Polygala sibiricum**	.	.	.	.	IV^{+}
116	**Speranskia tuberculata**	.	.	.	.	III^{+}
117	**Jasminum undiflorum S**	.	.	.	.	I^{+}
	Jasminum undiflorum G	.	.	.	.	III^{+-1a}
118	**Ulmus begrmanniana T**	.	I^{1b}	.	.	.
	Ulmus bergmanniana S	.	.	.	.	II^{1a}
	Ulmus bergmanniana G	.	.	.	.	III^{+}
119	**Gentiana zollingeri**	.	.	.	.	IV^{+}
	Species in < 6% of plots					
120	Aspidistra elatior	I^{+}				I^{+}
121	Carpesium nepalense	I^{+}				
122	Celtis biondii S	I^{+}				
123	Cornus hemslyi G	I^{+}				
124	Cotoneaster dicariatus G	I^{+}				
125	Clematis akebioides	I^{+}				
126	Epimedium brevicorum	I^{+}				
127	Hypericum petiolulatum	I^{+}				
128	Ixeris denticulate	I^{+}				
129	Lespedeza bicolor	I^{+}				
130	Lespedeza floribunda S	I^{1a}				
131	Lotus spec.	I^{+}				
132	Lychnis fulgens	I^{+}				
133	Lysimachia spec	I^{+}				
134	Picrasma quassioides S	I^{+}				
135	Rhamnus erythroxilon S	I^{+}				
136	Roegneria kamoji	I^{+}				
137	Berberis reticulata G		I^{+}			
138	Mentha spicata		I^{+}			
139	Lysimachia pentapetala		I^{+}			
140	Medicago minima		I^{+}			
141	Euphorbia hylonoma		I^{+}			
142	Geum allepicum		I^{+}			
143	Galium paradoxon		I^{+}			
144	Euonymus verrucosoides G		I^{+}			
145	Cynanchum auriculatum		I^{+}			
146	Cacalia deltophylla		I^{+}			
147	Boragniaceae spec		I^{+}			
148	Sedum aizoon		I^{+}			

149	Isodon spec.	I^{+}			
150	Duchesnea indica		I^{+}		
151	Euonymus fortunei G		I^{+}		
152	Fragraria ananassa		I^{+}		
153	Vitis flexuosa		I^{+}		
154	Adenophora gmelinii		I^{+}		
155	Picris japonica		I^{+}		
156	Asterareae div spec.			I^{+}	
157	Bothriochloa ischaemum			I^{+}	
158	Cynanchum chinense			I^{+}	
159	Euphorbia helioscoia			I^{+}	
160	Indigoferae kirilowii			I^{+}	
161	Lilium div spec.			I^{+}	
162	Linum stelleroides			I^{+}	
163	Rhamnus helmsleyana G			I^{+}	
164	Adenophora stricta			I^{+}	
165	Veronica linarifolia			I^{+}	
166	Themedea triandra			I^{+}	
167	Orobanchae cornulescens			I^{+}	
168	Quercus aliena G			I^{+}	
169	Potentilla nivea				I^{+}
170	Amphicarpea trisperma				I^{+}
171	Astragalus complanatus				I^{+}
172	Leontopodium spec				I^{+}
173	Cotinus coggygria				I^{+}
174	Cygnoglossum spec				I^{+}
175	Glochidion spec				I^{+}

3. He Zhuang Ping Degraded Secondary Steppes 2000-2002

		mesic group	xeric group
1	Amygdalus davidiana S	I^{+}	.
	Amygdalus davidiana G	I^{+}	.
2	Berberis spec	I^{+}	.
3	Eleagnus umbellata S	I^{+}	.
	Eleagnus umbellata G	I^{+}	.
4	Euonymus bungeanus	I^{+}	.
5	Robinia pseudoacacia T	I^{2a-3}	.
	Robinia pseudoacacia S	I^{+}	.
	Robinia pseudoacacia G	I^{+}	.
6	Spiraea mollifolia S	I^{+}	.
	Spiraea mollifolia G	I^{+-1a}	.
7	Spiraea spec S	I^{+}	.
	Spiraea spec G	I^{+-1a}	.
8	Acalypha australis	I^{+}	.
9	Adenophora potaninii	I^{+}	.
10	Agrimonia pillosa	I^{+}	.
11	Anaphalis spec	II^{+}	.
12	Anemone tomentosa	I^{+}	.
13	Apiaceae div spec	I^{+}	.
14	Aristolochia contorta	I^{+}	.
15	Asparagus densiflorus	I^{+}	.
16	Asterarceae div spec	II^{+}	.
17	Astragalus complanatus	I^{+-1a}	.
18	Bidens parviflora	I^{+}	.
19	Bupleurum scorzonerifolium	II^{+}	.
20	Cannabis sativa	I^{+}	.
21	Caragana korshinskii	I^{+}	.
22	Cirsium monocephalum	I^{+}	.
23	Cirisum cetosum	I^{+}	.
24	Cynara cardunculus	I^{+}	.
25	Delphinium grandiflorum	I^{+}	.
26	Digitaria sanguinalis	I^{+}	.
27	Euphorbia humifusa	I^{+}	.
28	Exoecaria acerifolia	I^{+}	.
29	Fabaceae spec	I^{+}	.
30	Fragraria ananassa	I^{+}	.
31	Geum allepicum	I^{+}	.
32	Glechoma biodiana	I^{+}	.
33	Incarvillea sinensis	I^{+}	.
34	Ixeris chinensis	I^{+}	.
35	Ixeris polycephala	III^{+}	.
36	Ixeris senchifolia	I^{+}	.
37	Lamiaceae spec.	I^{+}	.
38	Lactuca spec	I^{+}	.
39	Ledebouriella seseloides	I^{+}	.
40	Leibnitzia anandria	I^{+}	.
41	Leonurus heterophyllus	II^{+-1b}	.
42	Ligularia spec	I^{+}	.
43	Lotus corniculatus	I^{+-1a}	.
44	Lotus spec	I^{1a}	.
45	Miscanthus sacchariflorus	I^{+}	.
76	Artemisia annua	I^{+-2a}	I^{+-1a}
77	Artemisia capillaris	IV^{+-2a}	III^{+-1a}
78	Artemisia lavandulaefolia/giraldii	V^{+-3}	V^{+-3}
79	Artemisia mongolica	V^{+-3}	V^{+-3}
80	Artemisia div spec	III^{+-2b}	II^{+-1b}
81	Aster div spec	V^{+-2a}	III^{+}
82	Astragalus melilotoides	II^{+}	I^{+}
83	Astragalus spec	I^{+-1a}	I^{+}
84	Bothriochloa ischaemum	II^{+-2a}	V^{+-2a}
85	Bupleurum longiradiatum	I^{+}	I^{+}
86	Carex lanceolata	II^{+-3}	I^{+}
87	Cirsium segetum	II^{+}	I^{+}
88	Convolvulus arvensis	I^{+}	I^{+}
89	Cynanchum chinense		I^{+}
90	Cynanchum komarowi	I^{+}	II^{+}
91	Cynanchum thesioides	I^{+}	I^{+}
92	Diarthron linifolium	I^{+}	I^{+}
93	Geranium wilfordii	I^{+}	I^{+}
94	Glechoma longituba	II^{+}	I^{+}
95	Glycyrrhiza uralensis	II^{+-1a}	II^{+}
96	Hemistepta lyrata	III^{+}	I^{+}
97	Indigofera potaninii	I^{+}	I^{+}
98	Leontopodium spec	I^{+}	I^{+}
99	Lespedeza caraganae	IV^{+-2a}	III^{+-1b}
100	Lespedeza juncea	II^{+-1a}	V^{+-1a}
101	Lespedeza spec	I^{+}	I^{+}
102	Lilium pumilum	I^{+}	I^{+}
103	Lilium spec	I^{+}	I^{+}
104	Linum stelleroides	I^{+}	I^{+}
105	Lycium sinensis	I^{+}	I^{+}
106	Oxytropis div spec	III^{+-}	II^{+}
107	Patrinia scabiosaefolia	IV^{+-1a}	I^{+}
108	Phragmites communis	II^{+-1a}	I^{+}
109	Phyllanthus simplex	I^{+}	I^{+}
110	Poa div spec	V^{+-3}	V^{+-2a}
111	Poaceae div spec	II^{+-2a}	I^{+}
112	Polygala sibirica	III^{+}	IV^{+}
113	Potentilla bifurca	III^{+}	I^{+}
114	Potentilla multifida	V^{+-1a}	II^{+-1a}
115	Roegneria kamoji	I^{+}	I^{+}
116	Rubia cordifolia	I^{+}	I^{+}
117	Rubia lanceolata	III^{+-1a}	I^{+}
118	Salsona collina	III^{+-1a}	III^{+-1a}
119	Senecio div spec	III^{+-1a}	I^{+}
120	Setaria glauca	IV^{+-2a}	I^{+-1a}
121	Setaria viridis	II^{+-1a}	I^{+}
122	Siphonostegia chinensis	I^{+}	I^{+}
123	Speranskia tuberculata	I^{+}	II^{+}
124	Taraxacum spec	III^{+}	I^{+}
125	Vicia villosa	IV^{+-1a}	I^{+}
126	Viola collina	II^{+}	I^{+}

46	Orobanche cornulescens	I^{+}	.
47	Lysimachia barystachys	I^{+}	.
48	Picris japonica	I^{+}	.
49	Plantago asiatica	I^{+}	.
50	Plantago depressa	I^{+}	.
51	Ranunculus spec	I^{+}	.
52	Salsona passerina	I^{+}	.
53	Senecio fruticosa	I^{+}	.
54	Sonchus oleraceus	II^{+-2a}	.
55	Themeda triandra	I^{+}	.
56	Thermopsis alpina	I^{+}	.
57	Thladiantha dubia	I^{+}	.
58	Torilis spec	I^{+}	.
59	Viola grypoceras	I^{+}	.
60	Viola spec	I^{+}	.
61	Ailanthus altissima G	I^{+}	I^{+}
62	Armeniaca sibirica G	I^{1b}	I^{+}
63	Buddleija alternifolia S	I^{+-2a}	II^{+-1b}
	Buddleija alternifolia G		I^{+-1a}
64	Caragana spec S	I^{+-2a}	I^{2a}
	Caragana spec G	I^{+-1a}	I^{+-1b}
65	Clematis fructicosa	I^{+}	IV^{+-1a}
66	Periploca sepium G	II^{+-2a}	III^{+-2a}
67	Prinsepia uniflora S	I^{1a-1b}	II^{+-1b}
	Prinsepia uniflora G	I^{+}	II^{+-1a}
68	Pyrus betulafolia S	I^{+}	
	Pyrus betulafolia G	I^{+}	I^{+}
69	Rhamnus erythroxylon S	I^{+}	I^{+-1b}
	Rhamnus erythroxylon G	I^{+}	II^{+}
70	Rubus mesogaeus	II^{+}	I^{+}
71	Sophora davidii S	I^{2b}	IV^{+-2b}
	Sophora davidii G	I^{+-2a}	IV^{+-2b}
72	Spiraea hirsuta	I^{+}	I^{+}
73	Syringa komarowi S	I^{1a}	.
	Syringa komarowi G	.	I^{+}
74	Ulmus pumila S	I^{+-1b}	Ib
	Ulmus pumila G	II^{+-1a}	I^{+}
75	Wikstroemia chamaedaphne S	I^{+}	I^{+-1b}
	Wikstroemia chamaedaphne G	I^{+}	III^{+-2a}

127	Viola dissecta	I^{+}	I^{+}
128	Viola yedoensis	II^{+}	I^{+}
129	Vitis piasezkii	II^{+}	II^{+}
130	Clematis aethusifolia	.	I^{+}
131	Malus baccata	.	I^{+}
132	Vitex negundo S	.	I^{1a}
	Vitex negundo G	.	I^{1a}
133	Zisiphus jujuba S	.	II^{+-2a}
	Zisiphus jujuba G	.	III^{+-2b}
134	Asparagus cochinchinensis	.	I^{+}
135	Carduus crispus	.	I^{+}
136	Duchesnea indica	.	I^{+}
137	Ixeris denticulata	.	I^{+}
138	Rehmannia glutinosa	.	I^{+}
139	Scorzonera austriaca	.	I^{+}
140	Thalictrum spec	.	I^{+}
141	Allium spec	.	II^{+}
142	Artemisia hedinii	.	I^{+}

4. Nan Niwan Degraded Secondary Steppes 2000-2002

		mesic group	**xeric group**
1	Acer ginnala G	I^{+}	.
	Acer stenolobum G	II^{+-1a}	.
2	Berberis reticulata G	I^{+}	.
3	Betula platyphylla T	I^{1b}	.
	Betula platyphylla G	I^{+}	.
4	Crataegus cuneata G	I^{+}	.
5	Lonicera maackii G	I^{1a}	.
6	Malus hupehensis G	I^{+}	.
7	Platycladus orientalis G	II^{+}	.
8	Quercus liaotungensis S	II^{+}	.
	Quercus liaotungensis G	II^{+}	.
9	Populus davidiana K	I^{+-1a}	.
10	Adenophora potaninii	II^{+}	.
11	Asparagus cochinchinensis	I^{+}	.
12	Asteraceae div spec	I^{+}	.
13	Belamcanda chinensis	I^{+}	.
14	Calophaca sinica	I^{+}	.
15	Cirisum cetosum	I^{+}	.
16	Cynanchum komarowi	I^{+}	.
17	Dioscora opposita	I^{+}	.
18	Duchesnea indica	II^{+-1a}	.
19	Geum allepicum	II^{+}	.
20	Ixeris chinensis	I^{+}	.
21	Ixeris denticulata	I^{+}	.
22	Leibnitzia anandria	I^{+}	.
23	Linum usitatissiumum	I^{+}	.
24	Lotus corniculatus	I^{+}	.
25	Pedicularis striata	I^{+}	.
26	Picris japonica	I^{+}	.
27	Plantago asiatica	I^{+}	.
28	Plantago major	I^{+}	.
29	Polygonatum odoratum	I^{+}	.
30	Polygala japonica	I^{+}	.
31	Prunella vulgaris	I^{+}	.
32	Scorzonera albicaulis	I^{+}	.
33	Sonchus oleraceus	I^{+}	.
34	Verbena officinalis	I^{+}	.
35	Youngia spec	I^{+}	.
36	Armeniaca sibirica G	II^{+}	I^{+}
37	Caragana arborescens S	I^{+}	I^{1a}
	Caragana arborescens G	I^{+}	I^{+}
38	Cerasus polytricha G	I^{+}	I^{+}
39	Cotoneaster ambiguus/multiflorus S	I^{1a}	I^{1a}

		mesic group	**xeric group**
75	Euphorbia div spec	I^{+}	I^{+}
76	Geranium spec.	I^{+}	I^{+}
77	Geranium wilfordii	I^{+}	I^{+}
78	Glycyrrhiza uralensis	I^{+}	III^{+-1a}
79	Hemistepta lyrata	III^{+}	I^{+}
80	Incarvillea sinensis	I^{+}	I^{+}
81	Ixeris polycephala	II^{+}	I^{+}
82	Ledebouriella seseloides	II^{+}	I^{+}
83	Leontopodium spec.	II^{+}	I^{+}
84	Lespedeza caraganae	V^{+}	III^{+-1a}
85	Lespedeza juncea	V^{+-1b}	IV^{+-1a}
86	Lilium pumilum	I^{+}	I^{+}
87	Linum stelleroides	I^{+}	I^{+}
88	Lonicera hispida K	III^{+-1a}	III^{+-1a}
89	Lysimachia stenosepala	III^{+}	I^{+}
90	Miscanthus sacchariflorus	I^{+}	I^{+-1a}
91	Oxytropis diverse spec	III^{+-1a}	III^{+-1a}
92	Patrinia scabiosaefolia	V^{+-1a}	II^{+}
93	Phragmites communis	I^{+}	I^{1a}
94	Poa div spec.	III^{+-2b}	IV^{+-2b}
95	Poaceae div spec	III^{+-1b}	II^{+-1a}
96	Polygala sibirica	II^{+}	III^{+}
97	Potentilla bifurca	I^{+}	I^{1a}
98	Potentilla multifida	V^{+-1b}	V^{+-1a}
99	Roegneria kamoji	I^{+}	I^{+}
100	Rubia cordifolia	I^{+}	I^{+}
101	Rubia lanceolata	V^{+}	III^{+}
102	Scorzonera austriaca	I^{+}	II^{+}
103	Siphonostegia chinensis	V^{+}	IV^{+}
104	Taraxacum spec.	III^{+}	I^{+}
105	Thalictrum spec.	I^{+}	II^{+}
106	Vicia villosa	V^{+}	I^{+}
107	Viola dissecta	IV^{+}	II^{+}
108	Viola yedoensis	IV^{+}	II^{+}
109	Vitis piasezkii	III^{+}	I^{+}
110	Ailanthus altissima G	.	I^{+}
111	Amygdalus davidiana S	.	I^{1b}
	Amygdalus davidiana G	.	I^{+}
112	Buddleija alternifolia S	.	I^{+-1b}
	Buddleija alternifolia G	.	I^{+}
113	Euonymus verrucosoides G	.	I^{+}
114	Koelreuteria paniculata T	.	I^{+-1b}
	Koelreuteria paniculata S	.	I^{+}

	Cotoneaster ambiguus/multiflorus G	III^{+}	I^{+}
40	Eleagnus umbellata S	I^{+-1a}	I^{1a}
	Eleagnus umbellata G	I^{+}	I^{+}
41	Hippophae rhamnoides S	I^{+}	I^{+}
	Hippophae rhamnoides G		I^{+-1a}
42	Ostryopsis davidiana S	I^{+-1a}	.
	Ostryopsis davidiana G	II^{+-1a}	I^{+}
43	Periploca sepium G	IV^{+-2a}	III^{+-1a}
44	Pyrus betulafolia S	I^{+}	II^{+-1a}
	Pyrus betulafolia G	III^{+}	III^{+-1a}
45	Rhamnus erythroxylon G	I^{+}	III^{+}
46	Rhamnus rosthornii S	I^{+}	I^{1a}
	Rhamnus rosthornii G	I^{+}	III^{+}
47	Rhamnus utilis G	I^{+}	.
48	Robinia pseudoacacia T	I^{1b-2a}	I^{+-1a}
	Robinia pseudoacacia S	.	I^{+}
	Robinia pseudoacacia G	.	I^{+}
49	Rosa xanthina S	II-1a	II^{+-1a}
	Rosa xanthina G	III^{+}	II^{+}
50	Rubus mesogaeus	V^{+-1a}	I^{+}
51	Spiraea hirsuta / mollifolia S	II^{+-1a}	I^{1a}
	Spiraea hirsuta / mollifolia G	II^{+-1b}	II^{+}
52	Syringa komarowi S	I^{+}	I^{+-1a}
	Syringa komarowi G	III^{+-1a}	III^{+-1b}
53	Syringa vulgaris S	.	I^{+}
	Syringa vulgaris G	I^{+}	I^{+}
54	Ulmus pumila S	.	I^{1a}
	Ulmus pumila G	III^{+-1a}	II^{+}
55	Wikstroemia chamaedaphne S	I^{+}	I+^{1a}
	Wikstroemia chamaedaphne G	I^{+}	I^{+}
58	Anaphalis spec.	I^{+}	I^{+}
59	Anemone tomentosa	V^{+-1a}	IV^{+-1a}
60	Aristolochia contorta	I^{+}	I^{+}
61	Artemisia annua	I^{+}	I^{+}
62	Artemisia capillaris	IV^{+-}	III^{+-1a}
63	Art. giraldii /Art. lavandulaefolia	I^{1b}	III^{+-2b}
64	Artemisia mongolica	V^{+-4}	V^{+-3}
65	Artemisia div spec.	IV^{+-2a}	II^{+}
66	Aster div spec.	IV^{+-1a}	V^{+}
67	Astragalus melilotoides	II^{+}	III^{+}
68	Bothriochloa ischaemum	I^{1b}	IV^{+-2a}
69	Bupleurum longiradiatum	III^{+}	II^{+}
70	Carex spec.	V^{+-3}	IV^{+-2b}
71	Cirsium segetum	II^{+}	I^{+}
72	Clematis fructicosa	II^{+}	I^{+}
73	Convolvulus arvensis	I^{+}	I^{+}
74	Diarthron linifolium	I^{+}	I^{+}
	Koelreuteria paniculata G	.	I^{+}
115	Lonicera hispida S	.	I^{+}
116	Celtis bungeana G	.	I^{+}
117	Pinus tabulaeformis G	.	I^{+}
118	Prinsepia uniflora G	.	I^{+}
119	Sophora davidii S	.	II^{+-2a}
	Sophora davidii G	.	III^{+-2b}
120	Ulmus bergmanniana G	.	I^{+}
121	Xanthoceras sorbifolia G	.	I^{+}
122	Zisiphus jujuba G	.	I^{+}
123	Artemisia hedinii	.	I^{+}
124	Asparagus densiflorus	.	I^{+}
125	Calystegia dahurica	.	I^{+}
126	Delphinium candelabrum	.	I^{+}
127	Dracocephalum spec	.	I^{+}
128	Euphorbia lathyris	.	I^{+}
129	Gentiana zollingeri	.	I^{+}
130	Melilotus spec	.	I^{+}
131	Orobanche cornulescens	.	I^{+}
132	Salsona collina	.	II^{+-1a}
133	Saxifraga confertifolia	.	I^{+}
134	Setaria viridis	.	I^{+}
135	Speranskia tuberculata	.	II^{+}
136	Xanthium sibiricum	.	I^{+}

T Tree Layer (> 3m)
S Shrub Layer (1-3m)
G Ground Vegetation Layer (< 1m)

5. Luochuan Degraded Secondary Steppes 2000-2002

		mesic group	**xeric group**			**mesic group**	**xeric group**
1	Eleagnus umbellata G	I^{+}	.	67	Adenophora himalayana	III^{+-1a}	II^{+}
2	Euonymus bungeanus G	I^{+}	.	68	Agrimonia pillosa	IV^{+-1a}	I^{+}
3	Ostryopsis davidiana G	I^{+}	.	69	Allium spec	IV^{+}	IV^{+}
4	Rhamnus heterophylla G	I^{+}	.	70	Anaphalis sinica	V^{+}	III^{+}
5	Spiraea hirsuta / mollifolia S	I^{+}	.	71	Anemone tomentosa	V^{+-1b}	IV^{+-1b}
	Spiraea hirsuta / mollifolia G	I^{+}	.	72	Anethum graveolens	II^{+}	II^{+}
6	Syringa vulgaris S	I^{1a}	.	73	Artemisia capillaris	III^{+}	V^{+-1b}
	Syring vulgaris G	I^{1a}	.	74	Artemisia hedinii	I^{+}	I^{2b}
				75	Artemisia lavandulaefolia/giraldii	V^{+-3}	V^{+-3}
7	Achnathrum spec	I^{+}	.	76	Artemisia mongolica	V^{+-3}	IV^{+-3}
8	Adenophora wawreana	II^{+}	.	77	Artemisia div spec	III^{+-2b}	I^{1a}
9	Apiaceae diverse spec	I^{1a}	.	78	Aster div spec	V^{+-1b}	IV^{+}
10	Artemisia japonica	III^{+-2a}	.	79	Astralagus complanatus	II^{+}	I^{+}
11	Asparagus cochinchinensis	I^{+}	.	80	Astragalus melilotoides	II^{+}	I^{+}
12	Asparagus gobicus	I^{+}	.	81	Astralagus spec	II^{+}	I^{+}
13	Asteraceae div spec	I^{+}	.	82	Bothriochloa ischaemum	V^{+-2b}	V^{+-3}
14	Belamcanda chinensis	I^{+}	.	83	Bupleurum longiradiatum	IV^{+}	II^{+}
15	Calystegia hederacea	I^{+}	.	84	Carduus crispus	III^{+}	III^{+}
16	Campylotropis macrocarpa	I^{+-1b}	.	85	Cirsium segetum	II^{+}	I^{+}
17	Carex lanceolata	III^{+-3}	.	86	Cynanchum paniculatum	I^{+}	II^{+}
18	Carpesium abrotanoides	I^{+}	.	87	Cynanchum thesioides	I^{+}	I^{+}
19	Cirisum monocephalum	I^{+}	.	88	Duchesnea indica	II^{+}	I^{+}
20	Clematis pogonandria	I^{+}	.	89	Elytrigia trichophora	I^{+}	I^{+}
21	Comastoma polycladum	I^{+}	.	90	Glycyrrhiza uralensis	I^{+}	I^{+}
22	Cynara cardunculus	I^{+}	.	91	Hemistepta lyrata	V^{+-1a}	IV^{+}
23	Cynoglossum spec	I^{+}	.	92	Ixeris polycephala	IV^{+}	III^{+}
24	Delphinium grandiflorum	I^{+}	.	93	Lespedeza caraganae	V^{+-1a}	V^{+-1a}
25	Denthranthema spec	I^{+}	.	94	Lespedeza bicolor	I^{+}	I^{+}
26	Dianthus chinensis	I^{+}	.	95	Lespedeza floribunda	II^{+-1b}	I^{+}
27	Diarthron linifolium	II^{+}	.	96	Lespedeza juncea	V^{+-1a}	V^{+-1a}
28	Epimedium brevicorum	I^{+}	.	97	Lespedeza tomentosa	I^{+}	I^{+}
29	Euphorbia humifusa	I^{+}	.	98	Lilium pumilum	IV^{+}	I^{+}
30	Fragraria ananassa	I^{+}	.	99	Linum stelleroides	I^{+}	I^{+}
31	Geranium wilfordii	I^{+}	.	100	Miscanthus sacchariflorus	V^{+-3}	I^{+}
32	Hibiscus triorum	I^{+}	.	101	Oxytropis hirta	III^{+-1a}	I^{+}
33	Kumerowia stipulacea	II^{+}	.	102	Oxytropis div spec	V^{+-1a}	V^{+}
34	Lamiaceae div spec	I^{+}	.	103	Patrinia scabiosaefolia	IV^{+-1b}	I^{+}
35	Lathyrus odoratus	I^{+}	.	104	Phragmites communis	II^{+-1a}	I^{+}
36	Ledebouriella seseloides	II^{+}	.	105	Poa div spec	III^{+-2b}	IV^{+-1a}
37	Leibnitzia anandria	II^{+}	.	106	Poaceae div spec	IV^{+-3}	IV^{+-1a}
38	Leontopodium leontopodioides	I^{+}	.	107	Polygala sibirica	III^{+}	II^{+}
39	Leontopodium spec.	I^{+}	.	108	Potentilla multifida	V^{+-1b}	V^{+-1b}
40	Leonurus heterophyllus	I^{+}	.	109	Potentilla saschinensis	II^{+}	IV^{+}
41	Linum amurense	I^{+}	.	110	Roegneria kamoji	III^{+-2a}	I^{+}
42	Lotus corniculatus	III^{+-1a}	.	111	Rubia lanceolata	II^{+}	II^{+}
43	Lotus tenuis	I^{+}	.	112	Scorzonera austriaca	II^{+}	III^{+}
44	Pedicularis spec	I^{+}	.	113	Scutellaria baicalensis	I^{+}	I^{+}
45	Picris japonica	I^{+}	.	114	Siphonostegia chinensis	III^{+-1a}	V^{+-1a}
46	Plantago asiatica	I^{+}	.	115	Taraxacum dissectum	II^{+}	I^{+}
47	Plantago depressa	I^{+}	.	116	Taraxacum spec	I^{+}	I^{+}
48	Polygala japonica	I^{+}	.	117	Vicia villosa	III^{+}	I^{+}

49	Potentilla bifurca	I^{+}	.
50	Sanguisorba officinalis	I^{1a}	.
51	Senecio argunensis	I^{+}	.
52	Themeda triandra	I^{1a}	.
53	Viola dissecta	I^{+}	.
54	Ailanthus altissima G	I^{+}	I^{+}
55	Caragana spec. G	I^{+}	I^{1a}
56	Clematis hexapetala G	I^{+}	I^{+}
57	Periploca sepium G	I^{+}	I^{+}
58	Pyrus betulafolia S	II^{+-1a}	I^{1a}
	Pyrus betulafolia G	III^{+-1a}	II^{+}
59	Rosa xanthina S	I^{1a}	I^{+}
	Rosa xanthina G	I^{+}	.
60	Rubus mesogaeus G	II^{+}	I^{+}
61	Sophora davidii S	I^{+-1a}	V^{+-2a}
	Sophora davidii G	I^{+}	V^{+-2a}
62	Sophora alopecuroides G	I^{+}	I^{+}
63	Ulmus pumila G	I^{+}	I^{+}
64	Vitex negundo S	II^{+-2a}	III^{1a-4}
	Vitex negundo G	III^{+-2a}	III^{+-1a}
65	Vitis piasezkii G	I^{+}	I^{+}
66	Zisiphus jujuba S	.	II^{+-2a}
	Zisiphus jujuba G	II^{+}	V^{+-2b}
118	Viola yedoensis	V^{+}	IV^{+}
119	Youngia spec	III^{+}	II^{+}
120	Cotoneaster ambiguus/multiflorus G	.	I^{+}
121	Cuscuta chinensis	.	I^{+}
122	Cuscuta lupuliformis	.	I^{+}
123	Prinsepia uniflora G	.	I^{+}
124	Ulmus bergmanniana S	.	I^{1a}
	Ulmus bergmanniana G	.	I^{+}
125	Ulmus macrocarpa G	.	I^{2a}
126	Ajania spec	.	I^{+}
127	Cynanchum chinense	.	I^{+}
128	Cynanchum komarowi	.	I^{+}
129	Indigofera carlesii	.	I^{+}
130	Indigofera potaninii	.	I^{+}
131	Lespedeza spec.	.	I^{+}
132	Potentilla nivea	.	I^{+}
133	Rehmannia glutinosa	.	I^{+}
134	Setaria viridis	.	I^{+}

Annex II: Anova Results

1. Environmental Parameters Analysis

1.1 Parameters (Means) over TWINSPAN Forest Communities in Nan Niwan

SITE PARAMETER		SUM OF SQUARES	DEGREE OF FREEDOM	MEAN SQUARE	F-RATIO	p-value
ELEVATION	Between Groups	131066,863	5	26213,373	9,804	,000*
	Within Groups	312812,812	117	2673,614		
	Total	443879,675	122			
EXPOSITION	Between Groups	27,584	5	5,517	17,698	,000*
	Within Groups	36,471	117	,312		
	Total	64,056	122			
SLOPE DEGREE	Between Groups	1726,139	5	345,228	2,527	,033*
	Within Groups	15982,560	117	136,603		
	Total	17708,699	122			
SPECIES TOTAL PER PLOT	Between Groups	2287,308	5	457,462	10,512	,000*
	Within Groups	5091,489	117	43,517		
	Total	7378,797	122			
UPPER SLOPE HILLTOP	Between Groups	5,023	5	1,005	4,703	,001*
	Within Groups	24,994	117	,214		
	Total	30,016	122			
MIDDLE SLOPE	Between Groups	3,079	5	,616	3,013	,014*
	Within Groups	23,913	117	,204		
	Total	26,992	122			
LOWER SLOPE VALLEY	Between Groups	12,987	5	2,597	33,118	,000*
	Within Groups	9,176	117	7,843E-02		
	Total	22,163	122			

*: indicates significance at the 5% error level

1.2 Bonferroni Multiple Comparisons

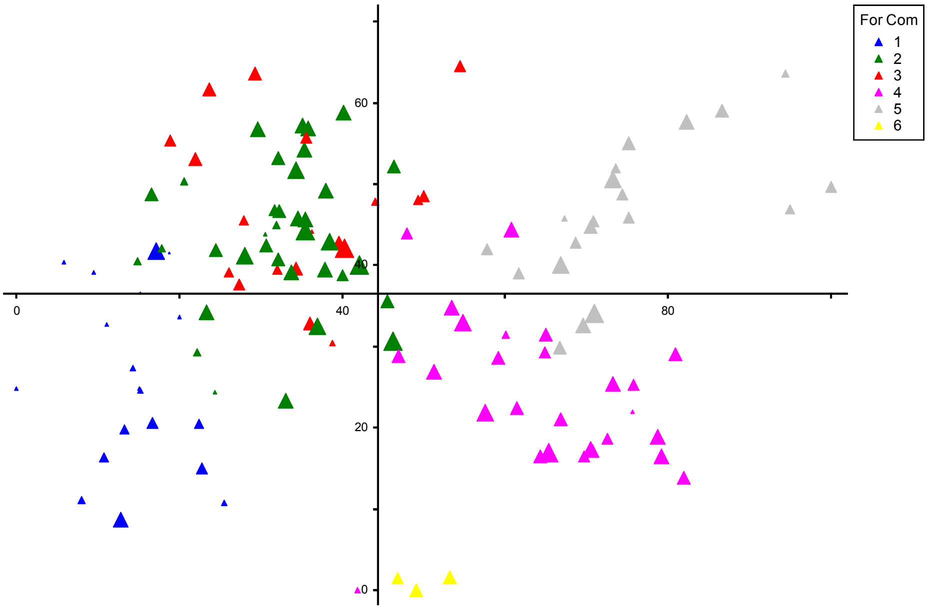
	Forest Community					
	1	**2**	**3**	**4**	**5**	**6**
	A. ginnala-Q. liaotungensis Community	*Q. liaotungensis Community*	*A. stenolobum Community*	*Mixed Xeric Community*	*P. orientalis Community*	*K. paniculata Community*
Elevation	2,3,4,5	1	1	1	1	-
Exposition	4,5	4,5	4,5	1,2,3	1,2,3	-
Slope Degree	-	5	-	-	2	-
Species per Plot	2,3,4,5	1	1	1	1	-
Upper Slope/ Hilltop	2,3,4,5	1	1	1	1	-
Middle Slope	4	-	-	1	-	-
Lower Slope/ Valley	2,3,4,5	1	1	1,6	1,6	2,3,4,5

The mean of the parameter (averaged over the respective community) differs significantly ($p < 0.05$) from the parameters means of the indicated communities.

1.3 Ordination: Correlation of DCA Scores (Plots) with Second Matrix

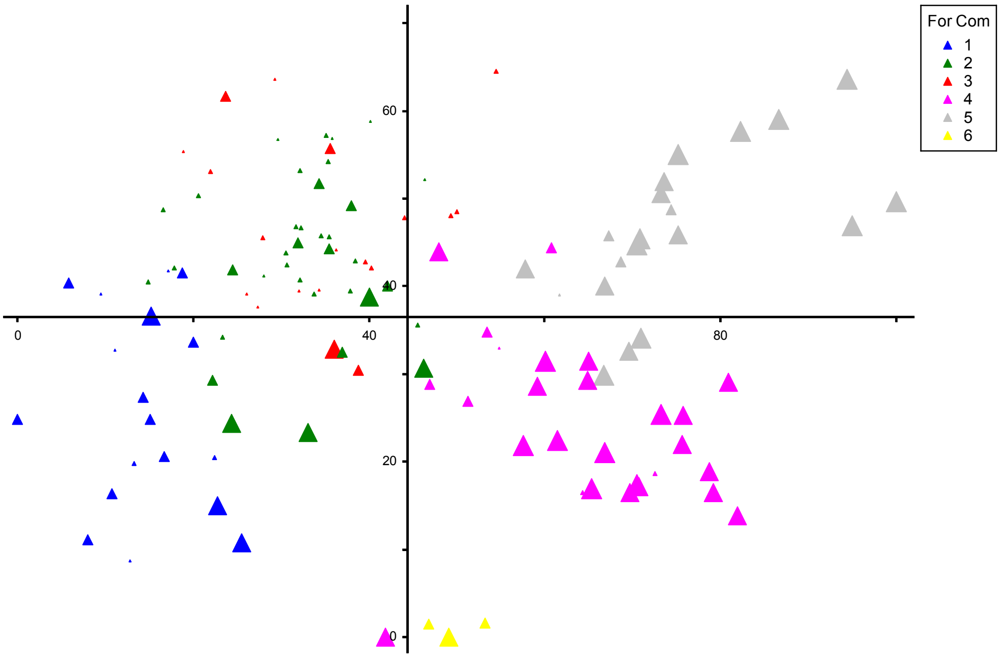
The figures represent correlations between plot ordination score and site parameter for every plot. Bold symbols indicate direction and strength of the correlation. Symbol size of each sample plot is scaled in % of the largest single parameter value observed. Graphs are illustrative to the above calculation results.

Elevation



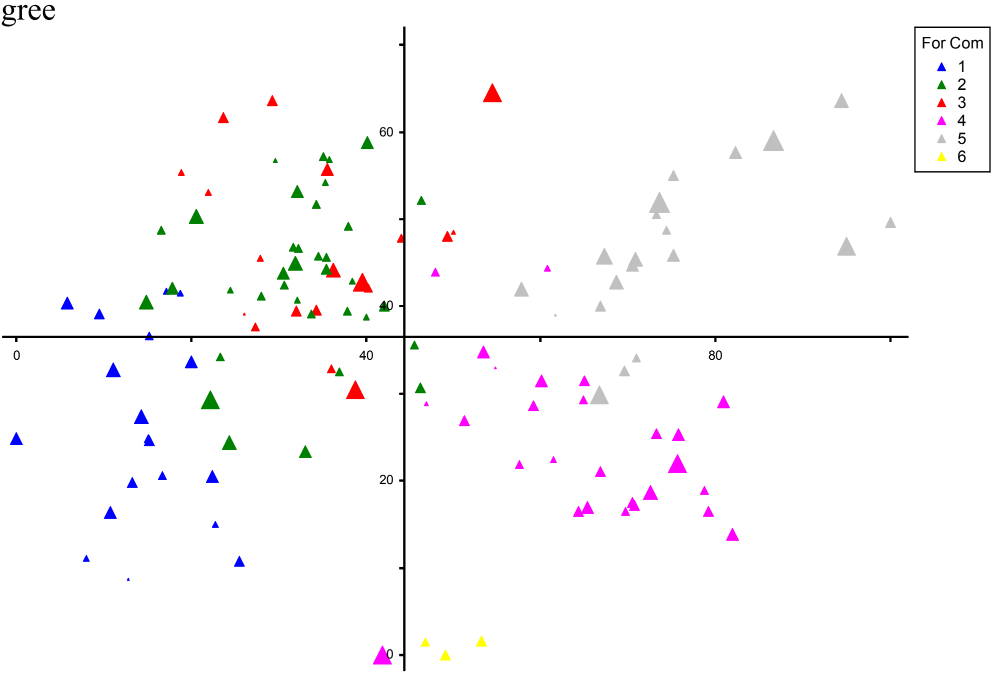
Note: Forest Communities: (1) Q. lioatungensis-A. ginnala community; (2) Q. liaotungensis community; (3) A. stenolobum community; (4) Mixed Xeric community; (5) P. orientalis community; (6) K. paniculata community

Exposition



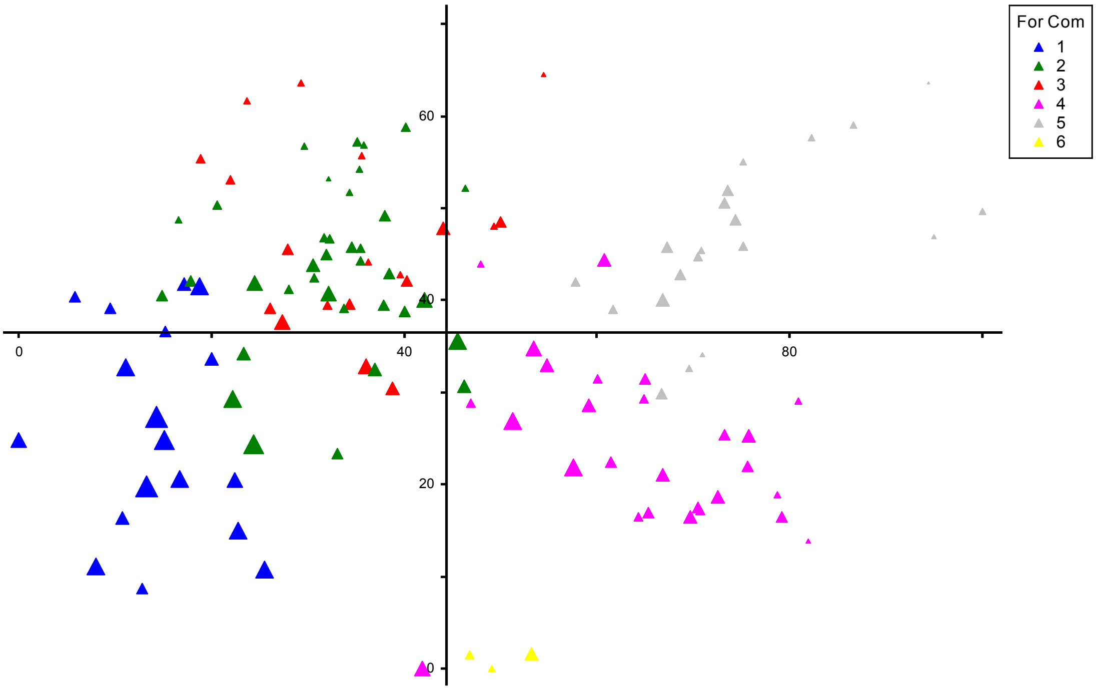
Note: Forest Communities: (1) Q. lioatungensis-A. ginnala community; (2) Q. liaotungensis community; (3) A. stenolobum community; (4) Mixed Xeric community; (5) P. orientalis community; (6) K. paniculata community

Slope Degree



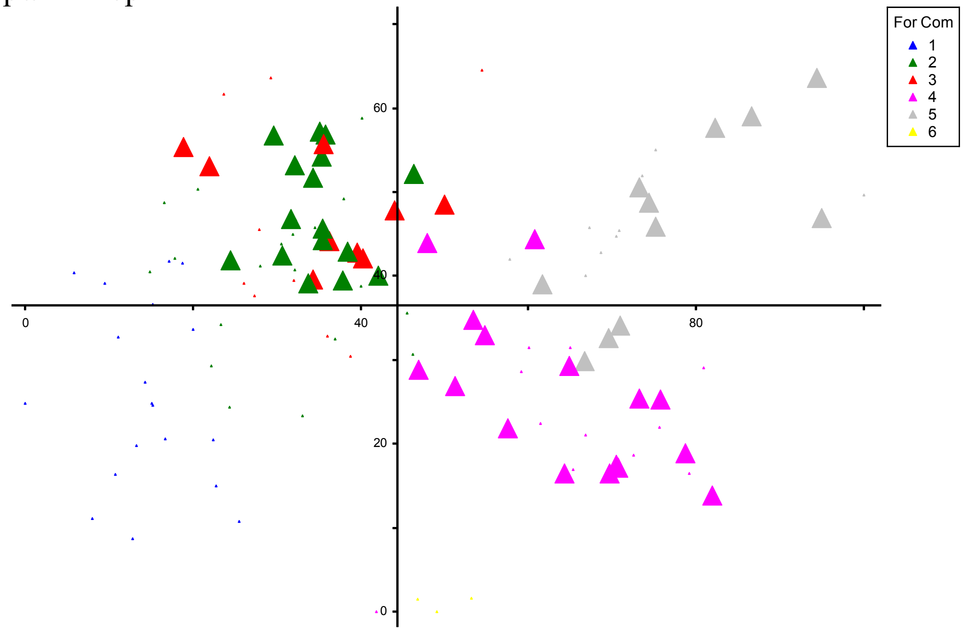
Note: Forest Communities: (1) Q. lioatungensis-A. ginnala community; (2) Q. liaotungensis community; (3) A. stenolobum community; (4) Mixed Xeric community; (5) P. orientalis community; (6) K. paniculata community

Species Total Per Plot



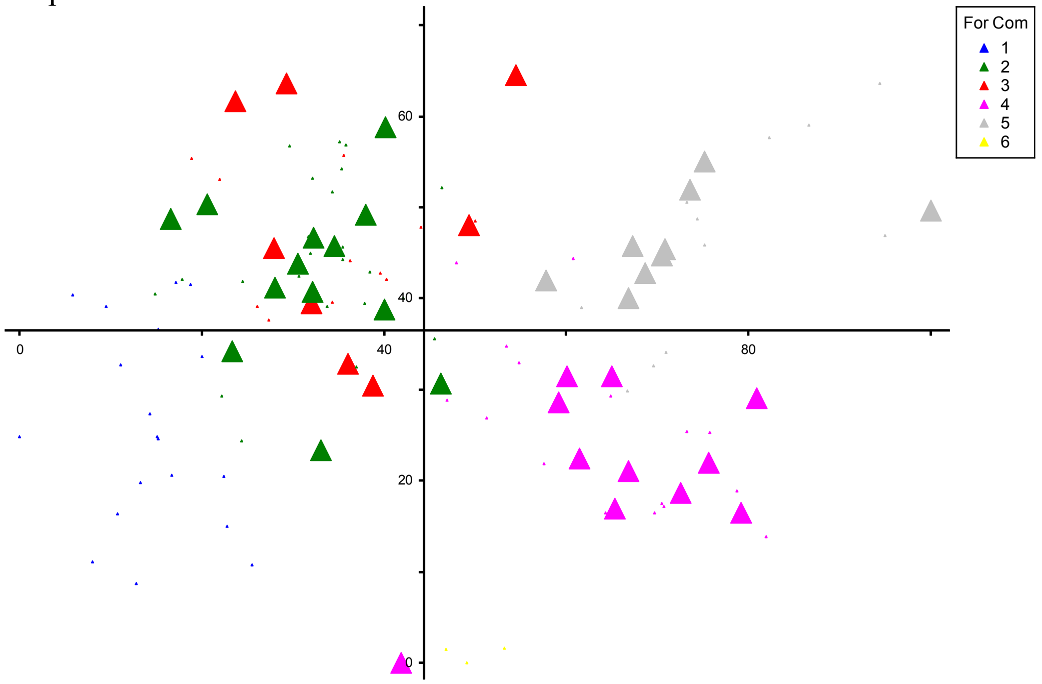
Note: Forest Communities: (1) Q. lioatungensis-A. ginnala community; (2) Q. liaotungensis community; (3) A. stenolobum community; (4) Mixed Xeric community; (5) P. orientalis community; (6) K. paniculata community

Upper Slope/ Hilltop



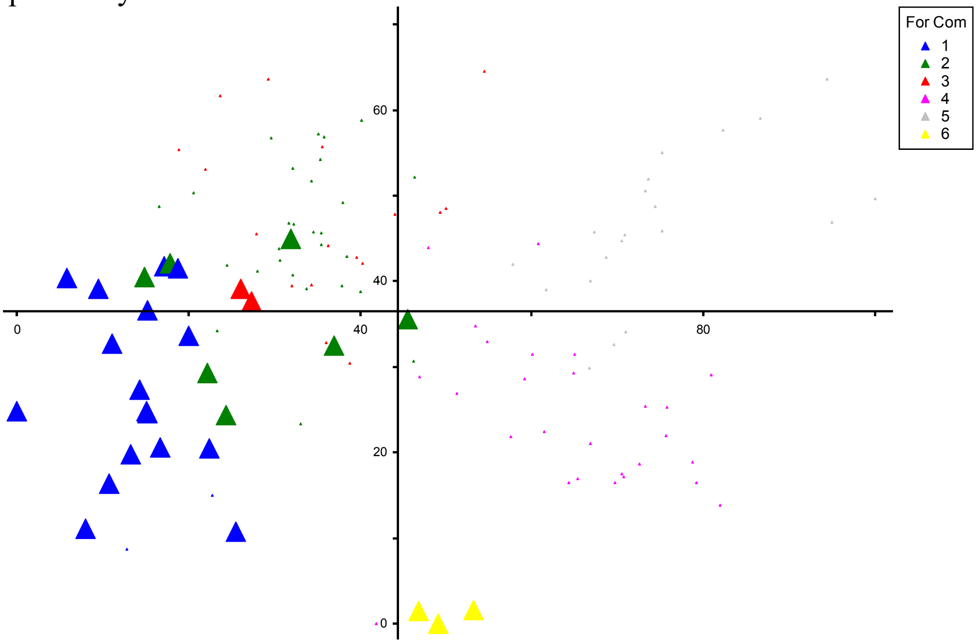
Note: Forest Communities: (1) Q. lioatungensis-A. ginnala community; (2) Q. liaotungensis community; (3) A. stenolobum community; (4) Mixed Xeric community; (5) P. orientalis community; (6) K. paniculata community

Middle Slope



Note: Forest Communities: (1) Q. lioatungensis-A. ginnala community; (2) Q. liaotungensis community; (3) A. stenolobum community; (4) Mixed Xeric community; (5) P. orientalis community; (6) K. paniculata community

Lower Slope/Valley



Note: Forest Communities: (1) Q. lioatungensis-A. ginnala community; (2) Q. liaotungensis community; (3) A. stenolobum community; (4) Mixed Xeric community; (5) P. orientalis community; (6) K. paniculata community

2. Species Distribution Analysis

2.1 Mean Cover over TWINSPAN Classified Forest Communities in Nan Niwan

Species		SUM OF SQUARES	DEGREE OF FREEDOM	MEAN SQUARE	F-Ratio	p-value
Acer ginnala	Between Groups	7,652	5	1,530	12,944	,000*
	Within Groups	13,833	117	,118		
	Total	21,485	122			
Acer stenolobum	Between Groups	9,547	5	1,909	7,748	,000*
	Within Groups	28,834	117	,246		
	Total	38,381	122			
Amygdalus davidiana	Between Groups	7,701	5	1,540	17,508	,000*
	Within Groups	10,293	117	8,798E-02		
	Total	17,995	122			
Armeniaca sibirica	Between Groups	1,650	5	,330	4,003	,002*
	Within Groups	9,643	117	8,242E-02		
	Total	11,293	122			
Euonymus verrucosoides	Between Groups	3,240	5	,648	4,595	,001*
	Within Groups	16,499	117	,141		
	Total	19,739	122			
Koelreuteria paniculata	Between Groups	3,337	5	,667	11,404	,000*
	Within Groups	6,848	117	5,853E-02		
	Total	10,185	122			
Malus baccata	Between Groups	3,168	5	,634	11,158	,000*
	Within Groups	6,643	117	5,678E-02		
	Total	9,811	122			
Platylcadus orientalis	Between Groups	21,964	5	4,393	37,341	,000*
	Within Groups	13,764	117	,118		
	Total	35,727	122			
Pyrus betulafolia	Between Groups	1,024	5	,205	3,128	,011*
	Within Groups	7,657	117	6,544E-02		
	Total	8,681	122			
Quercus liaotungensis	Between Groups	44,566	5	8,913	36,632	,000*
	Within Groups	28,468	117	,243		
	Total	73,035	122			
Sophora davidii	Between Groups	12,829	5	2,566	54,819	,000*
	Within Groups	5,476	117	4,681E-02		
	Total	18,305	122			
Xanthoceras sorbifolia	Between Groups	,521	5	,104	3,870	,003*
	Within Groups	3,147	117	2,690E-02		
	Total	3,667	122			

* indicates significance of mean (cover) values at 95% confidence level

2.2 Bonferroni Multiple Comparisons

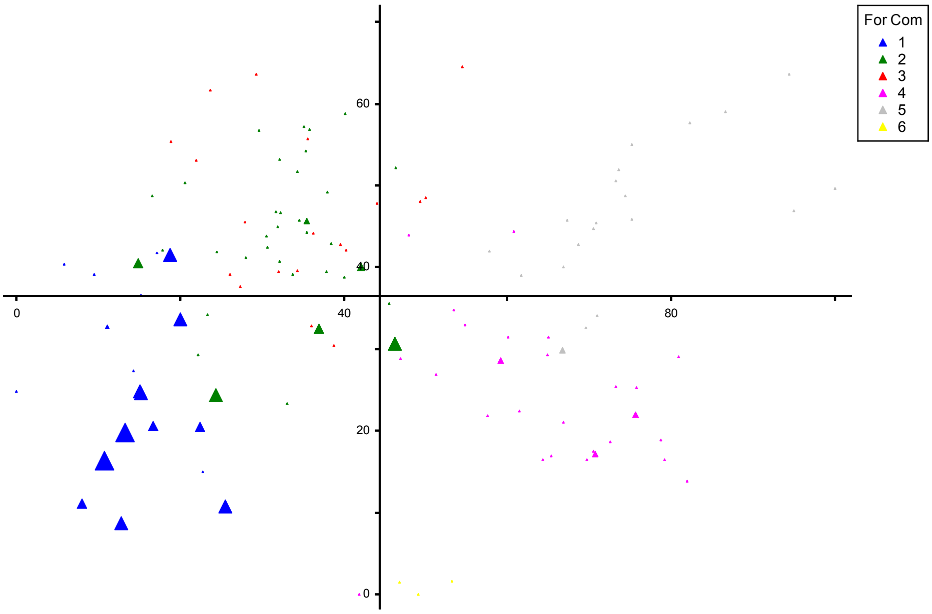
	Forest Community					
	1	**2**	**3**	**4**	**5**	**6**
	A. ginnala-Q. liaotungensis Community	*Q. liaotungensis Community*	*A. stenolobum Community*	*Mixed Xeric Community*	*P. orientalis Community*	*K. paniculata Community*
*Acer ginnala**	2,3,4,5,6	1	1	1	1	1
Acer stenolobum	3	3	1,2,5	-	3	-
Amygdalus davidiana	4,6	4,6	4	1,2,3,5	4,6	1,2,5
Armeniaca sibirica	3	3,4	1,2	2	-	-
Euonymus verrucosoides	-	-	4,5	3	3	-
Koelreuteria paniculata	6	6	6	6	6	1,2,3,4,5
Malus baccata	2,3,4,5,6	1	1	1	1	1
Platycladus orientalis	5	5	5	5	1,2,3,4,6	5
Pyrus betulafolia	-	-	-	-	-	-
Quercus liaotungensis	4,5,6	3,4,5,6	2,4,5	1,2,3	1,2,3	1,2
Sophora davidii	4,5,	4,5,6	4,5	1,2,3,5	1,2,3,4,6	1,2,3
Xanthoceras sorbifolia	-	4	-	2,5	4	-

*The mean of the species cover (only tree layer averaged over the respective community) differs significantly ($p < 0.05$) from the species means of the indicated communities.

2.3 Ordination: Correlation of DCA Scores with First Matrix (species)

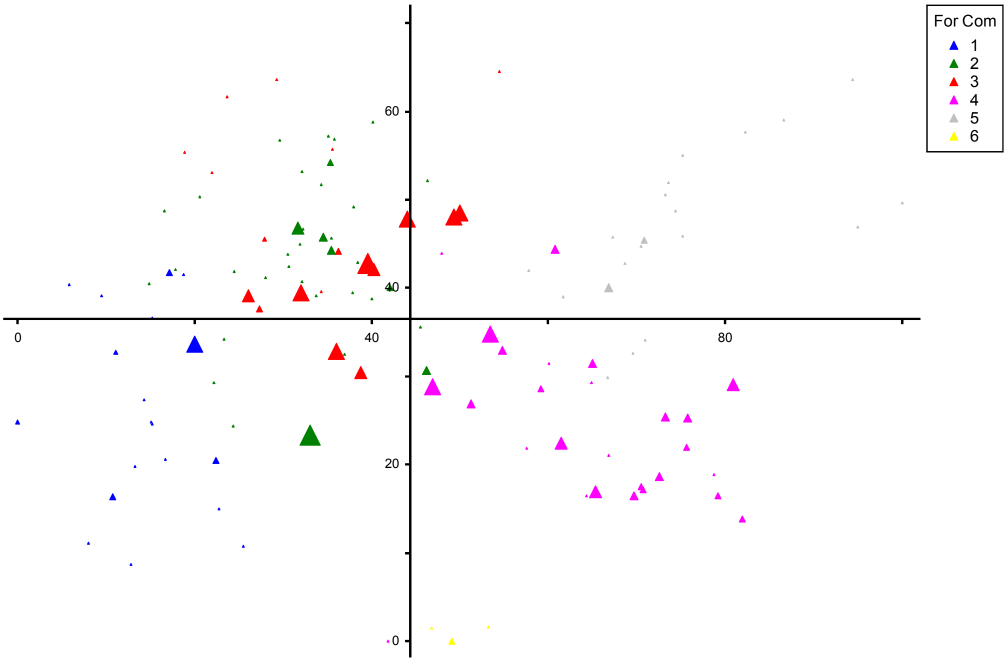
The figures represent correlations between plots scores and tree species occurrences whereby bold symbols indicate direction and strength of the correlation. Symbol size of each sample plot is scaled in % of the largest single parameter value (cover of respective species) observed They are illustrative to the above calculation results.

Acer ginnala



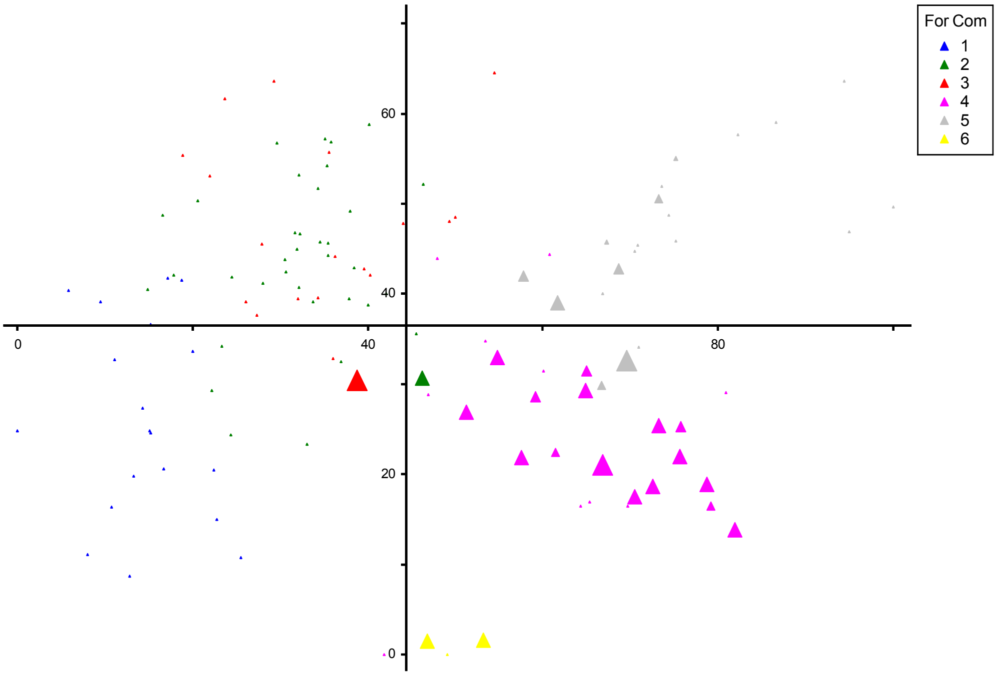
Note: Forest Communities: (1) Q. lioatungensis-A. ginnala community; (2) Q. liaotungensis community; (3) A. stenolobum community; (4) Mixed Xeric community; (5) P. orientalis community; (6) K. paniculata community

Acer stenolobum



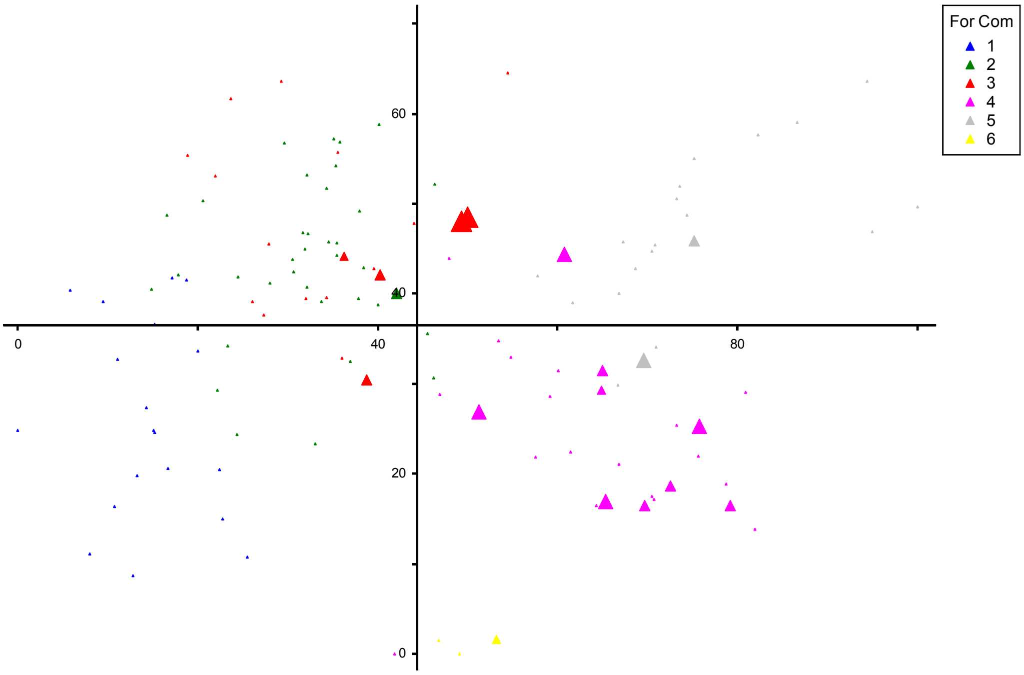
Note: Forest Communities: (1) Q. lioatungensis-A. ginnala community; (2) Q. liaotungensis community; (3) A. stenolobum community; (4) Mixed Xeric community; (5) P. orientalis community; (6) K. paniculata community

Amygdalus davidiana



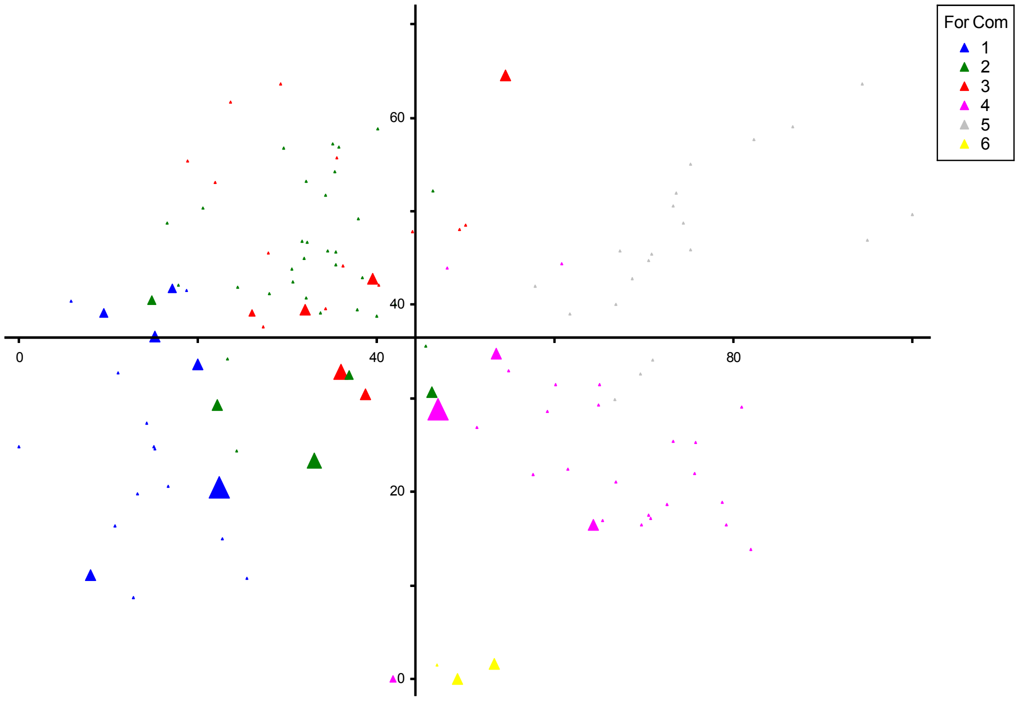
Note: Forest Communities: (1) Q. lioatungensis-A. ginnala community; (2) Q. liaotungensis community; (3) A. stenolobum community; (4) Mixed Xeric community; (5) P. orientalis community; (6) K. paniculata community

Armeniaca sibirica



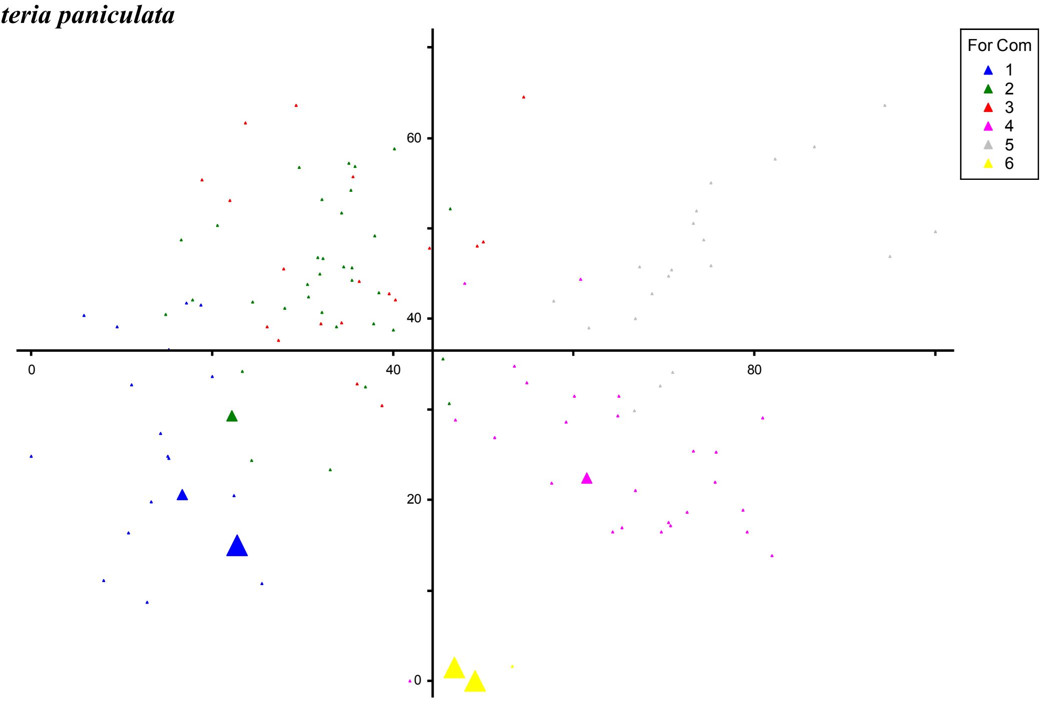
Note: Forest Communities: (1) Q. lioatungensis-A. ginnala community; (2) Q. liaotungensis community; (3) A. stenolobum community; (4) Mixed Xeric community; (5) P. orientalis community; (6) K. paniculata community

Euonymus verrucosoides



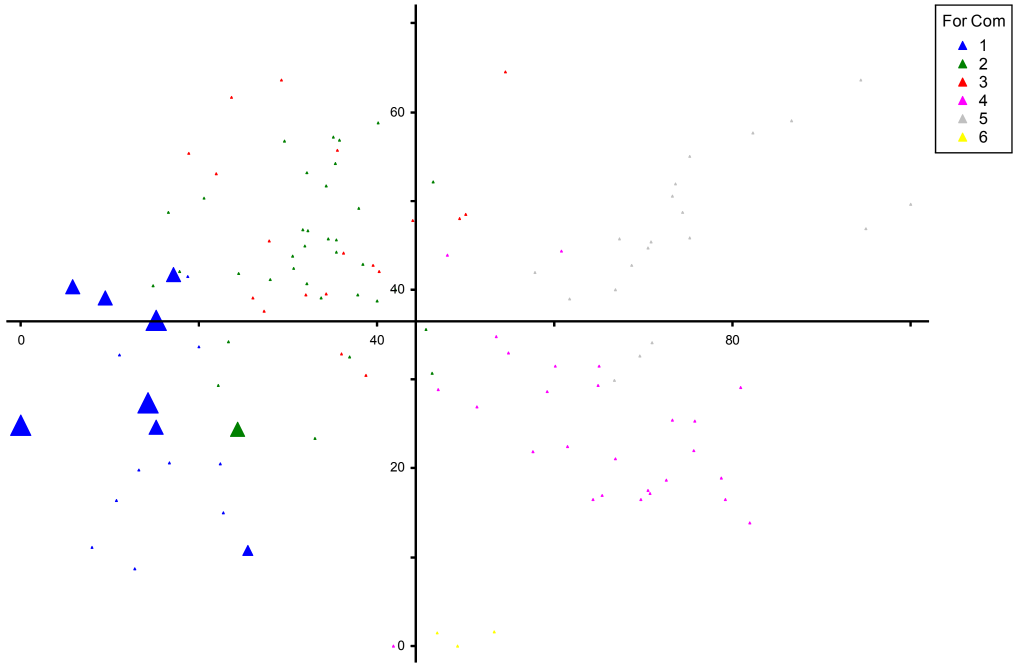
Note: Forest Communities: (1) Q. lioatungensis-A. ginnala community; (2) Q. liaotungensis community; (3) A. stenolobum community; (4) Mixed Xeric community; (5) P. orientalis community; (6) K. paniculata community

Koelreuteria paniculata



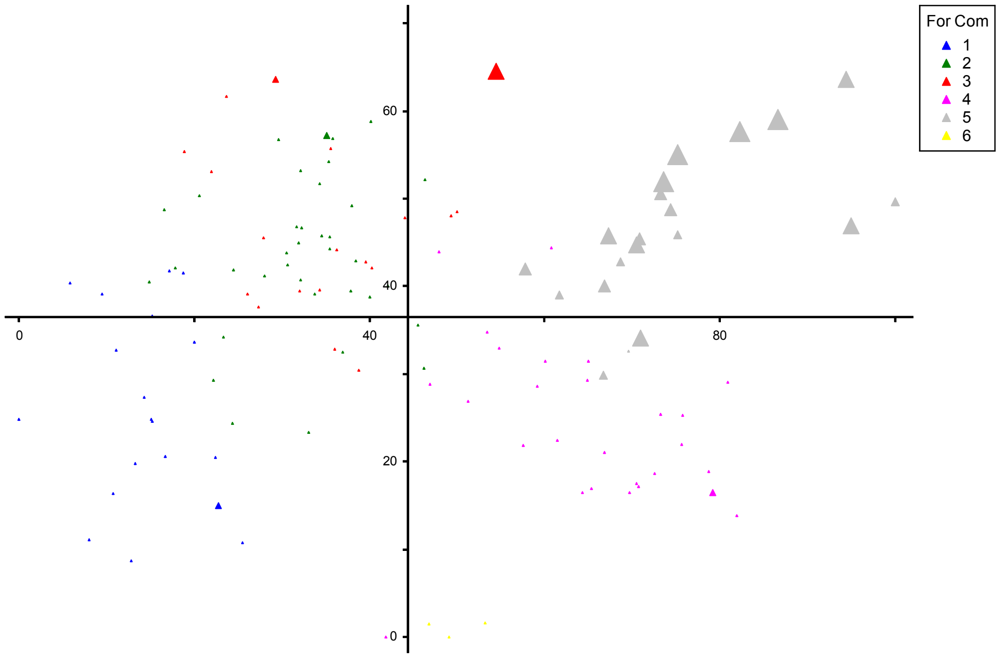
Note: Forest Communities: (1) Q. lioatungensis-A. ginnala community; (2) Q. liaotungensis community; (3) A. stenolobum community; (4) Mixed Xeric community; (5) P. orientalis community; (6) K. paniculata community

Malus baccata



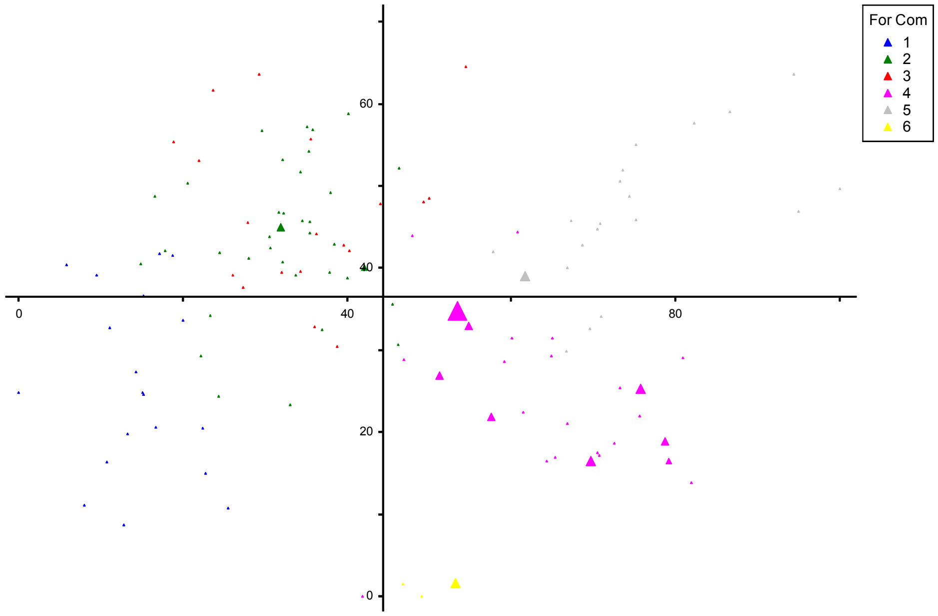
Note: Forest Communities: (1) Q. lioatungensis-A. ginnala community; (2) Q. liaotungensis community; (3) A. stenolobum community; (4) Mixed Xeric community; (5) P. orientalis community; (6) K. paniculata community

Platycladus orientalis



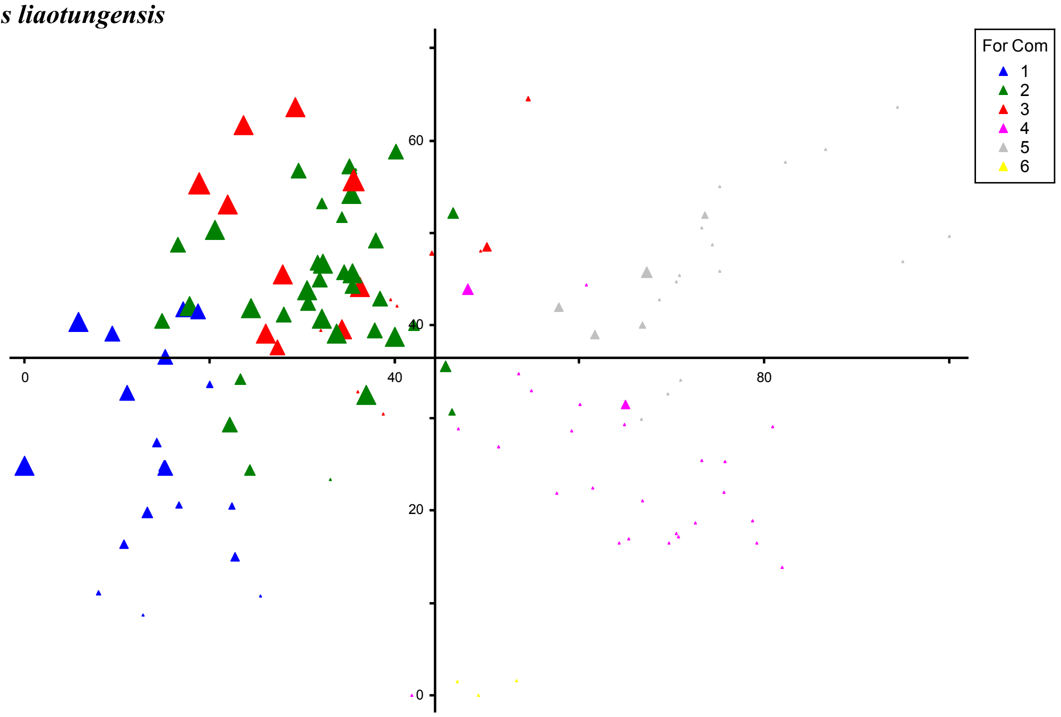
Note: Forest Communities: (1) Q. lioatungensis-A. ginnala community; (2) Q. liaotungensis community; (3) A. stenolobum community; (4) Mixed Xeric community; (5) P. orientalis community; (6) K. paniculata community

Pyrus betulafolia



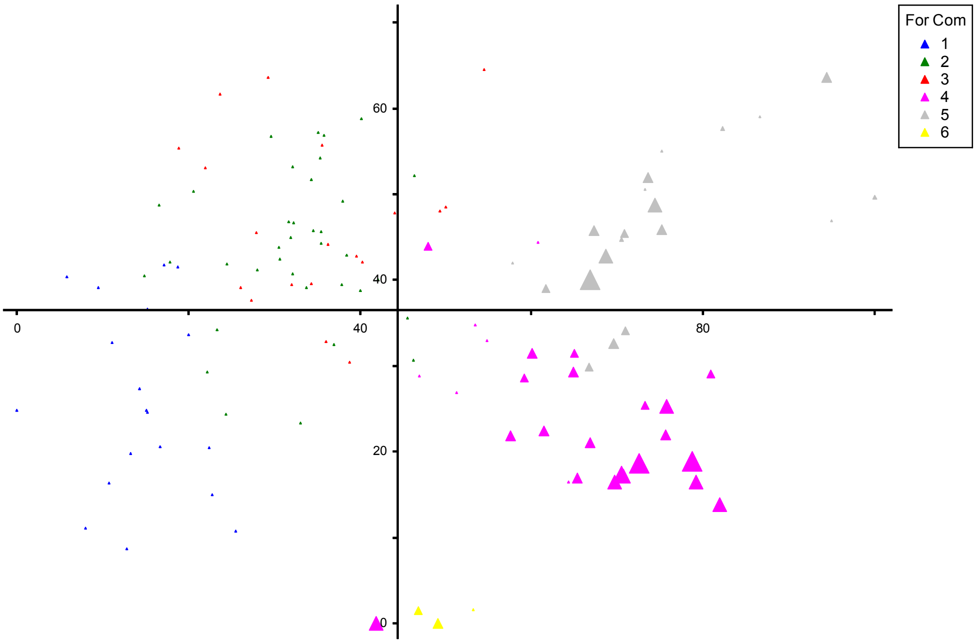
Note: Forest Communities: (1) Q. lioatungensis-A. ginnala community; (2) Q. liaotungensis community;
(3) A. stenolobum community; (4) Mixed Xeric community;
(5) P. orientalis community; (6) K. paniculata community

Quercus liaotungensis



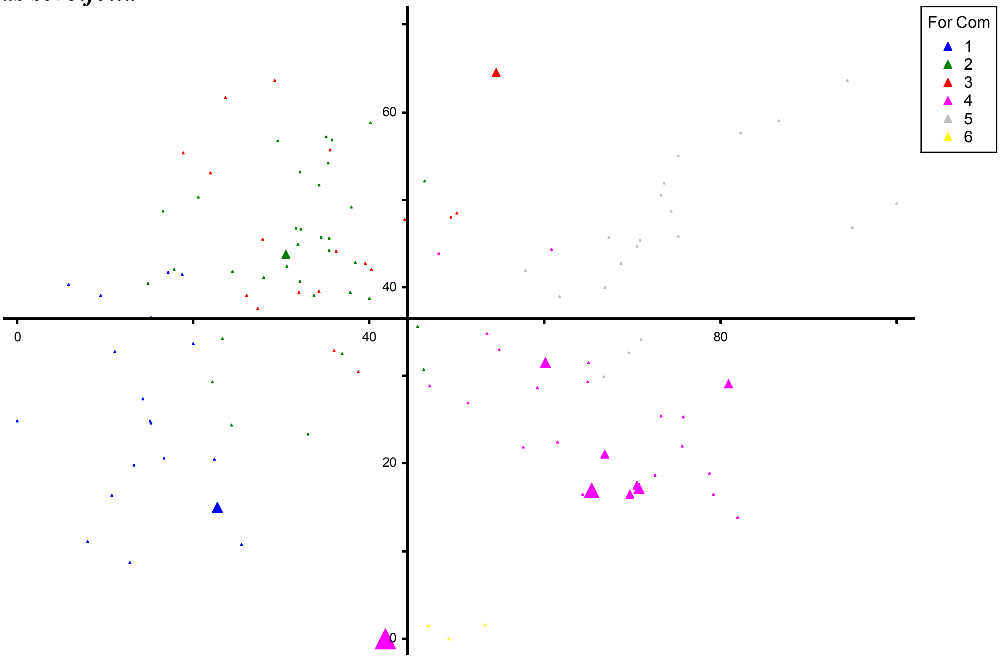
Note: Forest Communities: (1) Q. lioatungensis-A. ginnala community; (2) Q. liaotungensis community;
(3) A. stenolobum community; (4) Mixed Xeric community;
(5) P. orientalis community; (6) K. paniculata community

Sophora davidii



Note: Forest Communities: (1) Q. lioatungensis-A. ginnala community; (2) Q. liaotungensis community; (3) A. stenolobum community; (4) Mixed Xeric community; (5) P. orientalis community; (6) K. paniculata community

Xanthoceras sorbifolia



Note: Forest Communities: (1) Q. lioatungensis-A. ginnala community; (2) Q. liaotungensis community; (3) A. stenolobum community; (4) Mixed Xeric community; (5) P. orientalis community; (6) K. paniculata community

Annex III: Socioeconomic Data

1. List of Surveyed Counties, Townships and Villages 2000-2002

County	Township	Village	Basic Farmland per capita (mu)	Total Number of Households	Total Population
Baota	Yanhewan Zhen	Cha Fang	1	46	216
		Si Yao Xian	1.5	49	230
		Fang Ta Cun	1.5	55	242
		Da Hua Qu	-	42	180
		Cui Zhuang	-	25	120
		Bai Cha Gou	-	50	240
		Hou Jia Gou	-	80	380
	Liu Lin Zhen	Ren Tai Cun	0.3	65	300
		Ye Jia Zhuang	0.8	60	260
		Kang Qi Lao	0.3-0.4	40	300
		Nan Zhuang He	-	75	450
	Nan Niwan	Gao Feng	1	50	300
		Jin Zhuang	1	100	400
		Ma Fang Cun	1	150	650
Ganquan	Lao Shan	Bai Tu Po	1	45	210
		Xiao Lao Shan Cun	1	78	322
		Wang Tai Cun	-	65	270
		Yang Tai Cun	-	-	-
		Deng Sanyu Cun	-	60	300
		Qian Tu Huang Gou	-	150	600
		Hou Tu Huang Gou	-	-	-
		Qian Tu Huang Gou	-	-	-
Fuxian	Jiao Dao	Tian Le Cun	1.3	112	460
		Bai Jia Cun	1	70	400
		Xun Cun	1.5	180	800
		Dong Ru Zi Cun	0.8	200	850
Luochuan	Jing Zhao	Shi Jia Zhuang Cun	1	80	400
		San Zong Wa	1.5	62	300
		An Shan Cun	1	104	430
		Ge Lao Cun	1.5	40	200
		Bei Fu Yi Cun	1.75	49	222
		Chang Jia Yuan	2.7	45	180

2. Household Questionnaire

HOUSEHOLD SURVEY DATE:

Village:

Household No:

Family Head and Wife (name/age)

Children (sex/age):

Employment/activities of children:

1. Land resources and crops planted (mu)

	Zhuangdi (nat. flatland)	Tiandi (terraces)	Shuidi (irrigation)	Podi (slope)	Yuandi (garden)	Huangdi (wasteland)
Total						
Potato						
Wheat						
Buckwheat						
Soybeans						
Millets						
Green Beans						
Other						
- Sunflower						
- Red Beans						
- Vegetables						
- Melons						
- Grapes						
- Green Pepper						

2. Crop yields, market prices and cash income

	average yield/mu	average market price/jin	approx. cash income/year
Potato			
Wheat			
Buckwheat			
Soybeans			
Millets			
Green Beans			
Other			
- Sunflower			
- Red Beans			
- Vegetables			
- Melons			
- Grapes			
- Green Pepper			

3. Livestock

	Amount	Purpose	Approx. Total Value	Cash Income Animal Products
Goats				
Pigs				
Ass/Mule				
Cattle				
Chicken				
Other				

4. Fertilizer and pesticides

Type of fertilizer/pesticide:

Consumption per year:

Unit price:

Total expenses:

5. Off-farm employment

Type and location of work:

Income/per day or per month:

Average duration per person:

Approx. total annual income:

6. Supplementary questions:

- subsistence level grain needs and total household income
- collection of firewood and purchasing of heating and cooking materials
- dept situation (purpose of lending; amount borrowed and interest rates)
- child education situation and annual expenses
- other annual expenses
- general land allocation status
- Sloping Land Conversion Program: How much land was abandoned and how did compensation work? In what ways was the household impacted?
- taxes and fees
- other comments

3. Yan'an Prefecture Household Level Data 2000-2002

	Econ. Family	Work Force	Flat Land	Sloping Land	Total	Flat-land/person	Slope-land/person	Total per capita	Farming Income	Off-farm Income	Livestock Income	Other Income	Total Income reported	Total Income calculated	Total Expenses	Tuition	Firewood	Fertilizer	Taxes/ Fees	Daily Exp.	Loan
H101	5	5,0	2,50	13,00	15,50	0,50	2,60	3,10	2768	10000	0	0	10000	12768	4917	0	357	900	1660	2000	.
H102	4	2,0	2,80	17,00	19,80	0,70	4,25	4,95	3800	4180	0	0	4500	7980	7197	2173	386	1600	1037	2000	10000
H103	3	2,0	4,10	16,10	20,20	1,37	5,37	6,73	4080	1000	732	0	2000	5813	9776	7000	0	20	756	2000	.
H104	4	2,0	6,00	13,00	19,00	1,50	3,25	4,75	2000	4900	985	0	6500	7885	3997	722	0	250	1025	2000	.
H105	4	3,0	7,00	18,60	25,60	1,75	4,65	6,40	1876	7225	493	0	.	9594	11077	7500	0	330	1247	2000	.
H106	5	3,5	5,00	5,00	10,00	1,00	1,00	2,00	1617	2000	1077	0	2000	4694	5429	2719	0	100	610	2000	.
H107	3	3,0	4,00	7,50	11,50	1,33	2,50	3,83	1526	3600	52	0	2000	5178	2783	0	0	110	673	2000	.
H108	4	3,0	7,00	40,00	47,00	1,75	10,00	11,75	2074	7900	443	0	10000	10417	4190	0	386	450	1354	2000	.
H109	4	2,0	10,00	12,50	22,50	2,86	3,57	6,43	2051	2280	0	1200	7000	5531	20000	15500	243	700	719	2838	.
H110	6	3,0	6,40	14,50	20,90	1,07	2,42	3,48	1070	500	508	0	3500	2078	4000	400	0	555	270	2775	0
H111	3	2,0	3,00	3,00	6,00	1,00	1,00	2,00	804	4200	167	0	5000	5171	3000	0	243	100	672	1985	0
H112	3	3,0	4,00	2,00	6,00	1,33	0,67	2,00	4846	0	426	0	7500	5272	10000	0	386	3800	685	5129	8000
H113	3	3,0	7,00	10,00	17,00	2,33	3,33	5,67	2494	6500	384	0	4500	9377	2500	0	0	405	1219	876	.
H114	3	3,0	1,50	13,00	14,50	0,50	4,33	4,83	1130	800	1009	0	2000	2939	2000	0	0	305	382	1313	.
H115	5	2,0	2,00	13,50	15,50	0,40	2,70	3,10	1482	0	409	0	.	1891	3000	400	0	465	246	1889	20000
H116	3	3,0	9,90	4,00	13,90	3,30	1,33	4,63	6123	675	514	0	4500	7312	4500	0	0	590	951	2959	0
H117	2	2,0	5,00	6,50	11,50	2,50	3,25	5,75	3098	0	626	0	.	3724	2949	0	0	465	484	2000	.
H118	5	4,0	5,50	15,00	20,50	1,10	3,00	4,10	1371	1400	83	250	.	3104	2954	0	0	550	404	2000	2000
H119	3	3,0	15,40	20,00	35,40	5,13	6,67	11,80	3643	0	626	1500	.	5769	2950	0	0	200	750	2000	.
H120	4	2,0	5,60	20,00	25,60	1,40	5,00	6,40	5455	0	217	0	3500	5672	6811	2173	0	1900	737	2000	10000
H121	2	2,0	9,50	13,00	22,50	4,75	6,50	11,25	3872	0	1436	500	6000	5808	8500	0	25	1650	755	6070	2500
H122	2	1,0	2,90	40,00	42,90	1,45	20,00	21,45	324	10200	1027	1200	15500	12751	4223	0	10	555	1658	2000	0
H123	2	1,0	7,00	20,00	27,00	3,50	10,00	13,50	2165	0	83	0	2000	2249	2000	0	15	-	292	1343	0
H124	6	2,0	4,00	2,00	6,00	0,67	0,33	1,00	1682	9036	818	0	8000	11537	5500	1000	0	1000	1500	2000	0
H125	2	1,0	1,00	4,50	5,50	0,50	2,25	2,75	872	0	4351	1500	1500	6722	1500	0	8	40	874	579	0
H126	2	1,5	6,40	20,00	26,40	3,20	10,00	13,20	8358	0	0	0	2000	8358	2000	0	0	75	1087	838	6000
H127	6	4,5	3,20	14,50	17,70	0,53	2,42	2,95	1801	3000	0	0	6500	4801	2500	350	40	600	624	886	6000
H128	2	1,5	5,70	24,00	29,70	2,85	12,00	14,85	4684	4500	0	0	.	9184	3294	0	0	100	1194	2000	12000
H129	6	2,0	5,50	39,00	44,50	0,92	6,50	7,42	1215	0	0	0	4000	1215	7026	4500	18	350	158	2000	12500
H130	2	2,0	3,00	37,00	40,00	1,50	18,50	20,00	1113	0	42	0	0	1155	1500	0	0	250	150	1100	0
H131	3	2,0	1,40	13,00	14,40	0,47	4,33	4,80	2567	0	0	0	2000	2567	2597	0	243	20	334	2000	5000
H132	2	2,0	2,80	20,00	22,80	1,40	10,00	11,40	941	0	0	1200	4500	2141	4500	0	386	230	278	3606	30000

H133	3	2,0	0,00	50,00	50,00	0,00	16,67	16,67	97	3000	409	0	4500	3507	5590	1813	572	750	456	2000	20000
H134	6	5,0	7,00	17,50	24,50	1,17	2,92	4,08	1507	5950	818	0	6500	8275	6500	0	357	805	1076	4262	5500
H135	4	3,0	4,00	20,00	24,00	1,00	5,00	6,00	1711	7500	597	0	5000	9808	4500	200	429	280	1275	2316	.
H136	4	4,0	7,50	10,00	17,50	1,88	2,50	4,38	4961	0	1652	0	4500	6614	4500	0	50	350	860	3240	3500
H137	2	1,0	4,80	10,00	14,80	2,40	5,00	7,40	3145	0	1966	0	2000	5110	2000	0	0	220	664	1116	2000
H138	5	2,5	4,80	12,00	16,80	0,96	2,40	3,36	1581	0	835	0	2500	2415	2500	722	336	570	314	558	3000
H139	5	2,0	6,00	15,00	21,00	1,20	3,00	4,20	2396	0	1603	0	2500	3999	2500	1500	50	320	520	110	1000
H140	3	2,0	2,40	5,00	7,40	0,80	1,67	2,47	1255	0	702	0	2000	1957	2000	0	30	350	254	1366	5000
H141	5	4,0	9,60	5,00	14,60	1,92	1,00	2,92	3708	0	3131	0	1500	6839	3786	200	30	667	889	2000	5000
H142	7	5,0	14,00	30,00	44,00	2,00	4,29	6,29	5758	600	981	0	5500	7339	15000	10000	30	2350	954	1666	1000
H143	3	2,0	7,75	5,50	13,25	2,58	1,83	4,42	2370	0	576	0	2500	2946	14000	11500	40	500	383	1577	.
H144	4	4,0	8,00	0,00	8,00	2,00	0,00	2,00	3257	0	856	0	3500	4113	8925	5000	430	960	535	2000	7000
H145	3	2,0	8,00	10,00	18,00	2,67	3,33	6,00	2862	0	1030	0	4000	3892	6500	4000	230	1040	506	724	5000
H146	6	3,0	12,00	2,00	14,00	2,00	0,33	2,33	4791	0	1688	0	3000	6487	14001	11000	50	1011	843	1096	16000
H147	4	4,0	11,00	9,50	20,50	2,75	2,38	5,13	8131	1250	1700	0	7500	11081	4951	0	310	1200	1440	2000	0
H148	4	2,0	4,80	6,00	10,80	1,20	1,50	2,70	3024	750	839	0	4000	4613	6000	3625	790	670	600	315	0
H149	4	2,0	5,40	12,00	17,40	1,35	3,00	4,35	3030	0	839	0	2000	3869	3000	400	50	394	503	1653	10600
H150	4	2,0	5,00	3,00	8,00	1,25	0,75	2,00	1816	0	1733	0	750	3549	13582	10000	220	900	461	2000	20000
H151	5	4,0	8,00	37,00	45,00	1,60	7,40	9,00	0	4500	1940	0	7500	6440	3451	300	0	314	837	2000	15000
H152	5	3,0	6,00	8,00	14,00	1,20	1,60	2,80	2200	0	4451	0	7500	6651	6500	1500	0	617	865	3519	0
H153	4	2,0	8,50	50,00	58,50	2,13	12,50	14,63	853	0	1106	0	5500	1960	3500	1000	0	363	255	1882	0
H154	3	2,0	3,00	10,00	13,00	1,00	3,33	4,33	2194	0	2522	0	3000	4716	10000	170	214	475	613	8528	0
H155	5	3,0	5,00	14,00	19,00	1,00	2,80	3,80	2063	0	1717	0	9500	3779	16000	13000	180	800	491	1529	3000
H156	4	4,0	6,00	0,00	6,00	1,50	0,00	1,50	186	0	2315	0	5000	2501	5000	0	0	125	325	4550	8000
H157	3	2,0	3,00	9,00	12,00	1,00	3,00	4,00	1745	4000	334	0	5000	6079	3500	0	0	252	790	2458	10000
H158	5	4,0	9,00	24,00	33,00	1,80	4,80	6,60	5532	7000	5474	0	11500	18006	10000	5000	0	965	2341	1694	13000
H159	5	2,0	5,50	15,00	20,50	1,10	3,00	4,10	1680	1500	3566	0	3500	6745	5389	2000	0	512	877	2000	.
H160	3	2,0	2,70	8,50	11,20	0,90	2,83	3,73	503	0	472	0	2000	984	2001	361	0	230	128	1282	0
H161	5	2,5	9,00	12,00	21,00	1,80	2,40	4,20	1997	0	4744	0	6000	6741	6000	3625	10	310	876	1179	0
H162	3	2,0	2,60	7,00	9,60	0,87	2,33	3,20	404	550	6478	0	4500	7432	4500	0	39	200	966	3295	13000
H163	4	2,0	2,80	25,00	27,80	0,70	6,25	6,95	629	1125	217	0	2000	1971	2000	800	0	313	256	631	500
H164	2	1,0	1,00	3,00	4,00	0,50	1,50	2,00	294	0	501	0	2000	795	2000	0	0	110	103	1786	3000
H165	3	2,0	2,40	30,00	32,40	0,80	10,00	10,80	644	0	3661	0	5500	4304	7500	0	243	200	560	6497	8000
H167	5	4,0	1,70	15,50	17,20	0,34	3,10	3,44	717	8000	0	0	.	3647	4500	0	0	175	474	3851	0
H168	3	2,0	2,00	3,50	5,50	0,67	1,17	1,83	658	2930	0	0	2000	1658	2000	0	0	120	216	1664	0
H169	6	4,0	3,60	3,00	6,60	0,60	0,50	1,10	914	1000	0	0	2000	3582	1978	722	25	75	466	690	5500
H170	6	4,0	6,20	30,00	36,20	1,03	5,00	6,03	3337	600	2240	0	2500	4537	5500	3625	28	600	590	658	55000

H171	3	2,5	3,90	0,00	3,90	1,30	0,00	1,30	3217	200	1000	0	8500	8217	4000	0	378	666	1068	1888	4000
H172	7	6,0	8,00	17,50	25,50	1,14	2,50	3,64	1434	5000	0	0	.	9719	4668	361	320	724	1263	2000	2600
H173	4	4,0	9,00	4,00	13,00	2,25	1,00	3,25	3913	7875	409	0	.	4213	12064	8167	140	1210	548	2000	12000
H174	4	3,0	8,00	5,00	13,00	2,00	1,25	3,25	2105	300	0	0	.	3355	5500	1000	450	1861	436	1753	1500
H175	4	2,0	8,40	0,00	8,40	2,10	0,00	2,10	664	1200	50	0	10000	3164	7500	4000	250	980	411	1859	16000
H176	4	3,0	8,00	2,00	10,00	2,00	0,50	2,50	4800	2500	0	0	4000	4883	4000	1813	286	800	635	467	0
H177	2	2,0	2,60	3,00	5,60	1,30	1,50	2,80	5352	0	83	0	4000	5352	4000	0	405	700	696	2199	0
H178	6	3,0	7,80	5,00	12,80	1,30	0,83	2,13	2000	0	0	0	5000	5728	8500	5500	0	1500	745	755	35000
H179	4	2,0	7,70	10,50	18,20	1,93	2,63	4,55	1766	2500	1228	0	10000	10766	10000	4000	140	1657	1400	2803	2500
H180	5	2,0	8,00	2,50	10,50	1,60	0,50	2,10	14450	9000	0	0	20000	24567	10000	2500	180	1546	3194	2581	20000
H181	6	4,0	12,80	12,80	25,60	2,13	2,13	4,27	12500	10000	117	0	16000	12900	18000	9000	286	1730	1677	5307	27000
H182	5	3,0	9,00	0,00	9,00	1,80	0,00	1,80	4000	0	400	0	4000	4000	4000	1813	143	1210	520	315	9000
H183	5	4,0	7,50	10,00	17,50	1,50	2,00	3,50	17528	0	0	0	15000	18062	10000	500	330	2062	2348	4760	0
H184	5	3,0	7,00	8,00	15,00	1,40	1,60	3,00	2230	0	533	0	4000	4280	7500	2000	180	107	556	4657	20000
H185	6	5,0	10,00	6,50	16,50	1,67	1,08	2,75	2064	2000	50	0	10000	8481	10000	0	345	1136	1102	7417	200
H186	5	3,0	7,50	5,50	13,00	1,50	1,10	2,60	8350	6000	417	0	8000	8433	11500	8000	143	450	1096	1811	8000
H187	5	2,5	5,90	7,50	13,40	1,18	1,50	2,68	923	0	83	0	4500	3923	4500	200	240	588	510	2962	0
H188	3	2,0	11,00	3,00	14,00	3,67	1,00	4,67	7981	3000	0	0	10000	7981	10000	0	396	1251	1038	7316	0
H189	4	2,0	4,40	1,25	5,65	1,10	0,31	1,41	1588	0	0	0	3000	2254	4000	361	260	650	293	2436	3000
H190	3	1,0	3,90	0,00	3,90	1,30	0,00	1,30	500	450	217	0	500	500	1000	0	0	0	65	935	6500
H191	4	2,0	4,00	3,00	7,00	1,00	0,75	1,75	18810	0	0	0	10000	18810	10000	600	420	1700	2445	4835	0
H192	3	2,0	7,00	0,00	7,00	2,33	0,00	2,33	17400	0	0	0	10000	23400	8000	400	440	2457	3042	1661	4000
H193	5	3,0	4,50	0,00	4,50	0,90	0,00	0,90	7990	6000	0	0	8000	9470	10000	0	160	936	1231	7673	
H194	5	4,0	6,30	0,00	6,30	1,26	0,00	1,26	6944	1375	105	0	2000	8069	5000	400	71	1810	1049	1670	12700
H195	2	2,0	6,70	0,00	6,70	3,35	0,00	3,35	7611	1125	0	0	8000	8811	10000	0	615	2515	1145	5724	0
H196	4	2,0	4,00	0,00	4,00	1,00	0,00	1,00	1200	0	0	1200	10000	1200	10000	3250	193	2010	156	4392	12000
H197	5	2,0	8,50	0,00	8,50	1,70	0,00	1,70	7362	0	0	0	10000	7362	10000	4000	260	2008	957	2775	0
H198	5	2,0	10,00	0,00	10,00	2,00	0,00	2,00	6906	0	0	0	10000	6906	9000	600	266	1673	898	5563	2000
H199	5	2,0	7,50	0,00	7,50	1,50	0,00	1,50	5954	0	0	0	20000	7304	13036	5550	540	3996	950	2000	0
H200	4	4,0	6,00	0,00	6,00	1,50	0,00	1,50	3150	1350	0	0	9500	8350	8000	0	270	2350	1086	4295	26000
H201	4	2,0	5,00	0,00	5,00	1,25	0,00	1,25	9033	4000	0	1200	3500	11033	5588	200	228	1726	1434	2000	0
H202	5	3,0	10,00	0,00	10,00	2,00	0,00	2,00	10000	2000	0	0	10000	13600	12038	5500	360	2410	1768	2000	8500
H203	4	2,0	5,30	0,00	5,30	1,33	0,00	1,33	9849	3600	0	0	4000	10667	6286	1500	394	1005	1387	2000	20000
H204	3	2,0	5,00	0,00	5,00	1,67	0,00	1,67	9375	0	818	0	16000	18975	10000	3500	330	1073	2467	2630	17500
H205	4	2,0	10,00	0,00	10,00	2,50	0,00	2,50	22000	9600	0	0	10000	22000	8500	1000	162	2320	2860	2158	2500
H206	7	2,0	13,00	0,00	13,00	1,86	0,00	1,86	31350	0	0	0	15000	32850	13500	2400	190	2506	4271	4133	3000
H207	5	4,0	10,00	0,00	10,00	2,00	0,00	2,00	11000	1500	0	0	11000	19400	9000	0	666	2153	2522	3659	0

H208	1	0,5	9,00	0,00	9,00	9,00	0,00	9,00	11250	8400	0	0	3000	11250	4685	0	184	1038	1463	2000	0
H209	4	2,0	10,00	0,00	10,00	2,50	0,00	2,50	6500	0	0	0	16000	10000	10000	1000	549	3046	1300	4105	0
H210	4	3,0	8,00	0,00	8,00	2,00	0,00	2,00	7000	3500	0	0	7000	7900	4500	400	20	1555	1027	1498	4300
H211	4	.	5,00	0,00	5,00	1,25	0,00	1,25	.	.	.	.	.	.	.	.	.	.	.	.	.
H212	6	.	12,00	0,00	12,00	2,00	0,00	2,00	.	.	.	.	.	.	.	.	.	.	.	.	.
H213	6	.	8,00	4,50	12,50	1,33	0,75	2,08	.	.	.	.	.	.	.	.	.	.	.	.	.
H214	5	.	18,00	4,50	22,50	3,60	0,90	4,50	.	.	.	.	.	.	.	.	.	.	.	.	.
H215	4	.	10,00	0,00	10,00	2,50	0,00	2,50	.	.	.	.	.	.	.	.	.	.	.	.	.
H216	5	.	5,00	0,00	5,00	1,00	0,00	1,00	.	.	.	.	.	.	.	.	.	.	.	.	.
H217	2	.	4,50	4,50	9,00	2,25	2,25	4,50	.	.	.	.	.	.	.	.	.	.	.	.	.
H218	3	.	7,00	0,00	7,00	2,33	0,00	2,33	.	.	.	.	.	.	.	.	.	.	.	.	.
H219	4	.	8,00	0,00	8,00	2,00	0,00	2,00	.	.	.	.	.	.	.	.	.	.	.	.	.
H220	4	.	6,00	4,50	10,50	1,50	1,13	2,63	.	.	.	.	.	.	.	.	.	.	.	.	.
H221	5	.	11,00	3,00	14,00	2,20	0,60	2,80	.	.	.	.	.	.	.	.	.	.	.	.	.
H222	4	.	2,00	2,00	4,00	0,50	0,50	1,00	.	.	.	.	.	.	.	.	.	.	.	.	.
H223	5	.	12,00	4,50	16,50	2,40	0,90	3,30	.	.	.	.	.	.	.	.	.	.	.	.	.
H224	6	.	11,00	3,00	14,00	1,83	0,50	2,33	.	.	.	.	.	.	.	.	.	.	.	.	.
H225	5	.	10,00	3,00	13,00	2,00	0,60	2,60	.	.	.	.	.	.	.	.	.	.	.	.	.
H226	2	.	4,00	0,00	4,00	2,00	0,00	2,00	.	.	.	.	.	.	.	.	.	.	.	.	.
H227	5	.	10,00	0,00	10,00	2,00	0,00	2,00	.	.	.	.	.	.	.	.	.	.	.	.	.
H228	7	.	10,00	2,00	12,00	1,43	0,29	1,71	.	.	.	.	.	.	.	.	.	.	.	.	.

4. Yan'an Prefecture: Cropping and Explanatory Variables 2000-2002

	Potato	Maize	Millets	Soy Bean	Renzi	Rice	Vege-tables	Apple (flat)	Apple (Slope)	Econ. Forest	Apricot	Walnut	Peach	Alfalfa	Landscape Type	Precipi-tation	MAT	Inter-cropping	Agricult. Income	Proximity to Forest
H101		1,0	0,0	-	-	-	1,0	-	4,50	4,50	4,0	-	-	-	1	531	8,8	-	2768	-
H102			0,0	-	-	-	1,0	-	7,00	-	-	-	-	-	1	531	8,8	-	3800	-
H103		0,6	0,0	-	-	-	-	-	3,40	-	-	-	-	-	1	531	8,8	-	4080	-
H104	1,00	3,5	1,5	-	-	-	-	-	1,00	-	-	-	-	-	1	531	8,8	-	2000	-
H105	2,00	3,0	2,0	-	-	-	-	-	2,00	-	-	-	-	-	1	531	8,8	-	1876	-
H106	1,00	4,0	3,0	2,00	-	-	-	2,0	-	-	-	-	-	-	1	531	8,8	-	1617	-
H107	1,00	1,0	2,0	1,00	-	-	-	-	1,00	2,75	2,8	-	-	-	1	531	8,8	-	1526	-
H108	1,00	3,0	1,0	2,00	-	-	-	-	6,50	16,75	16,8	-	-	-	1	531	8,8	-	2074	-
H109	2,00		1,0	2,00	-	-	-	5,0	-	6,25	6,3	-	-	-	1	531	8,8	-	2051	-
H110	1,00	1,4	4,0	1,00	-	-	-	-	3,00	5,25	5,3	-	-	-	1	531	8,8	-	1070	-
H111		3,0	0,0	-	-	-	-	-	-	1,00	1,0	-	1,0	-	1	531	8,8	-	804	-
H112		1,0	0,0	-	-	-	2,0	-	-	1,00	1,0	-	-	-	1	531	8,8	-	4846	-
H113	1,00	1,0	0,0	5,00	-	-	-	-	4,50	2,75	2,8	-	-	-	1	531	8,8	-	2494	-
H114	2,00	1,5	2,0	-	-	-	-	-	0,40	2,87	2,9	2,9	-	-	1	531	8,8	-	1130	-
H115	2,50	2,0	0,0	-	-	-	-	-	2,50	4,25	4,3	-	-	-	1	531	8,8	-	1482	-
H116	2,00	2,0	2,4	2,00	-	-	1,5	-	2,00	1,00	1,0	-	-	-	1	531	8,8	-	6123	-
H117	2,10	1,0	0,5	0,40	-	-	-	-	1,00	2,75	2,8	-	-	-	1	531	8,8	-	3098	-
H118	1,00	2,0	2,0	1,00	-	-	-	-	-	3,60	3,6	-	3,6	3,2	1	531	8,8	-	1371	-
H119	1,00	3,0	3,0	5,00	-	-	-	3,0	-	9,50	4,8	-	-	-	1	531	8,8	-	3643	-
H120	3,00	1,0	1,0	-	-	-	2,0	-	1,00	-	-	-	-	-	1	531	8,8	-	5455	-
H121	4,00	5,5	2,0	-	-	-	-	-	2,00	-	3,3	-	2,5	-	1	553	9,4	-	3872	1,00
H122		0,9	0,0	-	-	-	-	-	4,50	11,83	11,8	-	-	11,8	1	553	9,4	-	324	1,00
H123	2,00	4,0	1,0	-	-	-	-	-	2,00	9,00	9,0	-	-	-	1	553	9,4	-	2165	1,00
H124	2,00	2,0	2,0	-	-	-	-	-	-	-	-	-	-	-	1	553	9,4	-	1682	1,00
H125	0,50	0,5	0,0	-	-	-	-	-	1,00	0,88	0,9	0,9	-	0,9	1	553	9,4	-	872	1,00
H126	2,00	2,0	0,0	-	-	-	2,4	-	1,00	4,75	4,8	4,8	4,8	-	1	553	9,4	-	8358	1,00
H127	1,00	1,2	0,0	-	-	-	1,0	-	5,50	1,80	1,8	1,8	1,8	-	1	553	9,4	-	1801	1,00
H128	1,00	3,4	0,6	-	-	-	1,7	-	20,00	-	-	-	-	-	1	553	9,4	-	4684	1,00
H129	1,00	2,5	2,0	-	-	-	-	-	8,50	-	-	-	-	-	1	553	9,4	-	1215	1,00
H130	0,25	2,0	0,8	-	-	-	-	-	17,00	-	-	-	-	-	1	553	9,4	-	1113	1,00
H131	0,80	1,0	0,0	-	-	-	-	-	10,00	-	-	-	-	-	1	553	9,4	-	2567	1,00
H132	0,50	0,8	1,5	-	-	-	-	-	20,00	-	-	-	-	-	1	553	9,4	-	941	1,00
H133	1,00	-	0,0	-	-	-	-	-	5,00	44,00	-	-	-	-	1	553	9,4	-	97	1,00
H134	3,00	-	0,0	4,00	-	-	-	-	-	8,75	-	8,8	-	-	1	553	9,4	-	1507	1,00
H135	2,50	-	3,0	1,00	-	-	-	-	10,00	-	-	-	-	-	1	553	9,4	-	1711	1,00
H136	2,00	3,0	0,0	-	2,5	-	-	-	-	-	-	-	-	10,0	1	553	9,4	-	4961	1,00
H137	0,50	2,0	0,0	-	4,8	-	-	-	-	-	-	-	-	8,5	1	553	9,4	-	3145	1,00
H138	0,50	3,2	0,0	-	1,2	-	-	-	-	-	-	-	-	12,0	1	553	9,4	-	1581	1,00
H139	1,00	2,0	0,0	-	4,0	-	-	-	-	-	-	-	-	14,0	1	553	9,4	-	2396	1,00
H140	-	2,4	0,0	-	4,0	-	-	-	-	-	-	-	-	-	1	553	9,4	-	1255	1,00
H141	-	2,3	0,0	-	3,3	4,00	-	-	-	-	-	-	-	-	1	553	9,4	-	3708	1,00
H142	-	4,0	0,0	-	6,0	4,00	-	-	-	15	-	-	-	-	1	553	9,4	-	5758	1,00
H143	1,00	2,0	0,0	-	4,0	0,75	-	-	-	5,5	-	-	-	-	1	553	9,4	-	2370	1,00
H144	-	3,0	0,0	-	3,0	2,00	-	-	-	-	-	-	-	-	1	553	9,4	-	3257	1,00

H145	-	4,0	0,0	-	3,0	1,00	-	-	-	-	-	-	-	-	1	553	9,4	-	2862	1,00
H146	1,00	-	1,0	-	6,0	2,00	-	-	-	-	-	-	-	-	1	553	9,4	-	4791	1,00
H147	-	2,0	0,0	-	6,0	3,00	-	-	-	2,0	-	-	-	-	1	553	9,4	-	8131	1,00
H148	-	2,0	0,0	-	4,0	0,80	-	-	-	-	-	-	-	-	1	553	9,4	-	3024	1,00
H149	-	4,0	0,0	-	2,2	1,20	-	-	-	-	-	-	-	-	1	553	9,4	-	3030	1,00
H150	-	3,0	0,0	-	1,0	1,00	-	-	-	-	-	-	-	-	1	553	9,4	-	1816	1,00
H151	-	-	0,0	-	-	-	-	3,0	-	-	37,0	-	-	-	1	561	8,6	-	0	-
H152	1,00	5,0	1,0	-	-	-	-	-	-	-	7,0	-	-	-	1	561	8,6	-	2200	-
H153	1,00	3,0	0,0	-	-	-	-	-	-	-	50,0	-	-	-	1	561	8,6	-	853	-
H154	-	3,0	0,0	-	-	-	-	-	-	-	10,0	-	-	-	1	561	8,6	-	2194	-
H155	-	5,0	0,0	-	-	-	-	-	-	-	-	-	-	-	1	561	8,6	-	2063	-
H156	-	-	0,0	3	-	-	-	0,3	-	-	-	-	-	-	1	561	8,6	-	186	-
H157	1,00	2,0	0,0	-	-	-	-	-	-	-	9,0	-	-	-	1	561	8,6	-	1745	-
H158	1,00	7,0	0,0	0,5	-	-	0,5	-	-	12,0	12,0	-	-	-	1	561	8,6	-	5532	-
H159	1,00	2,0	0,5	-	-	-	-	-	-	-	15,0	-	-	-	1	561	8,6	-	1680	-
H160	0,70	1,0	1,0	-	-	-	-	-	-	-	-	-	-	-	1	561	8,6	-	503	-
H161	1,50	7,0	0,0	0,5	-	-	-	-	-	-	-	-	-	12,0	1	561	8,6	-	1997	-
H162	0,60	2,0	0,0	-	-	-	-	-	-	3,5	-	-	-	3,5	1	561	8,6	-	404	-
H163	0,30	1,0	0,5	-	-	-	-	-	-	12,5	12,5	-	-	-	1	561	8,6	-	629	-
H164	0,30	0,2	0,5	-	-	-	-	-	-	3,0	-	-	-	-	1	561	8,6	-	294	-
H165	-	2,4	0,0	-	-	-	-	-	-	-	10,0	-	10,0	10,0	1	561	8,6	-	644	-
H167	0,50	1,0	0,2	-	-	-	-	-	-	15,5	-	-	-	-	1	561	8,6	-	717	-
H168	1,00	1,0	0,0	-	-	-	-	-	-	1,8	1,8	-	-	-	1	561	8,6	-	658	-
H169	-	3,6	3,0	-	-	-	-	-	-	-	-	-	-	-	1	561	8,6	-	914	-
H170	1,20	3,0	0,0	-	-	-	2,0	-	-	15,0	15,0	-	-	-	1	561	8,6	-	3337	-
H171	-	-	0,0	0,5	-	-	-	3,4	-	-	-	-	-	-	0	600	9,2	-	3217	-
H172	-	2,5	0,0	-	-	-	-	8,0	-	-	-	-	-	-	0	600	9,2	3,00	1434	-
H173	-	2,0	0,0	-	-	-	-	9,0	2,0	-	-	-	-	-	0	600	9,2	9,00	3913	-
H174	-	-	0,0	-	-	-	-	8,0	5,0	-	-	-	-	-	0	600	9,2	8,00	2105	-
H175	-	-	0,0	-	-	-	-	8,4	-	-	-	-	-	-	0	600	9,2	-	664	-
H176	-	-	0,0	-	-	-	-	8,0	-	2,0	-	-	-	-	0	600	9,2	8,00	4800	-
H177	-	-	0,0	-	-	-	-	2,6	3,0	-	-	-	-	-	0	600	9,2	2,60	5352	-
H178	-	-	0,0	-	-	-	-	7,8	-	5,0	-	-	-	-	0	600	9,2	-	2000	-
H179	-	0,5	0,0	-	-	-	-	7,7	-	10,0	-	-	-	-	0	600	9,2	7,70	1766	-
H180	-	-	0,0	-	-	-	-	8,0	-	-	-	-	-	-	0	600	9,2	8,00	14450	-
H181	-	-	0,0	-	-	-	-	12,8	-	-	-	-	-	-	0	600	9,2	12,80	12500	-
H182	-	-	0,0	-	-	-	-	9,0	-	-	-	-	-	-	0	600	9,2	9,00	4000	-
H183	-	1,0	1,0	-	-	-	-	7,5	-	8,0	-	-	-	-	0	600	9,2	7,50	17528	-
H184	-	3,5	0,0	-	-	-	-	7,0	-	-	-	-	-	-	0	600	9,2	7,00	2230	-
H185	-	-	0,0	-	-	-	-	9,0	-	3,3	-	-	-	-	0	600	9,2	8,00	2064	-
H186	-	-	0,0	-	-	-	-	7,5	5,5	-	-	-	-	-	0	600	9,2	13,00	8350	-
H187	-	2,5	0,0	-	-	-	-	3,4	3,8	3,8	-	-	-	-	0	600	9,2	3,40	923	-
H188	-	-	0,0	-	-	-	-	11,0	-	-	-	1,5	-	1,5	0	600	9,2	6,00	7981	-
H189	-	-	0,0	-	-	-	-	4,4	-	-	-	-	-	1,3	0	600	9,2	2,40	1588	-
H190	-	-	0,0	-	-	-	-	3,9	-	-	-	-	-	-	0	600	9,2	3,90	500	-
H191	-	-	0,0	-	-	-	-	4,0	3,0	-	-	-	-	-	0	621	9,2	-	18810	-
H192	-	-	0,0	-	-	-	-	7,0	-	-	-	-	-	-	0	621	9,2	-	17400	-
H193	-	-	0,0	-	-	-	-	4,5	-	-	-	-	-	-	0	621	9,2	1,00	7990	-
H194	-	-	0,3	-	-	-	-	6,0	-	-	-	-	-	-	0	621	9,2	-	6944	-
H195	-	-	0,0	-	-	-	-	6,7	-	-	-	-	-	-	0	621	9,2	-	7611	-

H196	-	-	0,0	-	-	-	-	4,0	-	-	-	-	-	-	0	621	9,2	-	1200	-
H197	-	-	1,0	1,0	-	-	-	6,5	-	-	-	-	-	-	0	621	9,2	-	7362	-
H198	-	-	0,0	-	-	-	-	10,0	-	-	-	-	-	-	0	621	9,2	3,70	6906	-
H199	-	-	0,0	-	-	-	-	7,5	-	-	-	-	-	-	0	621	9,2	0,70	5954	-
H200	-	-	0,0	-	-	-	-	6,0	-	-	-	-	-	-	0	621	9,2	-	3150	-
H201	-	-	0,0	-	-	-	-	5,0	-	-	-	-	-	-	0	621	9,2	0,10	9033	-
H202	-	-	0,0	-	-	-	-	10,0	-	-	-	-	-	-	0	621	9,2	-	10000	-
H203	0,30	-	0,0	-	-	-	-	5,0	-	-	-	-	-	-	0	621	9,2	-	9849	-
H204	-	-	0,0	-	-	-	-	5,0	-	-	-	-	-	-	0	621	9,2	-	9375	-
H205	-	-	0,0	-	-	-	-	10,0	-	-	-	-	-	-	0	621	9,2	-	22000	-
H206	-	-	0,0	-	-	-	-	13,0	-	-	-	-	-	-	0	621	9,2	-	31350	-
H207	-	-	0,0	-	-	-	-	10,0	-	-	-	-	-	-	0	621	9,2	-	11000	-
H208	-	-	0,0	-	-	-	-	9,0	-	-	-	-	-	-	0	621	9,2	4,00	11250	-
H209	-	-	0,0	-	-	-	-	10,0	-	-	-	-	-	-	0	621	9,2	-	6500	-
H210	-	-	0,0	-	-	-	-	8,0	-	-	-	-	-	-	0	621	9,2	-	7000	-
H211	-	-	0,0	0,0	-	-	-	-	3,0	5,0	0,0	0,0	0,0	0,0	1	531	8,8	-	2422	-
H212	4,00	-	6,0	0,0	-	-	-	-	6,0	18,0	0,0	0,0	0,0	0,0	1	531	8,8	-	4688	-
H213	3,00	0,8	4,0	2,0	-	-	-	-	2,8	11,0	0,0	0,0	0,0	0,0	1	531	8,8	-	3957	-
H214	7,50	-	4,0	9,0	-	-	-	-	7,0	25,0	0,0	0,0	0,0	0,0	1	531	8,8	-	11388	-
H215	3,00	2,0	2,0	1,0	-	-	-	-	0,0	12,0	0,0	0,0	0,0	0,0	1	531	8,8	-	2267	-
H216	2,00	-	2,0	0,0	-	-	-	-	3,0	8,0	0,0	0,0	0,0	0,0	1	531	8,8	-	2085	-
H217	-	-	2,0	1,0	-	-	-	-	0,0	0,0	0,0	0,0	0,0	0,0	1	531	8,8	-	2112	-
H218	3,00	-	4,0	2,0	-	-	-	-	4,0	13,0	0,0	0,0	0,0	0,0	1	531	8,8	-	1955	-
H219	3,00	-	1,0	3,0	-	-	-	-	5,4	39,0	0,0	0,0	0,0	0,0	1	531	8,8	-	2416	-
H220	3,00	2,5	1,5	0,0	-	-	-	-	6,0	12,0	0,0	0,0	0,0	0,0	1	531	8,8	-	3031	-
H221	6,00	2,5	2,5	2,5	-	-	-	-	10,0	24,0	0,0	0,0	0,0	0,0	1	531	8,8	-	6206	-
H222	2,00	2,5	2,0	0,0	-	-	-	-	6,0	10,0	0,0	0,0	0,0	0,0	1	531	8,8	-	2821	-
H223	7,00	-	4,5	2,0	-	-	-	-	3,0	17,0	0,0	0,0	0,0	0,0	1	531	8,8	-	3157	-
H224	5,00	3,0	6,0	0,0	-	-	-	-	3,0	21,0	0,0	0,0	0,0	0,0	1	531	8,8	-	3935	-
H226	6,00	-	6,0	1,0	-	-	-	-	3,0	16,0	0,0	0,0	0,0	0,0	1	531	8,8	-	2917	-
H227	-	2,5	2,0	1,0	-	-	-	-	3,0	7,0	0,0	0,0	0,0	0,0	1	531	8,8	-	2989	-
H228	-	2,5	0,0	2,0	-	-	-	-	2,0	11,0	0,0	0,0	0,0	0,0	1	531	8,8	-	4022	-
H229	2,50	-	4,0	2,0	-	-	-	-	3,0	15,0	0,0	0,0	0,0	0,0	1	531	8,8	-	3868	-

5. Analysis of Income Distribution between Townships

5.1 Parameters (Means) over Townships in Yan’an

Township Characteristic		Sum of Squares	DEGREE OF FREEDOM	MEAN SQUARE	F-RATIO	p-value
Income from Farming	Between Groups	963387303,227	5	192677460,645	11,852	,000*
	Within Groups	1674438367,838	103	16256683,183		
	Total	2637825671,064	108			
Income form Off-Farm Employment	Between Groups	85245148,011	5	17049029,602	2,067	,076
	Within Groups	849551956,925	103	8248077,252		
	Total	934797104,936	108			
Income from Livestock	Between Groups	61582906,642	5	12316581,328	12,190	,000*
	Within Groups	104066215,798	103	1010351,610		
	Total	165649122,440	108			
Firewood Consumption	Between Groups	861448,990	5	172289,798	6,221	,000*
	Within Groups	2852638,332	103	27695,518		
	Total	3714087,321	108			
Fertilizer/Pesticide Use	Between Groups	34206285,782	5	6841257,156	17,713	,000*
	Within Groups	39395790,468	102	386233,240		
	Total	73602076,250	107			

*: indicates significance at the 5% error level

5.2 Bonferroni Multiple Comparisons

	Townships of Yan’an					
	1	**3**	**4**	**5**	**6**	**7**
	Yanhewan (Baota)	*Liu Linzhen (Baota)*	*Nan Niwan (Baota)*	*Laoshan (Ganquan)*	*Jiao Dao (Fuxian)*	*Jing Zhao (Luochaun)*
Income from Farming	7	7	7	7	7	1,3,4,5,6
Income form Off-Farm Employment	No significant differences between townships					
Income from Livestock	5	5	6,7	1,3,6,7	4,5	4,5
Firewood Consumption	7	-	-	6,7	5	1,5
Fertilizer/Pesticide Use	7	7	7	6,7	5,7	1,3,4,5,6

The mean of the parameter (averaged over the respective community) differs significantly ($p < 0.05$) from the parameters means of the indicated communities.

Curriculum Vitae

ULRICH SCHMITT

Date of Birth:	April 26, 1971
Gender:	Male
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Education

1/00-3/03	Research Associate/Doctoral Student at the Department of Ecology (Vegeta tion Science) Technische Universität München, Germany
1/01-11/02	Postgraduate Diploma in Economics at the University of London, UK
10/91-3/96	MSc. in Forestry (Diplom Forstwirt Univ.) at the Ludwig-Maximilians-Universität München, Germany

Professional Experience

Since 09/03	The World Bank, Washington DC, U.S.A., Environment and Rural Development Department
6/02-03/03	Consultant, Chinese Centre for Agricultural Policy (CCAP)/World Bank, P.R. China
3/02- 10/02	Team Leader - Deutsche Gesellschaft für Technische Zusammenarbeit – GTZ Beijing, “Monitoring/MIS – Three North Shelterbelt Program in China”
9/99-11/00	Project Assistant - Deutsche Gesellschaft für Technische Zusammenarbeit – GTZ Beijing “Monitoring/MIS – Three North Shelterbelt Program in China”
9/97-7/99	Program Associate, World Wide Fund for Nature – China Program Office, P.R. China

Others

8/96-6/98	Full-time scholarship “Language and Practical Work in the P.R. China” – German Academic Exchange Service (DAAD)
9/96-7/97	Chinese language studies - Beijing Normal University, P.R. China