Waldvegetation und Standort
Grundlage für eine standortsangepasste Baumartenwahl in naturnahen Wäldern der Montanstufe im westlichen Qinling Gebirge, Gansu Provinz, China

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Inhaltsverzeichnis

1 Einleitung

1.1 Bewirtschaftung von Wäldern in China und Nachhaltigkeit

In China bedecken Wälder rund 195 Millionen ha bzw. 20 % der Gesamtfläche nach Angaben der 7. Nationalen Waldinventur von 2004-2008 (PETRY & ZHANG 2009, SFA 2010a). In der 5. Nationalen Waldinventur von 1994-1998 waren sie sogar nur 17 % (SFA 2000a). Die Waldfläche wurde in den letzten Jahren durch großflächige Aufforstungsprojekte vergrößert, doch der durchschnittliche Holzvorrat in China beträgt lediglich 85 m^3/ha (PETRY & ZHANG 2009, SFA 2010a), während er in Deutschland bei 320 m^3/ha liegt (BMELV 2002). Die bewaldete Fläche pro Kopf in China beträgt 0,15 ha, dieser Wert entspricht den Verhältnissen in Deutschland, ist jedoch viel geringer als der weltweite Durchschnitt von 0,6 ha pro Kopf. Der durchschnittliche Holzvorrat pro Kopf in China liegt nur bei ca. 10 m^3, d.h. viel geringer als der weltweite Wert von 78 m^3 und der in Deutschland von 41 m^3, somit ist er einer der niedrigsten Vorräte der Welt (BMELV 2002, ZHU & KANG 2010, FAO 2011).

In den letzten Jahren konnte eine fortschreitende Waldzerstörung beobachtet werden, die einen Verlust der Biodiversität durch einseitiges Interesse an kurzzeitig maximalem Profit und wirtschaftlichem Wachstum zur Folge hat. Die chinesischen Waldökosysteme erwiesen sich als empfindlich und instabil (YIN 1998, HE & JIAO 2000, SHI et al. 2006). Diese wirtschaftliche Entwicklung dezimierte die natürlichen Waldflächen, verursachte eine reduzierte Bodenfruchtbarkeit sowie eine Übernutzung der Wälder und zerstörte die Lebensräume für viele Arten. Die lokalen hydrologischen und klimatischen Bedingungen wurden verändert, was wiederum zu immer häufigeren Naturkatastrophen führte (YIN 1998, STUDLEY 1999, HE & JIAO 2000, LANG 2002, NDRC 2007).

Wegen der Überschwemmungs-katastrophen in den Wassereinzugsgebieten der Flüsse Yangtze, Songhua und Nenjiang im Jahr 1998 hat die chinesische Regierung entschieden, sich diesem bedrohlichen Umweltproblem mit Nachdruck zu widmen: Sechs prestigeträchtige Nationalprogramme zur Wiederherstellung der Waldökosysteme, vor allem das „Natural Forest Protection Program“ (NFPP) und das „Conversion of Cropland to Forests Program“ (CCFP), wurden gestartet bzw. durchgeführt. Das NFPP-Programm zum Schutz der „natürlichen Wälder“ kam besonders in den Wassereinzugsgebieten des Yangtze, des Gelben Flusses und des

Qinling Gebirges zum Tragen, sowie auch in den wichtigen staatlichen Waldgebieten in Nordostchina und der Inneren Mongolei (SFA 2000b, 2000c, 2010c, 2010d, NDRC 2007).

1.2 Naturnaher Wirtschaftswald und seine Bedeutung

Schätzungsweise bestehen nur 2 % der gesamten Waldfläche Chinas aus Naturwald (GREENPEACE 2006). Der Schutz und die nachhaltige Bewirtschaftung der naturnahen Wirtschaftswälder sind wichtig. Wenn man den gesamten chinesischen Wald betrachtet, ist der größte Prozentsatz davon Sekundärwald. Nach Auskunft der „Chinese State Forestry Administration“ (SFA 2010a) beträgt die gesamte Waldfläche ca. 195 Millionen ha, zwei Drittel davon Wälder als „natürliche Wälder“ bezeichnet, und ein Drittel sind Plantagen. Die „natürlichen Wälder“ sind nach Definition der chinesischen National-Waldinventur durch natürliche Verjüngung entstandene Wälder. Sie sind größtenteils nicht gepflegte, aber mit unterschiedlichen Intensitäten genutzte naturnahe Wirtschaftswälder oder degenerierte Wälder.

1.2.1 Funktion der naturnahen Wirtschaftswälder

Im Gegensatz zu Monokulturen sind die naturnahen Wirtschaftswälder zumeist ein Mischbestand aus Bäumen unterschiedlichen Alters. Diese Struktur begünstigt einheimische Baumarten mit natürlicher Verjüngung (HE et al. 2003, C.-M. YUAN et al. 2009, ZHU et al. 2009, X.-Z. LIU et al. 2010).

Die naturnahen Wirtschaftswälder stellen einen wichtige Grundlage für den Schutz von Biodiversität (KWOK & CORLETT 2000, GAO et al. 2001, ZHOU et al. 2005, GAO & ZHANG 2006), von Gewässern und zur Vorsorge gegen Erosion (FU et al. 2009, BRUELHEIDE et al. 2010, HOU et al. 2010, HUANG et al. 2010, WANG et al. 2012) dar. Deswegen sind auch die naturnahen Wirtschaftswälder in den Wassereinzugsgebieten des Yangtze und des Gelben Flusses (einschließlich das Qinling Gebirge, **Fig. 2.1**), die etwa 33 Mio. ha ausmachen (SFA 2011), wichtig in ihrer Schutzfunktion und zur Erhaltung der Wälder, aber auch für die Wirtschaftlichkeit der lokalen Forstämter, insbesondere in Bezug auf die Holzproduktion (YIN & LI 2001).

1.2.2 Herausforderung für die chinesische Forstwissenschaft

Seit 1998 wurde in 17 Provinzen der VR China der Holzeinschlag in „natürlichen Wäldern“ gestoppt. Die Forstpolitik, Forstwirtschaft und Forstverwaltung des Landes haben sich seitdem stark verändert (LI 2004, C. LIU et al. 2010, DONG et al. 2010, THE WORLD BANK 2010, MULLAN et al. 2011, YU et al. 2011).

Es ist eine große Herausforderung für die chinesische Forstwissenschaft, Konzepte für den Schutz und das nachhaltige Management der naturnahen Wirtschaftswälder zu entwickeln. Dies betrifft das Waldökosystem-Management, die Pflege und die Regeneration degradierter Bestände, den Schutz und das nachhaltige Management der allgemeinen Waldressourcen, den Aufbau eines entsprechenden Monitoring- und Evaluations-Systems sowie die Priorisierung von Waldschutzgebieten (LU & ZHANG 2003, SFA 2006).

Bis heute fehlen jedoch wichtige forstwissenschaftliche Grundlagen für den Schutz und das nachhaltige Management (SFA 2006). Beispielsweise sind Untersuchungen auf standörtlicher Grundlage über Struktur, Funktion und Dynamik der Waldökosysteme noch ausgesprochen selten. Zur Durchführung des Waldschutzes und des nachhaltigen Forstmanagements fehlt in China eine Kartierung von Standort und potentiell natürlicher Vegetation, eine grundlegende Inventur und ein Aufnahmesystem der Waldressourcen wie auch eine aktuelle Information über den Zustand und die Veränderung der Waldgesellschaften, der Diversität und der Walddynamik (SFA 2002, 2010b).

1.2.3 Internationale Zusammenarbeit

Die Einführung der gesamten Schutzmaßnahmen für die naturnahen Wirtschaftswälder in China führt zu neuen Problemen. Der Holzbedarf wächst immer stärker, so dass der Druck auf den internationalen Holzmarkt bzw. auf viele Naturwälder in der übrigen Welt steigt, z.B. durch die chinesische Nachfrage nach Holz aus Russland, Brasilien und Indonesien (TOYNE et al. 2002, SHEN et al. 2006, UN 2008, YIN & YIN 2010, YIN et al. 2010, SFA 2011). Der Schwerpunkt der internationalen Zusammenarbeit mit China wurde daher in den letzten Jahren auf den Schwerpunkt Schutz und nachhaltiges Management der naturnahen Wirtschaftswälder gelegt (ROZELLE et al. 2000, MANN 2012).

1.3 GTZ-Projekt „Protection and sustainable management for forests in Western China”

Von 2005 bis 2007 führte die Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) ein praxisorientiertes Projekt unter dem Titel „Protection and sustainable management for forests in Western China“ durch. Im Rahmen der Zusammenarbeit zwischen der GTZ und der Albert-Ludwigs-Universität Freiburg sollte ein waldbauliches Konzept für eine naturnahe Waldwirtschaft der öffentlichen Wälder in Westchina auf der Grundlage der technischen, ökonomischen, sozialen und Umweltbedingungen vor Ort entwickelt werden. Die Problematik bestand in der Prüfung der Möglichkeiten für eine nachhaltige Bewirtschaftung von übernutzten und naturnahen Wirtschaftswäldern als Alternative zu der derzeitigen chinesischen Politik bezüglich des Schutzes von „natürlichen Wäldern“ und der Förderung zur Aufforstung. Das gesamte Projekt wurde in Zusammenarbeit mit dem Xiaolongshan-Forstamt der Gansu-Provinz, welches in das nationale Naturwaldschutzprogramm einbezogen ist, durchgeführt. Die Grundidee dieses Projektes war, eine nachhaltige Waldwirtschaftsstrategie von Deutschland nach China zu übertragen und den chinesischen Verhältnissen anzupassen. Bald wurde deutlich, dass bis dahin die Grundlagen über den Zustand und die Veränderung der Waldgesellschaften, der Diversität und der Walddynamik in China noch nicht bekannt waren. So fehlten z.B. Waldstandortkartierungen, Kenntnisse über die Standortsansprüche der Baumarten und verlässliche Informationen durch permanente Inventurmethoden über Zustand und Veränderung der Waldgesellschaften.

1.4 Rahmenbedingungen

Die Beurteilung der Nachhaltigkeit erfolgt auf Grundlage der von der Montreal Process Working Group verabschiedeten Kriterien und Indikatoren für die nachhaltige Bewirtschaftung von Wäldern in Argentinien, Australien, Kanada, Chile, China, Japan, Korea, Mexico, Neuseeland, der Russischen Föderation, der USA und Uruguay, in denen 90 % der temperierten und borealen Wälder weltweit repräsentiert sind (MONTREAL PROCESS WORKING GROUP 1995) (**Tab. 1.1**). Die Beurteilung fußt ferner auf den 1998 von der International Tropical Timber Organisation (ITTO) in Yokohama entwickelten Kriterien und Indikatoren für die nachhaltige Bewirtschaftung von tropischen Wäldern in Entwicklungsländern, einschließlich Teilen von China (ITTO 1998) (**Tab. 1.1**).

Tab. 1.1: Kriterien des Montreal-Prozesses (Montreal Process Working Group 1995) und der International Tropical Timber Organisation (ITTO 1998) zur nachhaltigen Waldbewirtschaftung, mit unterlicher Priorität (vereinfachte Darstellung).

	KRITERIEN	
	Montreal-Prozesses	**ITTO**
Kriterium 1	Conservation of biological diversity	Enabling conditions for SFM
Kriterium 2	Maintenance of the productive capacity of forest ecosystems	Forest resource security
Kriterium 3	Maintenance of forest ecosystem health and vitality	Forest ecosystem health and condition
Kriterium 4	Conservation and maintenance of soil and water resources	Flow of forest produce
Kriterium 5	Maintenance of forest contribution to global carbon cycles	Biological diversity
Kriterium 6	Maintenance and enhancement of long-term multiple social and economic benefits to meet the needs of societies	Soil and water
Kriterium 7	Legal, institutional and economic framework for forest conservation and sustainable management	Economic, social and cultural aspects

In China fehlen Informationen über grundlegende waldbauliche und naturschutzliche Aspekte für eine diesen Kriterien entsprechenden Beurteilung der nachhaltigen Bewirtschaftung von naturnahen Wirtschaftswäldern. Im Einzelnen liegen keine konkreten Ergebnisse darüber vor, wie naturnahe Waldgesellschaften, die von den örtlichen Standortverhältnissen abhängen, nach vegetations- und standortkundlichen Kriterien differenziert werden sollen. Es liegen ebenso wenig konkrete Ergebnisse über die standörtliche Ausgangssituation der vielfältigen Arten naturnaher Bestände der seit 1998 geschützten naturnahen Wirtschaftswälder vor.

Außerdem gibt es keine konkreten Richtlinien darüber, wie Waldstandorte bzgl. ihrer Eignung und Wuchsdynamik der Baumarten zu erfassen oder zu beschreiben sind. Weiterhin fehlen Informationen darüber, ob es ausreichende Verjüngung der naturnahen Wirtschaftswälder gibt, im Zuge der üblichen und regelmäßig durchgeführten Hiebverfahren der Forstämter.

Es ist schließlich ungewiss, welche Beziehung zwischen den Lichtverhältnissen und der natürlichen Verjüngung der wichtige Baumgattung Eiche (*Quercus* sp.) hinsichtlich eines nachhaltigen waldbaulichen Konzeptes zu erwarten ist.

1.5 Ziel und Fragestellung der Forschung

In der vorliegenden Untersuchung steht im Zentrum die Fragestellung, wie können Arten der Vegetation, Waldtypen und Verjüngung in Relation zu den Standorten in naturnahen Wirtschaftswäldern gesetzt werden. Die waldbaulichen Maßnahmen sollten auf standörtlichen Grundlagen beruhen und Elemente der natürlichen Dynamik integrieren.

Drei Fragestellungen lassen sich den entsprechenden Themenbereichen zuordnen:

1. **„Vegetation und Standort"**
   Welche Waldgesellschaften der naturnahen Wirtschaftswälder lassen sich abgrenzen, welche Standortsfaktoren sind für sie jeweils charakteristisch?
2. **„Bestandestruktur"**
   Welche Bestandestrukturen, Naturverjüngung von welchen Baumarten, und welche Bestandesdynamiken kommen vor?
3. **„Naturverjüngung"**
   Wie beeinflussen Lichtverhältnisse die Naturverjüngung von Eichen?

Die Ergebnisse dieser Fallstudie sollen als Grundlage für eine naturnahe Waldbewirtschaftung dienen und ein Bespiel bieten, inwieweit standortangepasste Baumartenwahl möglich ist.

1.6 Untersuchungsgebiet

1.6.1 Die eichen-dominierten naturnahen Wirtschaftswälder im Xiaolongshan-Forstamt im westlichen Qinling Gebirge

Das Xiaolongshan-Forstamt liegt im westlichen Qinling-Gebirge, im Südosten der Gansu-Provinz (104°22'-106°43' O, 33°30'-34°49' N) in einer Höhenlage zwischen 850-3330 m (**Fig. 2.1**). Die meisten Wälder sind auf den Höhenlagen zwischen 1000-2300 m zu finden. Die Höhenunterschiede zwischen Tal und Bergrücken liegen zwischen 500-900 m. Die Gesamtfläche beträgt 0,8 Mio. ha auf steilen bis sehr steilen Hanglagen (**Tab. 1.2**), von denen 0,7 Mio. ha Forstland sind. 60 % des Forstlands sind die bestockte Waldfläche. 28 % der Gesamtfläche liegen im Wassereinzugsgebiet des Gelben Flusses (*Huang He*) und 72 % im Wassereinzugsgebiet des Yangtze Flusses (*Chang Jiang*). Die

Walderschließung des Forstamts beträgt durchschnittlich 4,4 m Forstweg/ha (FOREST BUREAU OF XIAOLONGSHAN 2006). Seit 1998 ist das Gebiet Bestandesteil des „Natural Forest Protection Program" (NFPP) (FOREST BUREAU OF XIAOLONGSHAN 2006, MA et al. 2007).

Tab. 1.2: Flächenanteile an der Gesamtfläche des Xiaolongshan-Forstamtes nach den Hangneigungsklassen (Forest Bureau of Xiaolongshan 1982a)

	Hangneigung in °			
	<25	**26-35**	**36-45**	**>46**
Flächenanteil (%)	<0,5	18	62	19

1.6.2 Gegenwärtige waldbauliche Ausgangslage

Seit den 1970er Jahren werden für die naturnahen Wirtschaftswälder des Xiaolongshan-Forstamtes genauere Vorschriften dokumentiert für Hiebmaßnahmen und sogar für Kahlschlag. **Tab. 1.3** zeigt den Standard der Hiebssatzbestimmung der Forstverwaltung in der Gansu-Provinz (FOREST DEPARTMENT OF PROVINCE OF GANSU 1976), der auch im Xiaolongshan-Forstamt in den 1970er Jahren verwendet wurde. In den 1980er Jahren erfolgte kleinflächiger Kahlschlag (5-10 ha) in den Beständen, in denen die Hangneigung <35° lag, um diese Bestände von einem vorratsarmen, degradierten naturnahen Wirtschaftswald (Deckungsgrad der Baumschicht <30 %) in einen Plantagenwald mit Nadelholz umzuwandeln. Seit den 1980er Jahren wurden bei einer Hangneigung >45° im Xiaolongshan-Forstamt keine Hiebsmaßnahmen mehr durchgeführt (FOREST BUREAU OF XIAOLONGSHAN 1982b).

Tab. 1.3: Hiebssatzbestimmung für die aus natürlicher Verjüngung entstandenen naturnahen Wirtschaftswälder nach Forstämtern der Gansu-Provinz(FOREST DEPARTMENT OF PROVINCE OF GANSU 1976). * Umtriebsperiode: wiederholter Einschlag in Jahre.

		Hangneigung	
		<35°	**>35°**
Hiebssatz des Ausgangsvorrates (%)		40-50 (max. 60)	30-40
Deckungsgrad nach dem Hieb (%)		>40	>50
Bestandesdichte nach dem Hieb (Bäume/ha, BHD ≤8 cm)		300	300
Umtriebsperiode* (Jahre)		>10	>10
Endnutzungsalter (Jahre)	**Eiche**	81-100	
	Andere Laubbaumarten	61-70	
	Kiefer	61-70	

Seit 1998 wurde dem Xiaolongshan-Forstamt der Holzeinschlag in „natürlichen Wäldern" gestoppt (keine Hiebsmaßnahmen mehr durchgeführt) und nur die kleinflächiger Kahlschlag im NFPP-Gebiet nur in Plantagen mit Hangneigung <35° (6 % der Gesamtwaldfläche des Forstamts) erlaubt (FOREST BUREAU OF XIAOLONGSHAN 2006). Die jeweiligen Anteile der Gesamtfläche im Xiaolongshan-Forstamt sind abhängig von den Hangneigungsklassen aufgelistet in **Tab. 1.2**. Die Fläche der aus natürlicher Verjüngung entstandenen naturnahen Wirtschaftswälder im Xiaolongshan-Forstamt umfasst 0,3 Mio. ha (71 % der gesamten Waldfläche), davon sind 58 % Eichenwälder mit 0,18 Mio. ha (FOREST BUREAU OF XIAOLONGSHAN 2006).

Tab. 1.4: Flächenanteil und durchschnittlicher Vorrat der aus natürlicher Verjüngung entstandenen naturnahen Wirtschaftswälder nach Bestandesaltersklassen (Forest Bureau of Xiaolongshan 2006)

	Jungbestand	Mittelaltbestand I	Mittelaltbestand II	Altbestand
Flächenanteil (%)	15	68	13	4
Vorrat (m^3/ha)	51	88	96	109-118

Tab. 1.5: Bestandesalterklassen (Jahre) der aus natürlicher Verjüngung entstandenen naturnahen Wirtschaftswälder, unterschieden nach Hauptbaumarten oder Baumarten-gruppen (Forest Bureau of Xiaolongshan 1982a)

	Jungbestand	Mittelaltbestand I	Mittelaltbestand II	Altbestand
Pappelwald	1-10	11-20	21-30	>31
Kiefernwald	1-30	31-50	51-60	>61
Eichenwald	1-40	41-60	61-80	>81
Fichten-/Tannenwald	1-60	60-100	101-120	>121

Die Altersstruktur der naturnahen Wirtschaftswälder nach Bestandesaltersklassen sind 15 % Jungbestand, 68 % Mittelaltbestand I, 13 % Mittelaltbestand II und 4 % Altbestand (FOREST BUREAU OF XIAOLONGSHAN 2006) **(Tab. 1.4),** d. h. nur ein ganz kleiner Anteil an Altbestand mit einem höheren Bestandesvorrat ist übriggeblieben. Der größte Anteil besteht aus Mittelaltbestand I bzw. Mittelaltbestand II mit niedrigem Bestandesvorrat, die jedoch ein großes Potential für das Bewirtschaften bedeuten. Die Bestandesaltersklassen sind unterschiedlich, je nach Hauptbaumarten- oder Baumarten-gruppe, z.B. bei Pappelwald <10 Jahre, bei Kiefernwald <30 Jahre, bei Eichenwald <40 Jahre (vgl. **Tab. 1.5**).

Eichen sind als dominante Baumgattung in den naturnahen Wirtschaftswäldern im Qinling-Gebirge in Höhen von 1400-2100 m weit verbreitet. Die Eichenwälder haben ein erhebliches Holznutzungspotenzial (**Tab. 1.6**) und eine hohe Bedeutung für den Natur- und Wasserschutz, insbesondere bei Flächen mit Hangneigung >35°(**Tab. 1.2**).

Tab. 1.6: Flächenanteile nach Baumarten und Baumartengruppen im Xiaolongshan-Forstamt (Forest Bureau of Xiaolongshan 2006)

	Waldfläche ha	**Anteil** %
Gesamte Waldfläche	439.214	100
Eiche (*Quercus*)	183.106	42
Edellaubbaum (hardwood)	78.839	18
Betula albo-sinensis	12.463	3
Weichlaubholzbäume	1.442	<0.5
Laubbaum-Mischwald	50.357	11
Pinus armandii	11.984	3
Pinus tabulaeformis	47.947	11
***Larix kaempferi* (syn. *L. leptolepis*)**	22.567	5
Pinus bungeana	1.631	<0.5
Platycladus orientalis	3.105	1
Picea* und *Abies	2.848	1
Nadelbaum-Mischwald	9.732	2
Nadel- Laubbaum-Mischwald	1.704	<0.5
Korkeiche *Quercus variabilis*	10.792	2
Betula platyphylla	77	<0.1
Pappel *Populus*	395	<0.1
Sonstige	225	<0.1

1.6.3 Kriterien zur Auswahl des Untersuchungsgebiets

Das Untersuchungsgebiet sollte hinsichtlich Geologie und Klima für die Gesamtsituation im westlichen Qinling-Gebirge als möglichst repräsentativ betrachtet werden können.

Für die Eignung als Untersuchungsfläche waren die folgenden Voraussetzungen wesentlich: Die Bestände sollten möglichst:

- naturnah sein (letzter Hieb mit Einzelbaumnutzung vor ca. 40 Jahren);
- topographisch vielfältig sein, d.h. eine große Spanne an Höhenlagen, vielfältige Reliefs und Hangneigungen abdecken;
- innerhalb eines Wassereinzugsgebietes liegen, und die Möglichkeit bieten, großflächige und dauerhafte Versuchsflächen einzurichten.

Die Bestände sollten vornehmlich durch Eichen geprägt sein und auch die anderen natürlich vorkommenden Mischbaumarten enthalten. Die Untersuchungsfläche sollte außerdem im Bereich einer kooperationsbereiten Forststation liegen.

Durch die Unterstützung der staatlichen Waldarbeiter und Forstbeamten wurde die Durchführung der Untersuchungen vereinfacht und eine Einbeziehung der Untersuchungsbestände in ein dauerhaftes Inventurflächennetzwerk des Xiaolongshan-Forstamtes und der ökologischen Monitoring-Station der Gansu-Provinz ermöglicht.

2 Vegetation of the deciduous mixed oak forest in the montane zone of the Western Qinling Mountains, China

The deciduous mixed oak forest in the montane zone (1900-2200m) of the Western Qinling Mountains (Photography: ALBERT REIF, 2008)

2.1 Introduction

The Qinling Mountains (32°5'-34°45'N, 104°30'-115°52'E; altitude from 700 m to 3200 m, the highest peak is Taibai Mountain 3767 m, **Fig. 2.1**) are an east-west stretching mountain range, which is also a biogeographic boundary separating the subtropical from warm-temperate zone in Eastern China (WU 1980). The Qinling Mts. separate the "East China deciduous broad-leaved forest sub-biodomain" from the "East China evergreen broad-leaved forest sub-biodomain" and the "Loess Plateau warm-temperate forest and shrub steppe biome", and are one of the biodiversity hotspots in China (NI et al. 1998). The vascular flora comprises about 3124 species in 158 families and 892 genera, among them 1428 species are endemic species of China, and 192 species are endemic species of Qinling Mts. (YING 1994).

The plant-geographical particular importance of the Qinling Mts. as natural separation beween two climate zones and watershed systems of the two biggest rivers was already compared in importance with the Alps in Europe by FERDINAND VON RICHTHOFEN (cited by DIELS 1901).

The Qinling Mts. are the major watershed of the upper Yangtze River (*Chang Jiang*) and the upper- and mid part of Yellow River (*Huang He*). Therefore the forests of that region are protected and were/are included by the State Forestry Administration of China in China's Natural Forest Protection Program (NFPP) since 1998 (SFA 2000b).

The extended forest area of the Western Qinling Mts. is most important for biodiversity conservation. In its neighbourhood there is the Loess Plateau, which has been exploited economically since ages. Exploitation also is a great risk for the seminatural forests.

To understand the forest vegetation in the montane zone, we selected in cooperation with the German GTZ programme "Forest Protection and Sustainable Management in Western China" a representative study area with still near-natural forests on the complete range of elevations and topography in the Forest Bureau of Xiaolongshan in the Western Qinling Mts.

The Forest Bureau of Xiaolongshan was and still is in charge of protection and management of these forests. This study tried to assist in getting ecological knowledge for these ecosystems.

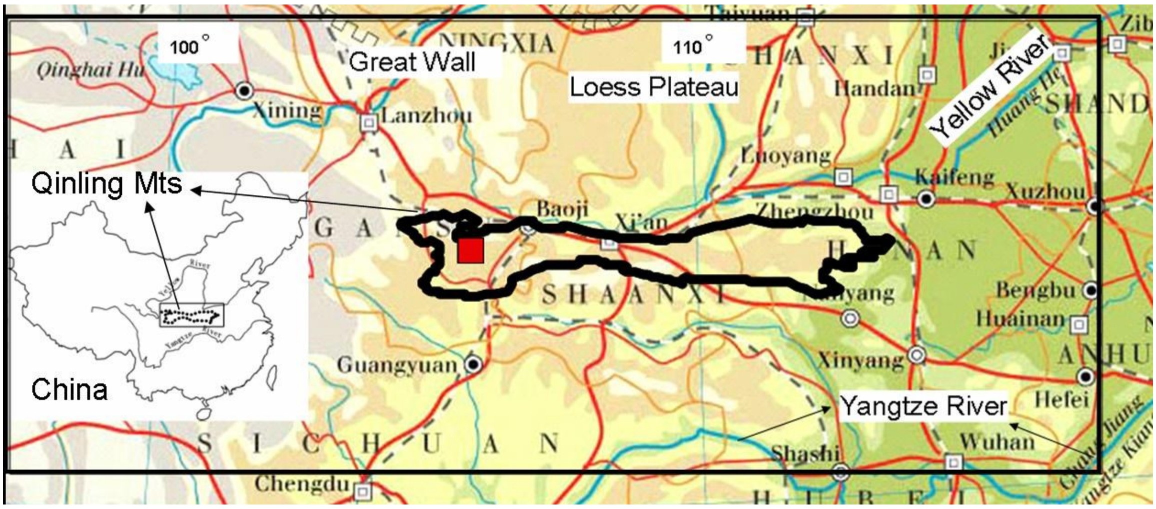


Fig. 2.1: Qinling Mountains, China (32°5'-34°45'N, 104°30'-115°52'E) (http://mappery.com/maps/China-Topographic-Map.jpg). The red mark is study area (34°21'30"-34°23' N, 106°21'50"-106°21'50" E).

The Western Part of Qinling Mts. is the highest part of whole range, with an altitude of peaks between 2000 and 3000 m (YING et al. 1990). The warm-temperate climate is related with an average yearly precipitation ranging between 700 and 1000 mm at altitudes between 1300 and 2200 m. Therefore an increase of the yearly precipitation with elevation of 12 up to 31 mm/100 m can be calculated (LIU 1997). Depending from elevation there is an average yearly temperature from 7 to 12ºC, with 170 to 220 frost-free days. The growing season (days with >5 degrees C) from April to October is warm and humid due to southwesterly and southeasterly monsoon winds from the Indian and the Pacific Ocean (LIU et al. 2003). 55 % of the annual precipitation occurs between Juli and September (LIU 1997). During winter, the East Asian winter monsoon brings dry cold air from north and northwest continental Mongol-Siberian high pressure (FANG et al. 2008). This means, the warm rainy summers are opposed to cold winters with little rain or snow, causing severe water deficit during spring (**Fig. 2.3**).

The potential natural zonal vegetation consists of mixed forests, dominated by deciduous oak species (*Quercus spp.*). The most important forest tree species have different elevational main distribution (*Quercus variabilis* main distribution 400-1600 m; *Quercus dentata* 800-1300 m; *Quercus aliena* var. *acutiserrata* 1400-1800 m; *Quercus mongolica* (syn. *Q. liaotungensis*) 1800-2200 m; *Betula albosinensis* 2000-2500 m; *Abies fargesii* 2600-3100 m; *Larix chinensis* 3100-3400 m) (WU 1980, THE COMPILED COMMISSION OF FORESTS OF GANSU 1998).

The study region itself is dominated by the ***Quercus aliena* var. *acutiserrata*-** and the ***Quercus mongolica*- forest** zone. Beneath the oak species, it is dominated by the tree species *Betula chinensis*, *Pinus armandii*, *Carpinus turczaninowii*, *Tilia oliveri*, *Tilia paucicostata* var. *dictyoneura* (syn. *Tilia dictyoneura*), *Sorbus folgneri*, *Sorbus alnifolia*, and *Carpinus cordata* (WU 1980). In some stands of earlier phases of succession, the pioneer tree species *Populus davidiana* and *Betula platyphylla* occur. Rare, protected woody species are *Euptelea pleiosperma*, *Paeonia suffruticosa* var. *papaveracea*, *Cephalotaxus sinensis*, and herb species like *Astragalus mongolicus* (syn. *Astragalus membranaceus*).

The existing syntaxonomic system commonly used in China is a **dominance type classification** system, with emphasis on the **dominant species** (WU 1980) excluding the large number of infrequent species from the classification. Until now, there are only few reliable and complete vegetation field inventories. Until recently, diagnostic species from complete species lists could not be extracted from the data sets and used for floristic classification (SONG 2001, 2011).

The vegetation of Central China was described in general by WU (1980), and the forest vegetation of the Qinling Mts. in the part of Gansu province by THE COMPILED COMMISSION OF FORESTS OF GANSU (1998). Studies of the Qinling Mts in general include investigations, e.g. on the flora, on biogeographic taxa; on vegetation and vegetation history of the central and eastern part of Qinling Mts (YING et al. 1990, YING 1994); on the altitudinal patterns of plant species diversity (TANG & KE 2004, TANG et al. 2004); on forest communities formed by the **dominant species** *Quercus aliena* var. *acutiserrata* (ZHU 1983, WANG 1989, ZHAO et al. 2003), *Quercus liaotungensis* (syn. *Q. mongolica*) (ZHU 1982); or on ecological species groups (KANG 1993).

No phytosociological studies investigated the forest vegetation in the ***Quercus aliena* var. *acutiserrata*-** and the ***Quercus mongolica*-forest zone** in the Western Qinling Mts. The existing studies are based on the dominant species using importance values of tree species (WANG 1989, JU & JU 1994, ZHAO et al. 2003a, 2003b); on descriptions of species diversity and structure of forest stands (ZHAO et al. 2008, ZHANG et al. 2010); on tree species diversity (SUO et al. 2004, JU et al. 2011); and on assessments of the niches of the 10 main tree species (CAO et al. 2006).

Recently, phytosociological classifications, using the basic principles of systematic field sampling and applying the BRAUN-BLANQUET syntaxonomy, were published from forests of the subtropical and tropical zone, e.g. JIN & OU (1998), WANG et al. (2006); from vegetation of the cold desert climate zone of semi-deserts and deserts in Inner Mongolia (KÜRSCHNER 2004); the cold-arid desert of the Xinjiang Province (THEVS et al. 2008); the cold temperate deciduous forests in northeast China (KRESTOV et al. 2006), *Pinus armandii* communities in Qinling Mts (LAN et al. 2006). The most related work to this study has analyzed the deciduous *Quercus* communities in the warm-temperate zone of China (TANG et al. 2009), based on 80 relevés coming from a very large region from 32°30' to 42°30'N, and 103°30' to 124°10'E, but excluding the forests of the Qinling Mts. So far there had been no other phytosociological vegetation study with BRAUN-BANQUET approach in this part of the Western Qinling Mts.

Therefore the aims of this study were **a**) to classify the vegetation into relevé and species groups; **b**) to provide a description and hierarchical grouping of the communities using diagnostic species; **c**) to describe the structure, diversity, life-forms and site conditions of the forest communities.

2.2 Material and Methods

2.2.1 Study area

The study area is located near the village of Dongliachun in the catchment of the Weihe River in the Western Qinling Mts. (**Fig. 2.1**). The study area comprises about 300 hectare in size (34°21'30"-34°23' N, 106°21'50"-106°21'50" E), and is located between two main ridges on north and south sides of a central valley which stretches in length about 2 km in east-west direction. It is unique, because it remained hardly used by any forest management for the last 40 years. The altitude ranges between 1600 m and 2160 m a.s.l. The length of the slopes between ridge and valley varies from ca. 300 m to 700 m. The inclination of slopes varies between 10 and 53 degrees, the average inclination, based on means of all plots, is 37 degrees. Mean annual temperature ranges between 4.3°C and 7.7°C, the mean temperature in the growing season from April to October from 10.3°C to 13.7°C. The average rainfall ranges from 600 up to 800 mm (see 2.2.5).

The parent geological material is slate, often covered by loess. The texture of the upper soil layers were mostly loam with small or medium clay content (Lt2, Lt3), of dark gray, dark brown, or dark reddish brown colours (ARBEITSKREIS FÜR STANDORTSKARTIERUNG

IN DER ARBEITSGEMEINSCHAFT FORSTEINRICHTUNG 2003). In the field, soil pH was estimated using indicator sticks after CASPARI & SCHACK-KIRCHNER (2006): Thorouthly mixed 1 part soils with 2.5 parts distill of water, and waited for ca. 5 minutes, then compared the colour combination of the stick with those of the cupplied colour scale. The pH was between 6.0 and 7.5. The humus-rich A-horizon was between 5 to 10 cm deep. The lower horizons were loamy or clay with low to medium silt content (Tu2, Tu3), of brown, dark yellowish brown, or reddish brown colours. The soils were 30 to more than 100 cm deep. Their skeleton content was medium to high, particularly on upper slopes and ridges. The available water storage capacity of soil of the investigated plots ranged between 42 and 176 mm.

2.2.2 Sampling design

Data of 120 plots (relevés) forest stands within totally 137 plots were recorded from June to August in 2007 and 2008 following a systematical design in a 100 × 200 m grid with slope correction (**Fig. 2.2**). The grid was linked to the Gauß-Krüger-coordinate system and combined with the grid of the Chinese national forest inventory (3 × 3 km). Thus the center of the 1st relevé corresponded with the center of one permanent plot of the Chinese national forest inventory. The starting point was identical to this systematical sampling. The study area was located between two main ridges of a central valley in southwest to northeast direction. Therefore the grid system avoided the superposition with linear structures of the landscape.

2.2.3 Vegetation sampling

At each grid point, the vegetation and site data were recorded in a nested plot design. The relevé size was kept constant for the different vegetation layers for herbs (<1 m, abbrev.: H) 100 m^2, and for tall trees (>10 m, T1), small trees (5-10 m, T2) and shrubs (1-5 m, S) 400 m^2 (see **Fig. 3.1** B**)**. For homogeneity reasons the plot shape varied: Quadrats (10 × 10 m and 20 × 20 m) were used on slopes, and rectangles (5 × 20 m and 10 × 40 m) on ridges or valleys bottoms. In each relevé, the cover and actual height of the 4 layers were assessed, and all vascular plant species of the 4 layers were recorded using the cover-abundance-scale of BRAUN-BLANQUET modified by BARKMAN et al. (1964).

The local nomenclature, i.e. Chinese botanic names, follows “Flora of China” (http://www.efloras.org), plus the latin botanic names followed by the adopted international names of “W³TROPICOS” of Missouri Botanical Garden (www.tropicos.org) (see **Annex 2.3**). The species were also named with chinese names according to “Flora of Xiaolongshan Mountain of Gansu Province” (AN 2001). The life-form type after RAUNKIAER (1934), modified by CAIN (1950) were based on the “Flora of Xiaolongshan Mountain of Gansu Province” (AN 2001) and “Flora of China” (http://www.efloras.org). The life-form type of species lacking sufficient prior information was assessed by own field observations. Identification of critical species was revised by the specialists JIAN-XIN SUN and HUI-MIN PEI.

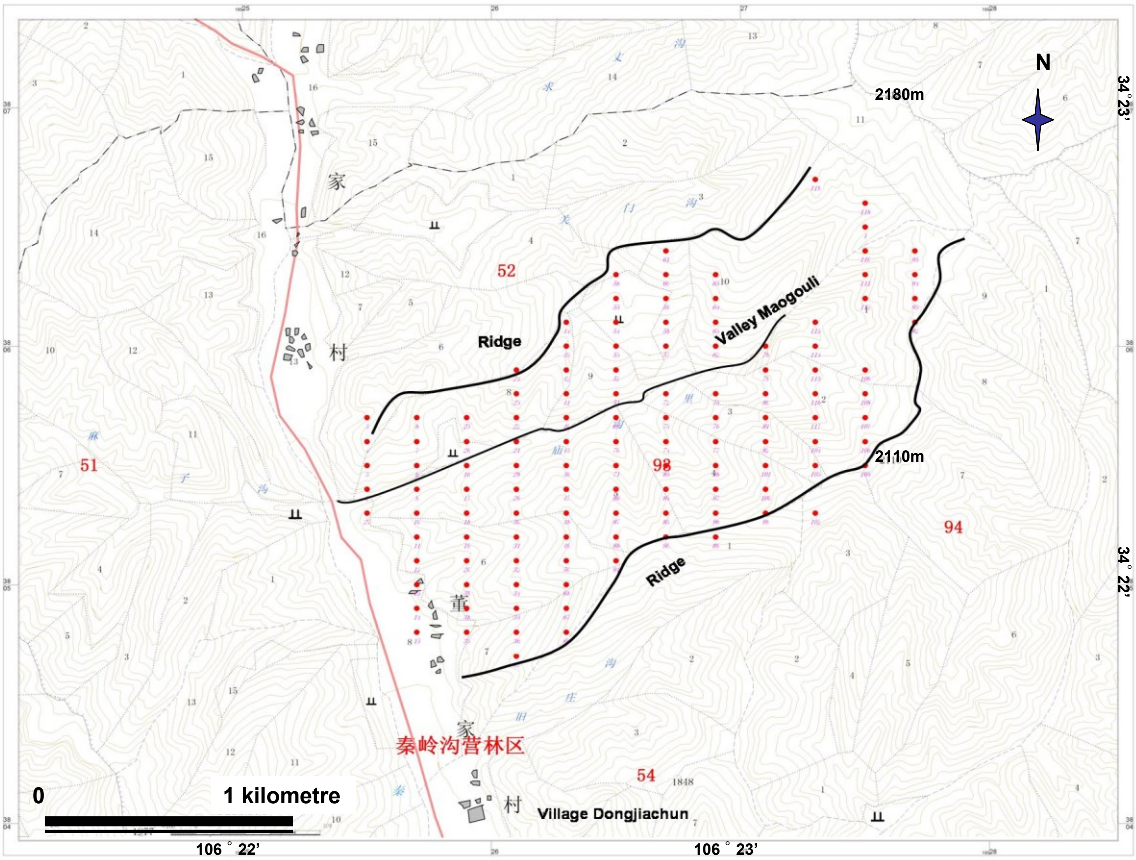


Fig. 2.2: Study area and sampling design. (The red points are relevés)

2.2.4 Site conditions

The site data altitude, relief (topographic position: upper-, middle-, or down-slope, ridge, valley), orientation (exposure) of slope, inclination, and sky view factor were measured for each relevé.

For each relevé a soil profile (N=120) up to 100 cm depth (or reaching the parent material) was dug to record the depths and textures of the different soil horizons, the skeleton and humus content, and the colors according to Munsell's Soil Color Charts, the pH (in H_2O), and the carbonate content (CASPARI & SCHACK-KIRCHNER 2006). For the last one, the presence of calcium carbonate was established by adding some drops of 10 % HCl to the soil.

The available water storage capacity (**AWSC**) of each profil was calculated, based on soil texture, depth of horizons, skeleton and humus content (ARBEITSKREIS FÜR STANDORTSKARTIERUNG IN DER ARBEITSGEMEINSCHAFT FORSTEINRICHTUNG 2003), indicating the amount of water that can be stored in soil available for plant growth.

The **direct solar radiation** (MJ/m^2) of April to October of each relevé was calculated using DACHRad based on sky view factor, altitude, exposures of slope, inclination, and latitude (FISCHER 2001).

2.2.5 Temperature and precipitation during April to October

The temperature has one function as indicator for the growth. Therefore, the temperature sum for each plot would be an important additional information. Temperature has another and additional function as component of the potential evapotranspiration (PET). In the research area, temperature and precipitation were measured during the years 2006 and 2007 every 10 min. with GSOFT 40K v7.8 in the Daijaguo weather station at an altitude of 1550 m a.s.l (**Fig. 2.3**). The long term data of monthly temperatures and precipitations (between 1971 to 2000 and 2006-2007) of the three neighboring climatic stations cities of Hanzhong, Tianshui and Wudu were used by <http://www.wetteronline.de/asieakt.htm>and http://cdc.cma.gov.cn. Their data for 2006 and 2007 were used to compare with the measured data in Daijaguo weather station. Therefore, long term data of monthly temperatures and precipitations (1971-2000) could be calculated for the research area by the method "Inverse Distance Weighted, IDW"(BARTIER & KELLER 1996).

Temperatures were estimated for each plot, assuming a decrease of 0.6° C per 100 m altitude (ARBEITSKREIS FÜR STANDORTSKARTIERUNG IN DER ARBEITSGEMEINSCHAFT FORSTEINRICHTUNG 2003) (**Fig. 2.3**).

The **growing season** (vegetation period) is normally defined as the average number of days within a year with a 24-hour average temperature of at least 5°C. Because this varies considerably with altitude, the climatic parameters were calculated for the period from April to October.

The **potential evapotranspiration (PET)** of the relevés was derived from direct solar radiation and temperature (see ZIMMERMANN 2000, ZIMMERMANN & ROBERTS 2001). PET represents a the evaporative demand of the atmosphere from a reference crop (ALLEN et al. 1998). This allows the comparison of different sites.

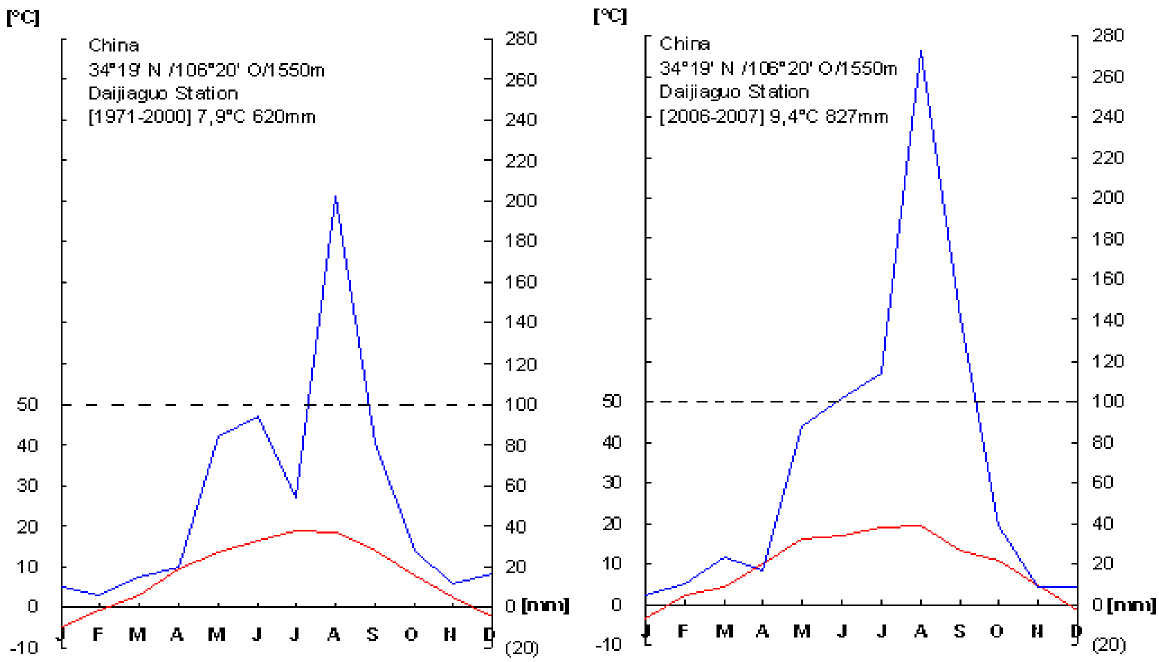


Fig. 2.3: Monthly climatic diagram. Left measured in 2006-2007, right calculated for 1971-2000.

2.2.6 Data analysis

The vegetation of herb layer reflects better the changes of forest site than the vegetation of the tree and shrub layers, therefore the vegetation data of herb layer was used to classify the vegetation and to identify the diagnostic species for each vegetation community (forest types). The classification of the vegetation data of **herb layer** (only species with absolut presence of more than 5) and the identification of **diagnostic species** principally followed the recommendation and sequence of WILDI (1989) using the software MULVA 5.1 (WILDI & ORLÓCI 1996). The cover-abundance-scale of BRAUN-BLANQUET (1-9) was trans-formed to percentage cover scale after (DIERSCHKE 1994)

(0.1 %-87.5 %) for all the species on the data set. Two steps can be distinguished, the classification of the relevés and of the species. Before classifying the relevés the data was transformed applying square root transformation and normalization. The “similarity ratio” was used as resemblance measure, minimum variance as cluster algorithm. The fusion levels were used to determine the number of relevé clusters: First the coefficients in an Excel table were chosen, the differences between two steps of fusion calculated; the number of clusters counts under two criteria: **a)** where was the biggest gap (biggest difference) between 2 coefficients? **b)**. Where was the definite stationary point (turning point) of the curve?

Before classifying the species, the data were transformed applying the absolute value of Log X+10 transformation and normalization. The “cross product without centering” was used as resemblance measure and minimum variance for clustering. To determine the number of species clusters fusion level was used (see above).

To extract the main gradient for a phytosociological table, a correspondence analysis was performed: the first axis was used to order the groups, relevés and species along the diagonal within the table. The correspondence analysis was applied using the following settings: after a square root transformation and double adjustment of contingency data (for vector transformation), “scalar product without centering” was used as resemblance measure. A concentration analysis arranged the species and relevé groups. Diagnostic species of herb layer were selected using Jancey´s ranking, $F_{0.05}$ (6, 113) ≈ 2.989, Rank = 123.

After the classification of the herb layer, the vegetation data (presence ≥5) of two tree layers and the shrub layer were attributed to the relevé groups which were derived from the classification of the ground vegetation, by using “Indicator Species Analysis” (DUFRÊNE & LEGENDRE 1997) to find diagnostic species of these 3 layers following the software of PC-ORD 5 (MCCUNE & GRACE 2002).

The vegetation table combining all layers follows the Cluster Analysis and Concentration Analysis of MULVA and Indicator Species Analysis of PC-ORD (see above).

Determination of diagnostic species: On the phytosociological table, the diagnostic species were found in higher frequency and with bigger Braun-Blanquet cover-abundance in a given community or also in a given community group, with a smaller frequency and cover in others.

Determination of dominant species: In the current study, dominant species were defined as those having a Braun-Blanquet cover-abundance scale higher than 3 in at least 10 % of relevés.

Determination of constant species: Constant species are those with a high occurrence frequency in the given vegetation unit (CHYTRY & TICHY 2003: 15). The threshold frequency values for constant species were selected differently for community groups (40 %) and communities (60 %), because the latter are more narrowly conceived, and therefore they are more homogeneous vegetation units.

An indirect gradient analysis, i.e. non-metric multidimensional scaling (nMDS) with 3 dimensions using the Bray-Curtis index as dissimilarity measure with the software PC-ORD 5 (KRUSKAL 1964, CLARKE 1993, MCCUNE & GRACE 2002) was used to visualize and represent the forest communities and to explore vegetation-environment relationships (ordination overlays). Before the indirect gradient analysis outlier analyses were applied, but no species or relevé was recognized as outlier based on the cutoff of 3 standard deviations from the grand mean.

The Chi-Square test with SPSS 20 was made to find correlations between the 7 communities and the 5 slope relief classes (see **Annex 2.1**).

For characterisation of the forest communities, the species richness (α-richness) (GREIG-SMITH 1983) based on (SHANNON 1949) were calculated, as well as life form compositions after RAUNKIAER (1934) (modified by CAIN 1950).

Nomenclature of communities: The communities were named after diagnostic species of the herb layer and a name of a dominant diagnostic tree species. The community groups were named after diagnostic and/or dominant tree species.

2.3 Results

2.3.1 General floristic features

The total number of species and subspecies of vascular plants recorded in the 120 relevés was **448**, they belong to 91 families and 267 genera. There were 9 families of Pteridophytes (15 genera and 17 species), and 2 families (2 genera and 3 species) of

Gymnosperms (**Table 2.1**). The family with the most species and subspecies (42 species and subspecies/22 genera) was Rosaceae (**Annex 2.4**). The 2nd largest family was Asteraceae (40/22). Other families rich of species and subspecies were *Liliaceae*, *Ranunculaceae* and *Lamiaceae*. The genus with the most species was *Lonicera* with 10 species; the 2nd biggest genera were *Euonymus*, *Viburnum* and *Acer* with 7 tree or shrub species.

Table 2.1: Number of species and subspecies, genera and families in each plant group of the data set (120 relevés)

	Families	Genera	Species and Subspecies
Pteridophyta	9	15	17
Gymnosperma	2	2	3
Magnoliopsida	73	221	376
Liliopsida	7	29	52
Total	**91**	**267**	**448**

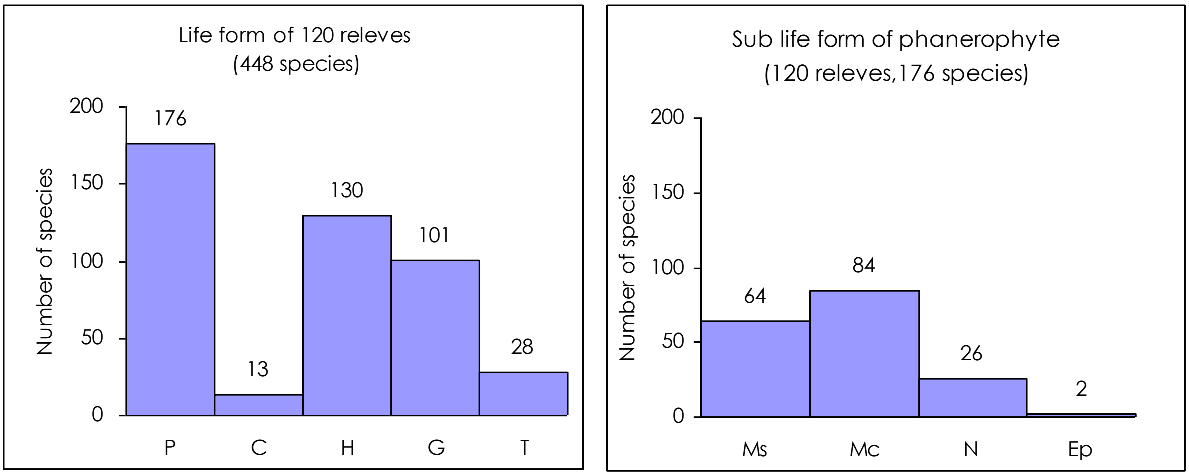


Fig. 2.4: Life-forms (left) and sub categories of phanerophyte (right) of the 448 sampled plant species in the total 120 relevés. **P:** phanerophyte, **C:** chamaephyte, **H:** hemicryptophyte, **G:** geophyte, **T:** therophyte, **Ms:** mesophanerophyte, **Mc:** microphanerophyte, **N:** nanophanerophyte, **Ep:** epiphytic-phanerophyte.

Numbers of species of RAUNKIAER's life forms (RAUNKIAER 1934 after CAIN 1950) for each relevé, as well as for each community are presented in **Fig. 2.4** (see also **Annex 2.5**). All communities were formed by a high amount of phanerophytes, among them many meso-phanerophytes and microphanerophytes. There were 176 species of phanerophytes including 64 species of mesophanerophytes (8-30 m), 84 species of microphanerophytes (2-8 m), 26 species of nano-phanerophytes (0.25 cm-2 m), and 2 species of epiphytic-phanerophytes. Next to phanerophytes were hemicryptophytes (130 species) and geophytes (101 species). There were only few therophytes (28 species) and chamaephytes (13 species) (**Fig. 2.4**).

2.3.2 Forest vegetation and sites – an overview

The forest vegetation could be classified in 3 community groups, which were subdivided into 7 communities (**Annex 2.1**):

1. *Quercus dentata*–*Quercus aliena* var. *acutiserrata*-community group (**QQ**):
    1a. *Vicia unijuga*–*Quercus aliena* var. *acutiserrata*-community (**VuQa**);
    1b. *Viola collina*–*Quercus aliena* var*. acutiserrata*-community (**VcQa**);
2. *Sorbus alnifolia*–*Quercus mongolica* (syn.*Q. liaotungensis*)-community group (**SQ**):
    2a. *Agrostis clavata-Quercus mongolica*-community (**AcQm**);
    2b. *Viola phalacrocarpa-Quercus mongolica*-community (**VpQm**);
3. *Juglans mandshurica*–*Corylus chinensis*-community group (**JC**):
    3a. *Laportea bulbifera-Corylus chinensis*-community (**LbCc**);
    3b. *Carex rubrobrunnea* var. *taliensis-Q. aliena* var. *acutiserrata*-community (**CrQa**);
    3c. *Oxalis griffithii*–*Juglans mandshurica*-community (**OgJm**).

2.3.3 Floristical similarity and vegetation-site relationship

The 3 community groups with their 7 communities display their floristical similarity-relation between the relevés, the species and their vegetation-site relationship in the Non-metric multidimensional scaling (nMDS)-ordination diagram (**Fig. 2.5**).

Showing the membership of relevés in the 7 communities, as well as in the 3 community groups was based on floristical criteria, i.e. diagnostic herb species (**Fig. 2.5**). Although the communities were classified within the 3 community groups, they share common diagnostic species. e.g. in the *Quercus dentata*–*Quercus aliena* var. *acutiserrata*-community group the diagnostic herb species *Vicia unijuga*, *Viola collina*; in the *Sorbus alnifolia*–*Quercus mongolica*-community group the diagnostic herb species *Agrostis clavata*, *Viola phalacrocarpa*; in the *Juglans mandshurica*–*Corylus chinensis*-community group the diagnostic herb species *Laportea bulbifera*, *Chrysosplenium biondianum* (**Fig. 2.5**, **Table 2.2**).

Table 2.2: PEARSON and KENDALL correlations of environmental parameters with ordination axes of the nMDS (**Fig. 2.5)** containing all plant communities. Abbreviations see **Fig. 2.5**

Axis	**1**			**2**			**3**		
N= 120	r	r-sq	tau	r	r-sq	tau	r	r-sq	tau
Altitude	0.280	0.079	0.228	0.311	0.097	0.227	-0.350	0.122	-0.196
WaterCap	0.075	0.006	0.032	-0.223	0.050	-0.171	-0.177	0.031	-0.122
dSolaRaV	-0.089	0.008	-0.085	-0.451	0.204	-0.321	-0.535	0.286	-0.410
aTempV30	-0.278	0.078	-0.230	-0.312	0.097	-0.229	0.354	0.126	0.206
PET_V30y	-0.195	0.038	-0.177	-0.543	0.295	-0.418	-0.383	0.147	-0.282

The *Vicia unijuga*–*Quercus aliena* var. *acutiserrata*-community (VuQa) and the *Viola collina*–*Quercus aliena* var*. acutiserrata*-community (VcQa) were floristically similar and formed the *Quercus dentata*–*Quercus aliena* var. *acutiserrata* community group (CG QQ) which was related to more direct solar radiation and warmer sites. The *Agrostis clavata*-*Quercus mongolica*-community (AcQm) and the *Viola phalacrocarpa*-*Quercus mongolica*-community (VpQm) were fused to the *Sorbus alnifolia*–*Quercus mongolica* community group (CG SQ) which occurred under relatively high direct solar radiation, but on higher elevation (cooler sites). The *Carex rubrobrunnea* var. *taliensis*-*Quercus aliena* var. *acutiserrata*-community (CrQa), the *Oxalis griffithii*–*Juglans mandshurica*-community (OgJm), and the *Laportea bulbifera*-*Corylus chinensis*-community (LbCc) were floristically similar and formed the *Juglans mandshurica*–*Corylus chinensis* community group (CG JC) on warmer sites with less direct solar radiation; soil water storage capacity seems to be less important.

The Chi-Square test with SPSS showed there were correlations (connections) between the 7 communities and the 5 relief classes (**Table 2.2**). Most relevés of *Carex rubrobrunnea* var. *taliensis*–*Quercus aliena* var. *acutiserrata* community (CrQa), *Oxalis griffithii*–*Juglans mandshurica* community (OgJm), *Laportea bulbifera*–*Corylus chinensis* community (LbCc) occur in the valleys and lower slopes, not on the ridges. Most relevés of C3 were on ridges and upper slopes, not in valleys. Most relevés of C2 were also in upper slopes. No relevés of C1 were in valleys; they were on the ridges, in upper-, mid- or lower slopes.

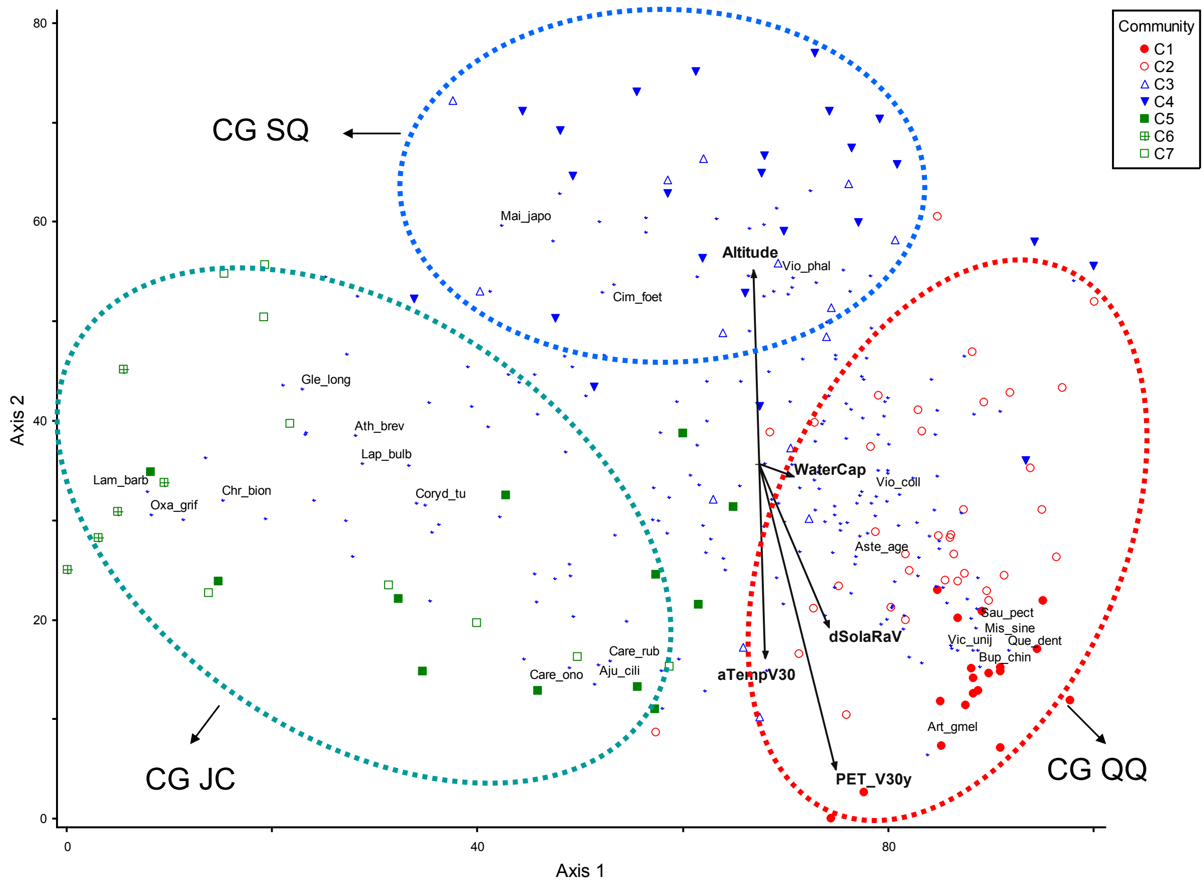


Fig. 2.5: Non-metric multidimensional scaling (**nMDS**) **diagram** (stress =16.38635) of 120 relevés for 7 communities (**C1**: *Vicia unijuga–Quercus aliena* var. *acutiserrata*-community, VuQa; **C2**: *Viola collina–Quercus aliena* var. *acutiserrata*-community, VcQa; **C3**: *Agrostis clavata-Quercus mongolica*-community, AcQm; **C4**: *Viola phalacrocarpa-Quercus mongolica*-community, VpQm; **C5**: *Carex rubrobrunnea* var. *taliensis-Quercus aliena* var. *acutiserrata*-community, CrQa; **C6**: *Oxalis griffithii–Juglans mandshurica*-community, OgJm; **C7**: *Laportea bulbifera-Corylus chinensis*-community, LbCc) and their upper units i.e. the 3 community groups (**CG QQ**: *Quercus dentata–Quercus aliena* var. *acutiserrata* community group; **CG SQ**: *Sorbus alnifolia–Quercus mongolica* community group; **CG JC**: *Juglans mandshurica–Corylus chinensis* community group).

Abbreviations of plotted parameters (see also 0): **Altitude**: altitude (a.s.l.); **WaterCap**: available water storage capacity (AWSC) of soil; **dSolaRaV**: direct solar radiation during growing season; aTempV30: average temperature in growing season (1971-2000); **PET_V30y**: Potential evapotranspiration during growing season (1971-2000). Abbreviations of the diagnostic species: **Art_gmel**: *Artemisia gmelinii*, **Bup_chin**: *Bupleurum chinense*, **Vic_unij**: *Vicia unijuga*, **Que_dent**: *Quercus dentata* (for C1); **Sau_pect**: *Saussurea pectinata*, **Aste_age**: *Aster ageratoides* (for CG1); **Vio_coll**: *Viola collina* (for C2); **Mai_japo**: *Maianthemum japonicum* (for CG2 & C4); **Cim_foet**: *Cimicifuga foetida* (for C3); **Vio_phal**: *Viola phalacrocarpa* (for CG2); **Care_ono**: *Carex onoei*, **Aju_cili**: *Ajuga ciliata*, **Care_rub**: *Carex rubrobrunnea* var. *taliensis* (for C5); **Lam_barb**: *Lamium barbatum*, **Oxa_grif**: *Oxalis griffithii*, **Chr_bion**: *Chrysosplenium biondianum* (for C6); **Gle_long**: *Glechoma longituba*, **Ath_brev**: *Athyrium brevisorum*, **Lap_bulb**: *Laportea bulbifera*, **Cory_tu**: *Corydalis turtschaninovii* (for C7).

2.3.4 Floristic composition and site demands of the 3 forest community groups and the 7 communities

***Quercus dentata*-*Quercus aliena* var. *acutiserrata*-community group (QQ)**
(**Annex 2.1**, col. 1-55)

Diagnostic species combination

Quercus aliena var. *acutiserrata* (T1,T2,S), *Quercus dentata* (T1), *Rhus potaninii* (S,H), *Pyrus xerophila* (T2,S), *Pinus armandii* (T2,S), ***Elaeagnus umbellata**** (S), ***Buckleya henryi**** (S), ***Rosa helenae**** (S), ***Euonymus sanguineus**** (S), ***Amelanchier sinica**** (S), ***Cornus macrophylla**** (S), ***Cornus hemsleyi**** (S), *Corylus heterophylla* (S), *Lespedeza formosa* (S), *Forsythia suspensa* (S), *Cerasus polytricha* (S), *Malus baccata* (S), *Toxicodendron vernicifluum (S), Prunus salicina* (S), *Vicia unijuga* (H), *Miscanthus sinensis* (H), *Bupleurum chinense* (H), *Adenophora paniculata* (H), *Pteridium aquilinum* var. *latiusculum* (H), *Anemone tomentosa* (H), *Viola collina* (H), *Aster ageratoides* (H), *Artemisia gmelinii* (H), *Elymus dahuricus* (H), *Thalictrum minus* var. *hypoleucum* (H), *Saussurea pectinata* (H), *Artemisia sylvatica* (H), *Indigofera bungeana* (H), *Adenophora potaninii* (H), *Acer ginnala* (H), *Lonicera ferdinandii* (H), *Agrimonia pilosa (H), Artemisia dubia* var. *subdigitata* (H), *Vitis heyneana* subsp. *heyneana* (H), *Chrysanthemum indicum* (H). (*: endemic species of the Qinling Mts.)

The **dominant specie**s with **high frequency** (≥60 %) were *Quercus aliena* var. *acutiserrata* (T1,T2,S,H), Corylus *heterophylla* (S), *Corylus heterophylla* (S,H), *Lindera obtusiloba* (S), *Crataegus wilsonii* (S), *Viburnum betulifolium* (S), *Lindera umbellata* (S), *Carex breviculmis* var. *fibrillosa* (H), *Lespedeza formosa* (H).

The species with **lower cover** and **high frequency** (≥60 %) were *Sorbus alnifolia* (S), *Pinus armandii* (S), *Rubia cordifolia* (H), *Smilax stans* (H), *Akebia trifoliata* (H), *Dioscorea nipponica* (H), *Toxicodendron vernicifluum* (H), *Celastrus orbiculatus* (H).

Ecology and distribution

The community group QQ prefers sunny slopes and was found at an altitude between 1600 and 1900 m.

Comparison with literature

From the floristic point of view, the *Quercus dentata*–*Quercus aliena* var. *acutiserrata* community group is comparable to the "Formation *Quercus aliena* var. *acutiserrata*" in the Qinling Mts (WU 1980) and (THE COMPILED COMMISSION OF FORESTS OF GANSU 1998). The "Formation *Quercus aliena* var. *acutiserrata*"**,** dominated by *Quercus aliena* var. *acutiserrata*, was recorded from the Qinling Mts. (WU 1980, ZHU 1983, WANG 1989), thus indicating a wider distribution of this forest type.

There are many endemic species in the diagnostic species combination in the community group QQ like ***Elaeagnus umbellata***, ***Buckleya henryi***, ***Rosa helenae***, ***Euonymus sanguineus***, ***Cornus macrophylla***, ***Cornus hemsleyi***, ***Amelanchier sinica***. According to FANG et al. (2009), they grow in Qinling Mts. and also in subtropical forest zones. They are not recorded from other deciduous *Quercus* communities in the cold temperate deciduous forests in northeast China or in the warm-temperate zone of China (KRESTOV et al. 2006, TANG et al. 2009).

The *Quercus dentata*–*Quercus aliena* var. *acutiserrata* community group consists of **2 communities**:

- *Vicia unijuga*–*Quercus aliena* var. *acutiserrata*-community (VuQa);
- *Viola collina*–*Quercus aliena* var. *acutiserrata*-community (VcQa).

Vicia unijuga–*Quercus aliena* var. *acutiserrata*-community (VuQa, C1) (Annex 2.1, col. 1-19)

The *Vicia unijuga*–*Quercus aliena* var. *acutiserrata*-community (VuQa) was defined on the basis of 19 relevés and contained 179 vascular plant species.

Diagnostic species combination (species name in bold print are endemic species of Qinling Mts.)

Quercus dentata (T1,T2,S,H), *Quercus aliena* var. *acutiserrata* (T1,T2,S), *Rhus potaninii* (T2,S), ***Dipelta floribunda*** (S), ***Paeonia suffruticosa* var. *papaveracea*** (S), *Indigofera bungeana* (S), *Acer ginnala* (S), *Tilia paucicostata* var. *dictyoneura* (S), *Lespedeza formosa* (S), *Corylus heterophylla* (S), *Vicia unijuga* (H), *Miscanthus sinensis* (H), *Bupleurum chinense* (H), *Adenophora paniculata* (H), *Pteridium aquilinum* var. *latiusculum* (H), *Anemone tomentosa* (H), *Elaeagnus umbellata* (H).

Physiognomy and composition

The *Vicia unijuga–Quercus aliena* var. *acutiserrata*-community has the lowest diversity in the **1st** tree layer (T1) compared to the other 6 communities (mean species richness per relevé 2.4) (**Annex 2.5**). The height of 1st tree layer was low (mean height 11 m). The canopy cover varies between 20 and 45 %. The mean species richness of 2nd tree (T2) and shrub (S) layers were 4.9 and 21.1. There were 95 species in the community: phanerophytes (53.1 % of the all life form of VuQa community), among them mesophanerophytes (37.9 %), microphanerophytes (45.3 %), nanophanerophytes (14.7 %), epiphytic phanerophytes (2.1 %). The **VuQa** community has lower diversity also in the herb layer, mean species richness per relevé was 32.8 (**Annex 2.5**). There were 26.8 % hemicryptophytes, and 14 % geophytes. There were few chamaephytes (5 %, as a majority in the 7 communities) and therophytes (1.1 %) (**Annex 2.5**).

The **dominant species** with **high frequency** (≥60 %) were *Quercus aliena* var. *acutiserrata* (T1,T2,S), *Corylus heterophylla* (S,H), *Lespedeza formosa* (S,H), *Carex breviculmis* var. *fibrillosa* (H), *Saussurea pectinata* (H).

The species with **high frequency** (≥60 %) were *Rhus potaninii* (S,H), *Lonicera fragrantissima* var. *fragrantissima* (S), *Acer ginnala* (S), *Thalictrum minus* var. *hypoleucum* (H), *Aster ageratoides* (H), *Adenophora potaninii* (H), *Rubia cordifolia* (H), *Indigofera bungeana* (H), *Akebia trifoliate* (H), *Dioscorea nipponica* (H), *Toxicodendron vernicifluum* (H), *Celastrus orbiculatus* (H).

Ecology and distribution

The *Vicia unijuga–Quercus aliena* var. *acutiserrata*-community was found on sunny slopes or ridges at altitudes between 1580 and 1800 m, mostly between 1600 and 1700 m; average gradient of slopes was about 30 degrees.

Comparison with literature

The Compiled Commission of Forests of Gansu (1998) described the *Corylus heterophylla–Quercus aliena* var. *acutiserrata* forest type, and also the *Lespedeza formosa–Quercus aliena* var. *acutiserrata* forest type with the dominante species *Quercus aliena* var. *acutiserrata, Corylus heterophylla* and *Lespedeza formosa.* There is a floristic similarity with the present study, where the *Vicia unijuga–Quercus aliena* var. *acutiserrata*–community was dominated by *Quercus aliena* var. *acutiserrata* in the tree layers and the two shrub species *Corylus heterophylla* and also *Lespedeza formosa* in the shrub layer in most of the relevés.

The diagnostic species of this VuQa community like *Dipelta floribunda* (S), *Paeonia suffruticosa* var. *papaveracea* (S) were found in this research area only. According to FANG et al.(2009), they are endemic species of the Qinling Mts. and also grow in subtropic forest zones in China. These species are not recorded from other deciduous *Quercus* communities in the cold temperate deciduous forests in northeast China or in the warm-temperate zone of China (KRESTOV et al. 2006, TANG et al. 2009).

Viola collina–Quercus aliena var. *acutiserrata* community (VcQa, C2) (Annex 2.1, col. 20-55)

The *Viola collina–Quercus aliena* var. *acutiserrata* community was defined on the basis of 36 relevés and contains 274 species of vascular plants.

Diagnostic species combination

Lindera obtusiloba (S), *Viola collina* (H).

Physiognomy and composition

In the VcQa community, the height of 1st tree layer (mean height 12.5 m) was higher than of the VuQa community.

The VcQa community had the highest diversity in the shrub layer compared to other 6 communities, where the mean species richness of relevé was 23.5 (**Annex 2.5**). Maybe the diversity there is due to the heigher trees or to the site condition.

In the **life form** spectra of the VcQa community, there were mostly phanerophytes (133 species, as majority in the 7 communities), among them mesophanerophytes (37.6 %), microphanerophytes (46.6 %), nanophanerophytes (15 %), epiphytic phanerophytes (0.8 %). Next to the phanerophytes, there were hemicryptophytes (27.7 %, as majority in the 7 communities), and geophytes (16.8 %). There were few therophytes (4.7 %) and chamaephytes (2.2 %) (**Annex 2.5**).

The **dominant species** with **high frequency** (≥60 %) were *Quercus aliena* var. *acutiserrata* (T1), *Lindera umbellata** (H), *Corylus heterophylla* (S,H), *Viburnum betulifolium* (S,H), *Sorbus alnifolia* (S), *Carex breviculmis* var. *fibrillosa* (H), *Viola collina* (H). ***:** endemic species of Qinling Mts.

The constant companion species (with **high frequency** (≥60 %) but **low coverage**) were *Quercus aliena* var. *acutiserrata* (S,H), *Lindera umbellata** (S), *Crataegus wilsonii* (S), *Lindera obtusiloba* (S), *Pinus armandii* (S), *Aster ageratoides* (H), *Asparagus filicinus* (H), *Smilax stans* (H), *Dioscorea nipponica* (H), *Rubia cordifolia* (H), *Akebia trifoliate* (H), *Fragaria orientalis* (H), *Phlomis umbrosa* (H), *Toxicodendron vernicifluum* (H), *Pinus armandi* (H).

The VcQa community is **a transition** between CG QQ and CG SQ. Highest species richness were observed this community.

Ecology and distribution

The *Viola collina*–*Quercus aliena* var. *acutiserrata* community was found on slopes with a variety of exposures (was not only on sunny slopes or ridges) at altitudes between 1590 m and 2120 m, mostly between 1700 and 1900 m. i.e. its site was mostly not as sunny as that of the VuQa community, and mostly as colder as that of the VuQa community (**Fig. 2.5**).

Comparison with literature

From the floristic point of view, the *Viola collina*–*Quercus aliena* var. *acutiserrata* community was dominated by *Quercus aliena* var. *acutiserrata* in the tree layers and *Corylus heterophylla* in the shrub layer. It could be also compared to the "forest type *Corylus heterophylla*–*Quercus aliena* var. *acutiserrata*" (THE COMPILED COMMISSION OF FORESTS OF GANSU 1998). Due to different approaches till now, a synhierarchical system was not available and the synsystematical position remains open.

***Sorbus alnifolia*–*Quercus mongolica*-community group (SQ)**

(**Annex 2.1**, col. 56-94)

Diagnostic species combination

Quercus mongolica (T1), ***Sorbus hupehensis**** (T1,T2,S), ***Acer davidii**** (T1), *Ostrya japonica* (T1), ***Meliosma cuneifolia**** (T2), ***Cornus hemsleyi**** (T2), *Sorbus alnifolia* (T2,S), *Carpinus turczaninowii* (T2), ***Acer stachyophyllum* subsp. *betulifolium**** (S), ***Berberis salicaria**** (S), ***Ribes glaciale**** (S,H), ***Lonicera serreana**** (S), ***Tetradium daniellii**** (S,H), ***Helwingia japonica**** (S,H), ***Spiraea rosthornii**** (S), ***Berberis dasystachya**** (S), ***Lindera umbellata**** (S), ***Fargesia nitida**** (S), ***Daphne tangutica**** (S), ***Staphylea holocarpa**** (S), *Cotoneaster acutifolius* (S), *Acer pictum* subsp. *mono* (S), *Tilia paucicostata* (S,H), *Carpinus cordata* (S), *Viola phalacrocarpa* (H), *Stellaria palustris* (H), *Dryopteris bissetiana* (H), *Paris polyphylla* (H), *Tiarella polyphylla* (H), *Maianthemum japonicum* (H), *Caulophyllum robustum* (H), *Sabia campanulata* subsp. *ritchieae* (H) (Mc);

The **dominant species with high frequency** (≥60 %) were *Quercus mongolica* (T1), *Lindera obtusiloba* (T2), *Sorbus alnifolia* (T2,S), *Lindera umbellata**(S,H), *Viburnum betulifolium* (S,H), *Dryopteris bissetiana* (H).

The species with **high frequency** (≥60 %) were *Lindera obtusiloba* (S), *Cotoneaster acutifolius* (S), *Acer pictum* subsp. *mono* (S), *Smilax stans* (H), *Toxicodendron vernicifluum* (H), *Dioscorea nipponica* (H).

There are more **geophytes** in this community group than in the other two community groups (**Annex 2.5**).

Ecology and distribution

The community group SQ was mostly found in sunny upper slopes or ridges at high altitudes (upward 2000 m).

Comparison with literature

From the floristic point of view, the *Sorbus alnifolia*–*Quercus mongolica*-community group was dominated by ***Quercus mongolica*** and ***Sorbus alnifolia*** with higher constancy, and also by *Acer pictum* subsp. *mono* in shrub layer with higher constancy, and by *Actinidia arguta, Carpinus cordata,* and *Kalopanax septemlobus* in single relevés, this community group can belongs to the Class „*Quercetea mongolica* Song ex Krestov et al. 2006“ sensu (KRESTOV et al. 2006). But there are many endemic species to the Qinling Mts. in the **diagnostic species combination** in the *Sorbus alnifolia*–*Quercus mongolica* community group like ***Sorbus hupehensis***, and ***Acer davidii*** in the 1st tree layer; ***Sorbus hupehensis***, ***Meliosma cuneifolia*, *and Cornus hemsleyi*** in the 2nd tree layer; ***Sorbus hupehensis***, ***Acer stachyophyllum* subsp. *betulifolium***, ***Berberis salicaria***, ***Ribes glaciale***, ***Lonicera serreana***, ***Tetradium daniellii***, ***Helwingia japonica*, *Spiraea rosthornii***, ***Berberis dasystachya***, ***Lindera umbellata***, ***Fargesia nitida***, ***Daphne tangutica***, and ***Staphylea holocarpa*** in the shrub layer. According to FANG et al. (2009), they grow in Qinling Mts. and also in subtropic forest zones. These species are not mentioned in the study about *Quercus mongolica* forest communities (KRESTOV et al. 2006) in the cold temperate deciduous forests in northeast China or in the study (TANG et al. 2009) about deciduous *Quercus* communities in the warm-temperate zone of China.

From the floristic point of view, the *Sorbus alnifolia*–*Quercus mongolica*-community group was dominated by ***Quercus mongolica*** with higher constancy, and also by *Betula* *platyphylla* in the some relevés in this study. It could be compared to the "**Formation *Quercus liaotungensis* (syn. *Q. mongolica*)**" (WU 1980), and (THE COMPILED COMMISSION OF FORESTS OF GANSU 1998). According to WU (1980)**,** this forest formation is widely distributed in the Qinling Mts. in Shaanxi Province and Gansu Province, in mountanious region of Shanxi Province and Hebei Province and north part of Liaotung Peninsula. The *Sorbus alnifolia*–*Quercus mongolica* community group has similarity to the forests dominated by the Class „*Quercetea mongolica* Song ex Krestov et al. 2006" sensu KRESTOV et al. (2006). In order to comfirm the syntaxonomic status of the communities, further phytosociological studies are needed to larger areas in the Qinling Mountains.

The *Sorbus alnifolia*–*Quercus mongolica*-community group consists of **2 communities**:

- *Agrostis clavata*–*Quercus mongolica*–community (AcQm);
- *Viola phalacrocarpa*–*Quercus mongolica*–community (VpQm);

Agrostis clavata–*Quercus mongolica*–community (AcQm, C3)

(**Annex 2.1**, col. 56-70)

The *Agrostis clavata*–*Quercus mongolica*–community was defined on the basis of 15 relevés and contained 228 species of vascular plants.

Diagnostic species combination

Betula albosinensis* (T1), *Betula platyphylla* (T1), *Quercus mongolica* (T2), ***Crataegus wilsonii**** (S), *Rosa acicularis* (S), *Geranium sibiricum* (H), *Agrostis clavata* (H), *Adonis davidii* (H), *Cimicifuga foetida* (H), *Anemone altaica* (H), *Fragaria orientalis* (H), *Triosteum pinnatifidum* (H), *Stellaria palustris* (H), *Duchesnea indica* (H), *Galium aparine* (H).

Physiognomy and composition:

The 1st tree layer of the **AcQm** community was of lower height, only up to 12 m (mean height 11.7 m). Their cover varies between 30 and 70. The cover of the herb layer was higher (mean cover 55 %) than in the other communties. There was a higher diversity of the **2nd tree** layer in the **AcQm** community than in the most communities, the mean species richness per relevé was 7.2.

In the life form spectrum of the *Agrostis clavata*–*Quercus mongolica*–community: there were more phanerophytes (107 species), among them mesophanerophytes

(39.3 %), microphanerophytes (46.7 %), nanophanerophytes (14 %), but no epiphytic phanerophytes. Next to phanerophytes, there were hemicryptophytes (25.4 %), and geophytes (21.5 %), only few therophytes (4.8 %) and chamaephytes (1.3 %) (**Annex 2.5**).

The **dominant species** with **high frequency** (≥60 %) were ***Quercus mongolica*** (**T1**), ***Betula platyphylla*** (**T1**), ***Lindera obtusiloba*** (**T2**), ***Crataegus wilsonii*** (**S**), ***Viburnum betulifolium*** (**S**). In the herb layer, the dominant species were ***Fragaria orientalis***, ***Carex breviculmis*** **var.** ***fibrillosa***, ***Stellaria palustris***, ***Viburnum betulifolium***, ***Lindera umbellata***. The constant companion species were *Dioscorea nipponica*, *Viola phalacrocarpa*, *Toxicodendron vernicifluum*.

The species with **high frequency** (≥60 %) were *Lindera umbellata** (S), *Acer pictum* subsp. *mono* (S). In the **herb** layer, the constant companion species were *Dioscorea nipponica*, *Viola phalacrocarpa*, *Toxicodendron vernicifluum*.

Ecology and distribution

The *Agrostis clavata*–*Quercus mongolica*–community was found in sunny upper slopes or ridges at high altitudes between 1960 m and 2160 m, mostly above 2000 m; slopes were flatter in the study area, average gradient was 25 degrees.

Comparison with literature

There are many endemic species in the **diagnostic species combination** of the *Agrostis clavata*–*Quercus mongolica* community like ***Betula albosinensis*** in the 1st tree layer; ***Crataegus wilsonii*** which also **dominante** in the shrub layer (diagnostic species and dominant species). According to FANG et al. (2009), they grow in Qinling Mts. and also in subtropic forest zones. These species are not mentioned in the studies about *Quercus mongolica* forest communities by KRESTOV et al. (2006) in the cold temperate deciduous forests in northeast China or by TANG et al. (2009) about deciduous *Quercus* communities in the warm-temperate zone of China.

Viola phalacrocarpa–*Quercus mongolica*–community (VpQm, C4)

(**Annex 2.1**, col. 71-94)

The *Viola phalacrocarpa*–*Quercus mongolica*–community was defined on the basis of 24 relevés and contained 239 species of vascular plants.

Diagnostic species combination

Quercus mongolica (T1), ***Cornus hemsleyi**** (T1), *Sorbus alnifolia* (T1,T2), *Carpinus turczaninowii* (T1), ***Hydrangea bretschneideri**** (S), ***Stachyurus chinensis**** (S), *Euonymus maackii* (S), *Viburnum betulifolium* (S), *Viola phalacrocarpa* (H), *Maianthemum japonicum* (H), *Tilia paucicostata* (H, Ms), *Tetradium daniellii* (H, Ms), ***Sorbus hupehensis**** (H, Ms), *Berberis salicaria* (H, N), *Lonicera serreana* (H, Mc), *Ampelopsis glandulosa* var. *brevipedunculata* (H, Mc), *Eleutherococcus giraldii* (H, Mc), *Viburnum lobophyllum* (H, Mc), *Staphylea holocarpa* (H, Mc), *Meliosma cuneifolia* (H, Mc). (**Ms:** mesophanerophyte, **Mc:** microphanerophyte, **N:** nanophanerophyte, **Ep:** epiphytic-phanerophyte)

The **rare tree species** (conserving species) *Euptelea pleiosperma* was found in one relevé in all the 4 layers.

Physiognomy and composition

Mean height of the 1st tree layer was 13.3 m, of the 2nd tree layer 8.2 m. The cover of the tree layers varies between 30 % and 85 %. The height of the herb layer was lower (mean height 0.4 m).

In the life form spectra of the *Viola phalacrocarpa*–*Quercus mongolica*–community: there were more phanerophytes (126 species), among them mesophanerophytes (39.7 %), microphanerophytes (48.4 %), nanophanerophytes (11.1 %), and epiphytic phanerophytes (0.8 %). Next to phanerophytes, there were geophytes (20.9 %) and hemicryptophytes (21.8 %). There were few chamaephytes (0.8 %) and therophytes (3.8 %) (**Annex 2.5**).

The VcQa community is a transition between CG SQ and CG JC. The VcQa community were observed the highest species richness in the 1st tree layer (mean species richness per relevé 6) (**Annex 2.5**).

The **dominant species** with **high frequency** (≥60 %) were ***Quercus mongolica*** (**T1**), ***Quercus aliena* var. *acutiserrata*** (**T1**), ***Sorbus alnifolia*** (**T2**), ***Lindera obtusiloba*** (**T2**), ***Viburnum betulifolium*** (**S**). In the herb layer, the dominant species were: ***Dryopteris bissetiana***, ***Viburnum betulifolium***, ***Meliosma cuneifolia***, ***Lindera umbellata***.

The species with **high frequency** (≥60 %) were *Sorbus alnifolia* (S), *Lindera obtusiloba* (S), *Lindera umbellata**(S), *Meliosma cuneifolia**(S), *Cotoneaster acutifolius* (S), *Acer pictum* subsp. *mono* (S, H). In the herb layer, the constant companion species were

Actaea asiatica, *Dioscorea nipponica*, *Smilax stans*, *Toxicodendron vernicifluum*, *Acer davidii*, *Schisandra sphenanthera*.

Ecology and distribution

The forest community *Viola phalacrocarpa–Quercus mongolica* was found on shady mid- or bottomslopes at altitudes between 1650 m and 2080 m, mostly between 1800 m and 1900 m; Slopes were very steep, average gradient of slopes was more than 35 degrees.

Comparison with literature

There are many endemic species in the **diagnostic species combination** of the *Viola phalacrocarpa–Quercus mongolica* community like ***Cornus hemsley*** in 1st tree layer; ***Hydrangea bretschneideri***, and ***Stachyurus chinensis*** in the shrub layer; ***Sorbus hupehensis*** in the herb layer. According to Fang et al. (2009), they grow in Qinling Mts. and also in subtropic forest zones. These species are not mentioned in the study about *Quercus mongolica* forest communities (KRESTOV et al. 2006) in the cold temperate deciduous forests in northeast China or in the study (TANG et al. 2009) about deciduous *Quercus* communities in the warm-temperate zone of China.

***Juglans mandshurica–Corylus chinensis*–community group (JC)**
(**Annex 2.1**, col. 95-120)

Diagnostic species combination

Juglans mandshurica* (T1), ***Corylus chinensis**** (T1, T2), ***Cornus macrophylla* var. *macrophylla**** (T1), ***Cornus controversa**** (T1), *Ulmus davidiana* var. *japonica* (T1), ***Fraxinus platypoda**** (T2,S), ***Meliosma cuneifolia**** (S), ***Viburnum erubescens**** (S), ***Malus hupehensis**** (S), *Rhamnus parvifolia* (S), *Aconitum sungpanense* (H), *Sanicula chinensis* (H), *Rubus mesogaeus* (H, Mc), *Matteuccia struthiopteris* (H), *Chrysosplenium biondianum* (H), *Urtica laetevirens* (H), *Cardamine tangutorum* (H), *Oxalis griffithii* (H), *Arisaema lobatum* (H), *Helleborus thibetanus* (H).

The species with **high frequency** (≥60 %) and **dominance** was ***Meliosma cuneifolia**** in the shrub layer. *Rhamnus parvifolia* was frequent in the shrub layer.

Ecology and distribution

The community group JC was mostly found on shady lower slopes and in humid valleys at altitudes between 1700 m and 1900 m.

Comparison with literature

From the floristic point of view, the *Juglans mandshurica*–*Corylus chinensis*–community group (JC), as well as its 3 sub-ranking communities, *Carex rubrobrunnea* var. *taliensis*–*Quercus aliena* var. *acutiserrata* community (CrQa), *Oxalis griffithii*–*Juglans mandshurica*–community (OgJm) or *Laportea bulbifer*–*Corylus chinensis*–community (LbCc) were unique, dominated by *Juglans mandshurica, Cornus controversa* or *Corylus chinensis*, but *Quercus aliena* var. *acutiserrata* less dominant in the forest stands. These communities in the Western Qinling Mts. have not been recorded till now. But according to THE COMPILED COMMISSION OF FORESTS OF GANSU (1998), there is a trend of succession of the *Quercus aliena* var. *acutiserrata* forests on humid valley site condition into deciduous broad-leaved mixed forests. These communities could be in accordance with this description.

There are many **endemic species** in the diagnostic species combination of the *Juglans mandshurica*–*Corylus chinensis*–community group (JC) like *Juglans mandshurica*, *Corylus chinensis*, *Cornus macrophylla* var. *macrophylla*, *Cornus controversa* in the 1st tree layer; *Corylus chinensis*, *Fraxinus platypoda* in the 2nd tree layer; *Fraxinus platypoda*, *Meliosma cuneifolia* (also dominant species), *Viburnum erubescens*, *Malus hupehensis* in the shrub layer (diagnostic species). According to FANG et al. (2009), they grow in Qinling Mts. and also in subtropic forest zones.

The *Juglans mandshurica*–*Corylus chinensis*–community group consists of the **3 communities**:

- *Carex rubrobrunnea* var. *taliensis*–*Quercus aliena* var. *acutiserrata*–community (CrQa,);
- *Oxalis griffithii*–*Juglans mandshurica*–community (OgJm);
- *Laportea bulbifera*–*Corylus chinensis*–community (LbCc).

***Carex rubrobrunnea* var. *taliensis*–*Quercus aliena* var. *acutiserrata* community (CrQa, C5)** (**Annex 2.1**, col. 104-115)

The *Carex rubrobrunnea* var. *taliensis*–*Quercus aliena* var. *acutiserrata*–community was defined on the basis of 12 relevés and contained 187 species of vascular plants.

Diagnostic species combination

Malus hupehensis* (T2,S), ***Forsythia giraldiana**** (S), *Viburnum mongolicum* (S), *Carex rubrobrunnea* var. *taliensis* (H), *Ranunculus sieboldii* (H), *Carpesium abrotanoides* (H), *Ajuga ciliata* (H), *Viola acuminata* (H), *Notopterygium franchetii* (H), *Carex onoei* (H), *Rubia ovatifolia* (H), *Circaea cordata* (H) *Dryopteris goeringiana*, *Fragaria orientalis*, *Laportea bulbifera* (H), *Phryma leptostachya* subsp. *asiatica* (H), *Glechoma longituba* (H), *Equisetum arvense* (H), *Schisandra chinensis* (H, Mc), *Eleutherococcus leucorrhizus* var. *setchuenensis* (H, Mc)**.**

Physiognomy and composition

The cover of 1st and 2nd tree layer was low, mean cover 12 % and 21 %. The height of the herb layer was lower (mean height 0.3 m).

In the life form spectrum of the **CrQa** community: there were more phanerophytes (90 species), among them mesophanerophytes (41.1 %) slightly fewer than microphanerophytes (44.4 %), nanophanerophytes (13.3 %), epiphytic phanerophytes (1.1 %). Next to phanerophytes, there were hemicryptophytes (22.5 %) and geophytes (22.5 %). There were more therophytes (4.8 %) than chamaephytes (2.1 %) (**Annex 2.5**).

The 2nd tree layer and herb layer of the **CrQa** community were mostly well developed and were rich in species (8 and 45 species per relevé) (**Annex 2.5**).

The **dominant species** with **high frequency** (≥60 %) were ***Quercus aliena* var. *acutiserrata*** (**T1,T2,S**)**,** ***Corylus chinensis*** (**T1**), ***Lindera obtusiloba*** (**T2,S**), ***Meliosma cuneifolia****(**S**), ***Corylus heterophylla*** (**S**). In the herb layer, the dominant species were ***Carex rubrobrunnea* var. *taliensis*, *Euonymus alatus*, *Viburnum lobophyllum***.

The species with **high frequency** (≥60 %) was *Lonicera fragrantissima* var. *fragrantissima* in the shrub layer. In the **herb** layer, *Stellaria palustris*, *Aconitum sungpanense*, *Asparagus filicinus*, *Aster ageratoides*, *Dioscorea nipponica*, *Quercus aliena* var. *acutiserrata* were the constant companion species.

Ecology and distribution

The *Carex rubrobrunnea* var. *taliensis*–*Quercus aliena* var. *acutiserrata*–community was found in flat, wide valleys, single relevés in down-slopes at altitudes between 1620 m and 1770 m, mostly below 1700 m; the average gradient lower than 20 degrees. This forest community grows on relatively deep, humid and fertile soils.

***Oxalis griffithii–Juglans mandshurica*–community (OgJm, C6)** (**Annex 2.1,** col. 116-120)

The *Oxalis griffithii–Juglans mandshurica*–community was defined on the basis of 5 relevés and contained 86 species of vascular plants.

Diagnostic species combination

Juglans mandshurica* (T1), ***Staphylea holocarpa**** (T2, S), *Fraxinus chinensis* (T2), ***Prinsepia utilis**** (S)**,** *Lonicera maackii* (S), *Rhamnus parvifolia* (S), ***Cornus controversa**** (S) (conserving tree species), *Oxalis griffithii* (H), *Lamium barbatum* (H), *Arisaema lobatum* (H), *Cardamine tangutorum* (H), *Urtica laetevirens* (H), *Chrysosplenium biondianum* (H), *Helleborus thibetanus* (H).

Physiognomy and composition

The 1st tree layer was the highest in the 7 communities, ranging from 18 m to 20 m. The cover of the 2nd tree layer and shrub layer remain lowest (10-15 %). There was closer cover in the herb layer (70-90 %), but its height was lowest (up to 0.20 m). The **OgJm** community has lower species diversity in the 2nd tree, shrub and herb layers (**Annex 2.5**).

In the life form spectrum in the *Oxalis griffithii–Juglans mandshurica* community: there were more phanerophytes (48 species), among them mesophanerophytes (52.4 %), microphanerophytes (45.2 %), nanophanerophytes (2.4 %), and no epiphytic phanerophytes. Next to phanerophytes, there were geophytes (30.2 %) more than hemicryptophytes (17.4 %). There were very few therophytes (3.5 %) and no chamaephytes (**Annex 2.5**).

The **dominant species** with **high frequency** (≥60 %) were ***Juglans mandshurica**** (**T1**), ***Staphylea holocarpa**** (**S**), ***Fraxinus chinensis*** (**T2**), ***Meliosma cuneifolia**** (**S**), ***Prinsepia utilis**** (**S**)**,** ***Rhamnus parvifolia*** (**S**). In the herb layer, the dominant species were ***Oxalis griffithii*, *Cardamine tangutorum*, *Chrysosplenium biondianum*, *Urtica laetevirens*, *Lamium barbatum***.

The species with **high frequency** (≥60 %), but lower cover were *Cornus controversa** (T1), *Staphylea holocarpa** (T2), *Fraxinus chinensis* (S), *Lonicera maackii* (S), *Cephalotaxus sinensis** (S) (conserving species), *Padus brachypoda** (S), *Malus hupehensis** (S), *Picrasma quassioides* (S), *Acer ceriferum** (S), *Ulmus bergmanniana** (S). In the herb layer, the constant companion species were *Paris polyphylla*, *Maianthemum* *japonicum*, *Polygonatum odoratum*, *Caulophyllum robustum*, *Sabia campanulata* subsp. *ritchieae*.

Ecology and distribution

The forest community *Oxalis griffithii–Juglans mandshurica* was found in shady and humid valleys at altitudes between 1800 m and 1880 m; average gradient of slopes was lower than 20 degrees. Thisjuglans forest community grows on relatively stony soils.

Laportea bulbifera–Corylus chinensis–community (LbCc, C7)

(**Annex 2.1**, col. 95-103)

The *Laportea bulbifera–Corylus chinensis*–community was defined on the basis of 9 relevés and contained 200 species of vascular plants.

Diagnostic species combination

Fraxinus platypoda* (T1), *Acer pictum* subsp. *mono* (T1), ***Juglans mandshurica**** (T2,S), ***Berchemia flavescens**** (S), *Morus australis* (S), *Sambucus williamsii* (S), *Laportea bulbifera* (H), *Thladiantha dubia* (H), *Glechoma longituba* (H), *Stellaria chinensis* (H), *Cystopteris pellucida* (H), *Corydalis turtschaninovii* (H), *Trollius buddae* (H), *Athyrium brevisorum* (H), *Viola selkirkii* (H), *Circaea canadensis* subsp. *quadrisulcata* (H), *Circaea cordata* (H).

Physiognomy and composition

The 1st tree layer was high, some relevés reach up to 25 m. There was closer cover of the 2nd tree layer, shrub layer, and herb layer (mean cover 45 %, 39 %, and 60 %). The herbs grew higher than in the *Laportea bulbifera–Corylus chinensis* community (0.2-0.8 m).

In the life form spectrum of the *Laportea bulbifera–Corylus chinensis* community: there were more (90 %) phanerophytes, among them mesophanerophytes (43.3 %), microphanerophytes (46.7 %), nanophanerophytes (10 %), and no epiphytic phanerophytes. Next to phanerophytes there were hemicryptophytes (25 %), and geophytes (22.5 %). There were more therophytes (6 %), and few chamaephytes (1.5 %) (**Annex 2.5**).

The **dominant species** with **high frequency** (≥60 %) was ***Juglans mandshurica****(**T1**). In the herb layer, the dominant species were ***Urticalaetevirens***, ***Laportea bulbifera***, ***Stellaria chinensis***, ***Dryopteris bissetiana***.

The species with **high frequency** (≥60 %) was *Viburnum betulifolium* (S). In the **herb** layer, the constant companion species was *Celastrus orbiculatus*. The rare tree species (protected species) ***Euptelea pleiosperma*** was found in single relevés in the **2nd tree** layer, the shrub layer and the herb leyer.

Ecology and distribution

The forest community *Laportea bulbifera*–*Corylus chinensis* was found in shady low part of slopes or in narrow valleys at altitudes between 1620 m and 2050 m, mostly between 1700 m and 1900 m; average gradient of slopes was 30 degrees.

2.4 Conclusions

The tree species *Quercus mongolica, Quercus aliena* var. *acutiserrata* and *Quercus dentata* are widespread and often dominant species in the temperature zones in China (WU 1980, FANG et al. 2009) and in the montane zone of Qinling Mts., but in different altitudinal belts (WU 1980, MENITSKY 2005). Until now, most studies were made with relative few relevés distributed over very large regions, and only referred to **dominant species**, including the studies of *Quercus aliena* var. *acutiserrata* forests (Chinese formation) (WU 1980, ZHU 1983, WANG 1989, YING 1994, ZHAO et al. 2003, ZHANG et al. 2010), and of the *Quercus mongolica* (*syn.Q. liaotungensis*) forests (Chinese formation) (WU 1980, THE COMPILED COMMISSION OF FORESTS OF GANSU 1998).

The present study used the BRAUN-BLANQUET appoach for the phytosociological vegetation recording, which was not employed in this region before. It used all vascular plant species of all layers for classification and ordination. Another-phytosociological vegetation study (TANG et al. 2009) with BRAUN-BLANQUET approach in the warm-temperate zone of China about deciduous *Quercus* communities was made in a very large region (from 32°30'-42°30'N, 103°30'-124°10'E with 80 relevés), but not in Qinling Mts. There are many endemic species of the Qinling Mts. in the **diagnostic species combination** the *Quercus dentata*–*Quercus aliena* var. *acutiserrata* community group and the *Sorbus alnifolia*–*Quercus mongolica* community group, only located on the Qinling Mts.

The studied forest vegetation was arranged in 7 communities and 3 community groups in a synhierarchical system. This approach, by differentiating, for instance, the species of the herb layer, provides more detailed information and a higher traceability of forest communities compared to the recent classification only by dominant tree species. The study of such a relatively small area (ca. 300 ha) showed already a great diversity of forest types (community groups and communities). There are combinations of several species that differ largely from the others, just "dominant types".

Until now, this classification was the only one of phytosociological study in this mountain range of Central China, which was based on complete species lists and their classification, and not on vegetation units derived from and named after the dominating species which until now is the common approach in China. Compared to the intensity of phytosociological research in Europe, there are only few studies in China with its extremely huge size and greatest diversity of vegetation in different geographic conditions and climate zones. It is most important that intensive studies are made all over China like the one in the Western Qinling Mts.

Results based on the phytosocialogical approach are most promissing for an exact description of the seminatural forests in the Western Qinling Mts. Presently an encyclopedia of Chinese vegetation is going to be compiled, and comments are sought to revise the vegetation classification system of China. SONG (2011) proposed "*Collection of communities with the same synusia structure and dominant species in dominant synusia, a similar species composition, as well as the same indentical indicative species group*". He suggsted to use the "diagnostic species" in classifying the association group and the association (SONG 2011), there should be for a new definition of "associations" and "association group" in the Chinese vegetation classification system. This present study with its phytosocialogical approach offers help to renew the Chinese vegetation classification system, in order to encourage/stimulate researches and to compare and to establish a new, complete hierarchical vegetation system in China.

The forest communities of this study are differentiated by edaphic and climatic factors (e.g. sun-exposed south-facing slopes on the lower elevations, i.e. with more direct solar radiation and warm by temperature, of *Quercus dentata*–*Quercus aliena* var. *acutiserrata* community group, compared to the *Sorbus alnifolia*–*Quercus mongolica*-community group, on the upper slopes or ridges and higher elevations, i.e. with also many direct solar radiation but cooler habitats. Or the same community group (*Quercus dentata*–*Quercus aliena* var. *acutiserrata* community group) compared to the *Juglans mandshurica*–*Corylus chinensis* community group, in valleys or on north-facing slopes and on the lower elevations, i.e. cooler and moister habitats.

Other communities are differentiated by their physiognomy as semi-open stands of *Quercus dentata*–*Quercus aliena* var. *acutiserrata* community group compared to nearly-closed and closed stands of the *Juglans mandshurica*–*Corylus chinensis* community group.

All communities were characterised by a high amount of phanerophytes, among them mostly mesophanerophytes and microphanerophytes. Next to phanerophytes were hemicryptophytes and geophytes. There were only few chamaephytes and therophytes. This means warm and water conditions generally are very well for trees and shrubs. This confirms the study about the life-form spectrum of forest plants in the warm temperate zone of China (GAO & CHEN 1998).

In non-metric multidimensional scaling (nMDS) diagram shows, obviously the site conditions of the relevés depend less from the available water contents of soil, but more important is the local impact of altitude (temperature) and direct solar radiation. The reasons may be: 1). the available water contents of soil of 75 % of relevés were moderate to high (90-180 mm). 2). The growing season from April to October is warm and humid (LIU et al. 2003) and the yearly period of concentration of rain is from Juli to September (55 %), often with heavy rain (LIU 1997).

Our study provides information about the species composition and diversity of 4 layers of vegetation in these near-natural forest areas. It may, therefore, act as a recommendation for selection of site-adapted timber species within seminatural forestry, e.g. certain tree species like *Quercus aliena* var. *acutiserrata* and *Quercus dentata* for the warm dry sites of the of *Quercus dentata*–*Quercus aliena* var. *acutiserrata* community group, *Corylus chinensis* and *Juglans mandshurica* for the shady moist sites of the *Juglans mandshurica*–*Corylus chinensis*–community group or *Quercus mongolica* and *Betula albosinensis* for the cool and fresh sites of the *Sorbus alnifolia*–*Quercus mongolica* community group.

Our study offers information not only about dominant species, but about all species, diagnostic species and also infrequent species, of forest vegetation and forest sites. It could be a good start for further research of indicator species and indicator species groups, to give the ecological basis for protection and sustainable management in this forest area, as an example for the total range of Qinling Mts.

These forests of our research area were hardly harvested officially by the Forest Bureau of Xiaolongshan within the last several decades, nevertheless a small-scale forest use occurred by local farmers. Thus the tree and shrub layer species should reflect near-natural species composition. There was a floristic abundance with a total of 448 vascular species in the 120 relevés of forest stands in this small area of 300 ha accounting for species richness. This richness corresponds to the general high diversity on the Qinling Mts., in comparison to other areas in similar warm temperature climate zones of China (CHENG et al. 1999, WU et al. 2004, GUO & SHANGGUAN 2005, LIU et al. 2006, KANG et al. 2007, SUN et al. 2011). Some species only grow in the montane zone of the Qinling Mts., like *Cornus hemsleyi*, or *Sorbus hupehensis*.

Highest species richnesses were observed for the *Viola collina*–*Quercus aliena* var. *acutiserrata*–community and for the *Viola phalacrocarpa*–*Quercus mongolica*–community. The community VcQa is the transition between *Quercus dentata*–*Quercus aliena* var. *acutiserrata*-community group (CG QQ) and *Sorbus alnifolia*–*Quercus mongolica*-community group (CG SQ), while the community VpQm is the transition between CG SQ and *Juglans mandshurica*–*Corylus chinensis*–community group (CG JC). The transitional position, better water situation and varied relief may be the main reasons of the high richness. There seems to be an urgent demand to continue with further efforts in researching natural vegetation, forest sites and monitoring of ecosystems in this area and all the Qinling Mts. The description of the present situation of the vegetations and forest sites also offers a basis for real vegetation map and for further recording of repeated studies of forest vegetation dynamic research.

There are many aspects left, waiting for research. Climate and geology combine a mosaic of biogeographic areas in multiple ways. In order to understand the relationship between forest site, the succession and productivity of seminatural forests in the montane zone of the Western Qinling Mts, we need still further analyses with more information about forest stand structure on the different forest sites.

3 Stand structure, regeneration and site quality of the species-rich mountain forests in the Western Qinling Mts. – Suggestions for conservation and silviculture on an ecological basis

Broad-leaf mixed forest on moist, shady, sub-montane site
(Photography: ALBERT REIF 2008)

3.1 Introduction

3.1.1 Natural Forests Protection Program

In China, the regions on the upper-middle catchments of Yangtze and Yellow rivers, including the forests of the Qinling Mountains (Qinling Mts.) provide important ecosystem functions and services such as biodiversity conservation, erosion control and water supply for a vast human population (SFA 2003). Forests in these regions have a long history of over-exploitation and degradation by humans. Therefore, a logging ban had been imposed upon these regions since the national Natural Forests Protection Program (NFPP) was started after the catastrophe of floods in 1998 (NDRC 2007, MEP 2008). The NFPP has been prolonged with a second phase till 2020 (SFA 2000b, 2010c). The State Forestry Administration's aim is to develop a future strategy for conservation and sustainable forest management in these regions following this interim protection program (LU & ZHANG 2003, SFA 2006).

In the Western Qinling Mts., the Forest Bureau of Xiaolongshan (ref. to Chapter 1) is looking for strategies to develop a sustainable forest management plan for its state-owned forest area of 0.8 Mio. ha under the national protection program NFPP (FOREST BUREAU OF XIAOLONGSHAN 2006).

3.1.2 Selective harvesting and forest products in the Western Qinling Mts.

In the research region in the Western Qinling Mts., all trees with a diameter >5cm can be sold profitably. Preferred species for timber are oaks, e.g. *Quercus aliena* var. *acutiserrata*, *Quercus mongolica*; pines, e.g. *Pinus armandii*, *Pinus tabuliformis*, and the deciduous broad-leaf tree species e.g. *Betula albosinensis*. For paper production *Populus* sp., and *Betula platyphylla* are used (FOREST BUREAU OF XIAOLONGSHAN 2006).

In the research region, ca. 20 % of the total forest area are at lower altitudes of hills and areas which are close to forest roads. These forests are often even-aged monoculture plantations with native conifer species for example *Pinus tabuliformis* (11 %), or *Pinus amandii* (3 %), or non-native conifer species like Japanese larch *Larix* *kaempferi* (5 %) which have been planted after the clear-cutting of the natural forests (ref. to Chapter 1.6).

In the oak forests of the research area (ca. 80 % of the total forest area) there was no actual clear-cutting, but in the past, it was strongly affected by selective cutting and thinning for timber, in short intervals, mostly by the Forestry Bureau Xiaolongshan (Forest Bureau of Xiaolongshan 2006). Few trees were probably cut by local farmers for building. As a result of over-exploitation of bigger trees, only very few trees of >20 cm diameter at breast height (dbh) are left, so the volume per ha is rather low (Forest Bureau of Xiaolongshan 2006). Dead wood was used as firewood by farmers living near the forest area. Cutting of live trees for firewood was forbidden by law, however, local farmers were allowed to collect standing or fallen dead trees for firewood in the state-owned forests. In this study, therefore, dead trees were not inventoried. Grazing was forbidden by law, nevertheless, a small quantity of cattle, goats, and sheep of local farmers were seen passing through the forests on the way to mountain pathes.

3.1.3 Knowledge about common tree species

The knowledge about common tree species in the Qinling Mts. and their characteristics and position in succession can be found in literature: The **distribution** of the species: *Quercus aliena* var. *acutiserrata* grows on altitudes 1500-1800 m a.s.l., *Quercus mongolica* on 1800-2000 m, *Betula albosinensis* on >2000 m. The species *Quercus dentata* occurs on warm sites at 1500 m, often after a forest fire (Wu 1980). Wu (1980) described the characteristics of the tree species *Quercus dentata, Quercus aliena* var. *acutiserrata*, *Quercus mongolica*, and *Betula albosinensis*, which prefer light, and are drought tolerant, with a longer life; *Corylus chinensis, Juglans mandshurica* are shade-tolerant, long living and prefering water; *Betula platyphylla* is a pioneer species, prefering light, and is short living; *Betula albosinensis* is longer living, prefers light and grows on cool sites; *Acer spp.* prefering water, are no long living species. The Compiled Commision of Forests of Gansu (1998) described the position of species in the **succession** according to altitudes:

1) The ***Quercus aliena* var. *acutiserrata*** dominated forests grow on slopes between 1500-1800 m, and have two different tendencies in slightly different site conditions:

- on the sunny slopes, *Quercus aliena* var. *acutiserrata* is dominant;
- on the shady slopes or in valleys, *Quercus aliena* var. *acutiserrata* is not any more dominant, but mixed with other native deciduous broad-leaf tree species.

2) The ***Quercus mongolica*** dominated forests grow on sites between 1800-2000 m, and have two different tendencies in slightly different site conditions:

- on the sunny slopes *Quercus mongolica* is dominant;
- on the shady slopes or in valleys: *Quercus mongolica* is not dominantly but mixed with other native deciduous broad-leaf tree species.

3) The ***Betula albosinensis*** mixed with ***Betula platyphylla*** forests grow on the sites >2000 m, *Betula albosinensis* dominanted often over *Betula platyphylla.*

3.1.4 The 3 forest community groups, the 7 communities and their sites

In Chapter 2, the oak forests and their sites were classified, by their understory vegetation into the **3 community groups** (site units) and the **7 communities** (7 sub-site units), including compositions of all vascular plant species (the diagnostic, the constant and the dominant species), and including site condition patterns. The differences within the 3 community groups and the 7 communities were the composition of herb, shrub, and tree species, esp. diagnostic species (details refer to Chapter 2). **Table 3.1** shows only the diagnostic tree species, their dominance and and their different sites.

3.1.5 Objectives and research questions

The forest areas were highly degraded by humans in the past, but they still have a great ecological value for water supply and for the people there. Therefore, their management should be oriented towards a system that supports natural processes. Silviculture on an ecological basis should help to maintain the biodiversity, and to increase the multifunction of the semi-natural production-forests (Wirtschaftwald). There should be less intervention and less disturbance by carefully using, and supporting their wide variety of potential timber and non-timber forest products. This would contribute to reducing poverty of the population (ref. to Chapter 1).

Table 3.1: The site conditions and diagnostic tree species of 3 community groups and 7 communties

Community group	Community	SITE: Altitude m	SITE: Ecological condition	Diagnostic tree species*	Dominant species
Sunny and dry slopes, warm, low altitudes					
CG1 Q. aliena forests on sunny, dry, warm, sub-montane site (**CG QQ**) (n=55)	**C1** *Quercus aliena* forest (**VuQa**) (n=19)	1600-1700	sunny slopes inclination of slopes ca. 30˚	*Q. aliena* var. *acutiserrata* *Q. dentata* *Pinus armandii*	*Q. aliena* var. *acutiserrata*
	C2 *Quercus aliena* mixed forest (**VcQa**) (n=36)	1700-1900	sunny to semi shady and variable positions slopes different exposition	*Q. aliena* var. *acutiserrata* Other species	*Q. aliena* var. *acutiserrata*
Sunny and fresh slopes, cool, high altitudes					
CG2 Q. mongolica forests on sunny, fresh, cool, montane site **(CG SQ)** (n=39)	**C3** *Q. mongolica*-*Betula* mixed forest (**AcQm**) (n=15)	2000-2150	ridges	*Q. mongolica* *Betula albosinensis* *Betula platyphylla*	*Q. mongolica* *Betula platyphylla*
	C4 *Q. mongolica* - *Sorbus* mixed forest (**VpQm**) (n=24)	1800-2000	variable positions of slopes upper slopes inclination of slopes >35˚	*Q. mongolica* *Cornus hemsleyi* *Sorbus alnifolia* *Carpinus turcyan*	*Q. mongolica* *Q. aliena* var. *acutiserrata*
Shady and moist valleys or lower slopes, low altitudes					
CG3 Broad-leaf mixed forests on shady, moist, warm, sub-montane site (**CG JC**) (n=26)	**C5** *Quercus aliena* mixed forest on warm and moist valleys (**CrQa**) (n=12)	1600-1700	shady valleys inclination of slopes <20˚	*Corylus chinensis* *Ulmus davidiana* var. *japonica*	*Q. aliena* var. *acutiserrata* *Corylus chinensis*
	C6 *Juglans- Fraxinus* mixed forest (**OgJm**) (n=5)	1800-1900	shady valleys inclination of slopes <20˚	*Juglans mandshurica* *Fraxinus chinensis*	*Juglans mandshurica* *Fraxinus chinensis*
	C7 Corylus-Acer mixed forest (**LbCc**) (n=9)	1700-1900	shady lower slopes inclination of slopes ca. 30˚	*Fraxinus platypoda* *Acer pictum* subsp. *mono* *Juglans mandshurica* *Corylus chinensis* *Ulmus davidiana* var. *japonica*	*Juglans mandshurica*

***Diagnostic species:** refer to Chapter 2.2.6, and **Annex 2.1** the phytosociological vegetation table. The **diagnostic species** were found in higher frequency and with bigger cover-abundance as to Braun-Blanquet in a given community or also in a given community group, with a smaller frequency and cover in others. i.e. they were indicator species for site conditions, but not always absolutely dominant species.
CG1 or **CG QQ:** *Quercus dentata–Quercus aliena* var. *acutiserrata*-community group. **C1 or VuQa:** *Vicia unijuga–Quercus aliena* var. *acutiserrata*-community. **C2** or **VcQa**: *Viola collina–Quercus aliena* var. *acutiserrata*-community. **CG2** or **CG SQ:** *Sorbus alnifolia–Quercus mongolica*-community group. **C3** or **AcQm:** *Agrostis clavata-Quercus mongolica*-community. **C4** or **VpQm:** *Viola phalacrocarpa-Quercus mongolica*-community. **CG3** or **CGJC:** *Juglans mandshurica–Corylus chinensis*-community group. **C5** or **CrQa:** *Carex rubrobrunnea* var. *taliensis-Quercus aliena* var. *acutiserrata*-community. **C6** or **OgJm:** *Oxalis griffithii–Juglans mandshurica*-community. **C7** or **LbCc:** *Laportea bulbifera-Corylus chinensis*-community.

Ecological and silvicultural knowledge about the forests in the region, however, is very poor so far. Therefore, it is important for managers and practioners to know more about forest sites conditions, about their relation with growth of tree species, and their regrowth, about forest dynamics to develop future strategies for conservation and a sustainable forest management in this area, after the national interim protection program NFPP (FOREST BUREAU OF XIAOLONGSHAN 2006).

The results of Chapter 1 offer informations about varying forest vegetation under different site conditions refering to temperature, light, and water, due to altitude, relief, soil. The **objectives** of this part of the study are to offer information concerning forest management and forest protection: 1) to analyse **stand structure**s related to the 7 communities and their 3 upper unit community groups in order to understand current and future forest succession processes, i.e. to find and to explain differences and similarities of stand structures between the different site types (forest vegetation types), based on their sites and their successions. 2) to **propose** the choice of site-adapted tree species for sustainable forest management. 3) to **anticipate** forest stand developments within oak forests in the Western Qinling Mts., protected since 1998. The research questions of this part of the study are:

1. To assess the **stand structure** in the 3 community groups and the 7 communities:
   - How do the number of trees per hectare, the basal area and the volume differ between the 3 groups and the7 communities?
   - How does the number of regrowth per hectare vary between the 3 different groups and the 7 different communities?
   - How do top heights reflect the site quality of the 3 community groups?
2. To find **successional pattern** or trends in the 7 communities:
   - How does the number of trees per hectare vary in different dbh classes for individual important tree species in the 7 communities?

- How does the number of regrowth per hectare vary in different height- and dbh-classes for individual important tree species between the 7 communities?

3. To assess **diversity** and **life form spectra** in the 3 community groups and the 7 communities:
   - How does the diversity vary in the 4 different vegetation layers between the 3 community groups and the 7 communities?
   - How do the life forms spectra in the herb layer differ between the 3 community groups and the 7 communities?

3.2 Methods

3.2.1 Study area

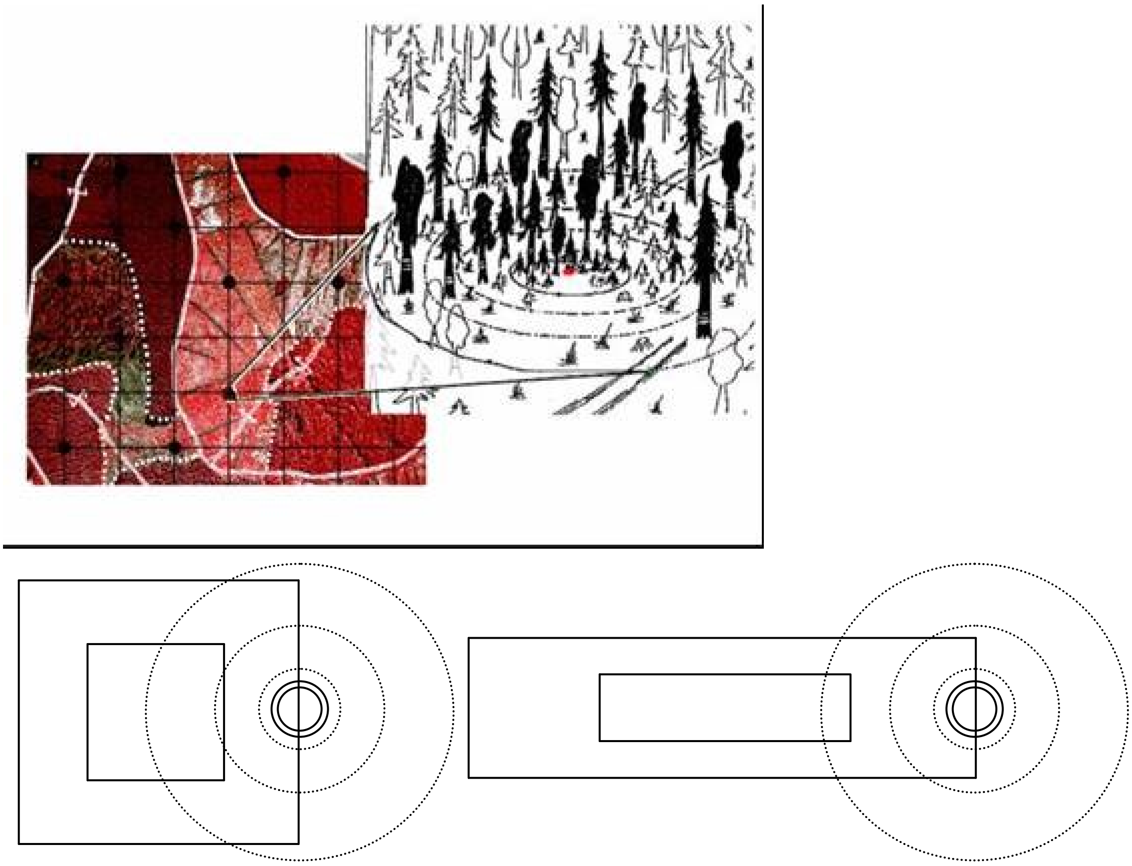
The inventoried sample forest stands were located in semi-natural mixed oak forests that were harvested about 40 years ago by the Forest Bureau of Xiaolongshan in Western Qinling Mts., central China. Since 1998 these forests have remained unthinned and under protection. The selection criteria of research area, its location and characteristics are described in Chapter 2.3 of this thesis.

3.2.2 Sampling design and measurement

120 plot data were recorded from June to August in 2007 and 2008 following a systematical design in a 100 × 200 m grid (ref. to Chapter 2.2.2 and **Fig. 2.2**). The grid was linked to the Gauß-Krüger-coordinate system and combined with the grid of the Chinese National Forest Inventory (3 × 3 km) (ref. to Chapter 2.2.2).

At each grid point a series of sample plots (N=120) consisting of concentric circles were established. This is the similar design developed by the Forest Administration of the Federal State Baden-Württemberg in Germany (FVA 2004). At each grid point also the vegetation releves (N=120) were established (**Fig. 3.1** and ref. to Chapter 2.2.2).

The parameters for the stand structure, e.g. species, height, dbh etc. were recorded (see **Annex 3.1**). For every tree dbh >5 cm, its exact position, i.e. azimuth and distance from the centre was recorded. All trees were measured according to their dbh and the height limit-ranges defined for each circle (**Table 3.2**). The place of measured trees for each circle was defined by their dbh and the height limits (**Table 3.2**). At each grid point the natural regrowth was recorded in the circles with different radii depending on the diameter class according to height- and dbh-classes as given in **Table 3.2.**



A.

B.

Fig. 3.1: Systematic sampling design with 5 concentric circle sample plots (radius = 1,5 m, 2 m, 3 m, 6 m, 12 m) used for the inventory of forest stand structure (adapted from FVA 2004 see A) and the location of the sampling plots of the vegetation survey relative to the structure plots Braun-Blanquet approach for vegetation inventory (square 20 ×20 m, 10 ×10 m and rectangle 10 × 40 m, 5 × 20 m) (B).

According to the Chinese standard of forest inventory, the measurable size of dbh was started with 5 cm for timber and dbh <5 cm for regrowth, and not with 10 cm like in Germany.

Table 3.2: Diameter (dbh) and height limits of the trees, recorded in the concentric circle sample plots of the inventory adapted from FVA (2004).

DBH cm	Height m	Radius of circle m	Area of circle m^2	1 measured tree equivalent to trees/ha
<5	**≤1.3**	1.5	7.1	1415
<5	**>1.3**	2	12.6	796
5-<10	**>1.3**	3	28.3	354
10-<20	**>1.3**	6	113.1	88
≥20	**>1.3**	12	452.4	22

To describe the forest stand structure, at first, the following important structural attributes density (trees/ha), basal area (m^2/ha), volume (m^3/ha) for each species (dbh ≥5 cm) and the density (trees/ha) of their regrowth (dbh <5 cm) were calculated for each plot. The basal area was derived from the dbh, the volume was caculated form the dbh and the height, depending upon site quality. Therefore, both are important the show the difference of sites.

The volumes (m^3/ha) of the measured trees were based on their diameter (dbh) and height after FOREST BUREAU OF XIAOLONGSHAN's allometric volume equation for species groups (**Table 3.3**).

The next step, the distribution of the above-mentioned structural attributes per diameter class (dbh classes for trees dbh ≥5 cm, height- and dbh-classies for regrowth) for each species was calculated for each plot.

Table 3.3: Functions of allometric volume equations (FOREST BUREAU OF XIAOLONGSHAN 2006)

Species	Allometric volume equation
Quercus sp.	$6.0970532\times10^{-5}\times D^{1.8735078}\times H^{0.94157465}$
Betula albosinensis	$5.2286055\times10^{-5}\times D^{1.8593621}\times H^{1.0140715}$
P. davidiana, *Butula platyphylla, Populus* sp.	$5.4031091\times10^{-5}\times D^{1.9440215}\times H^{0.93067368}$
Pinus sp.	$5.9973839\times10^{-5}\times D^{1.8334312}\times H^{1.0295315}$
Other broad-leaf	$5.7887451\times10^{-5}\times D^{1.8445849}\times H^{0.98088457}$

All indices were summarized and presented for the 3 community groups and the 7 forest communities:

- Totals of all species (56 tree species together);
- 10 important species separately (*Quercus aliena* var. *acutiserrata, Quercus*

mongolica, Betula platyphylla, Ulmus davidiana var. *japonica, Sorbus alnifolia, Corylus chinensis, Juglans mandshurica, Quercus dentata, Betula albosinensis*, *Pinus armandii*);

- 46 other, less important species together.

The "**important species**" were those which occurred with high frequency like *Quercus aliena* var. *acutiserrata*, *Quercus mongolica*, *Betula platyphylla*, *Ulmus davidiana* var. *japonica*; and are valuable from forest utilization point of view i.e. timber, non-timber forest products (NTFP) like *Pinus armandii*; act as indicator of forest site like *Sorbus alnifolia*, *Corylus chinensis*, *Juglans mandshurica*, *Quercus dentata*, *Betula albosinensis*.

3.2.3 Tree top height

The measurements of the tree top heights were used to evaluate the quality of soil in the different stands, concering different tree species also in mixed stands. The dominant trees as top height trees were selected ignoring the species, but the top heights of each species or each species groups were calculated individually, following ZINGG (1999). The top height was calculated from the average height of the 2 biggest dbh trees (as the top height trees) of each species or each species groups in each plot, according to FVA (2004). In the research area, however, this is the first study about different groups based on vertical classification, according to the guidelines of the Forest Administration of the Federal State Baden-Württemberg in Germany (FVA 2004). Therefore, the height of all the trees were measured in the stands before stratifying them into "dominant tree species" or "subdominant tree species", based on height and dbh.

The determination of **age** of the top height trees was not done by counting the year rings of each measured tree, but by counting the year rings of trunks nearby, by counting the whorls of coniferous trees, by referring to secondary sources ("field book", Revierbuch), or by estimating the age while considering site growth dynamics, according FVA (2004).

The height distribution of the top height trees in the 3 tree species groups: the *Quercus* species, the broad-leaf tree species, and the *Betula*/*Populus* species were calculated as indicator of site productivity (Standort-Bonität). These calculations were done in the 3 community groups (site types). The 3 tree species groups followed the tables of the site index (SI) (FOREST BUREAU OF XIAOLONGSHAN 1982b) with absolute top heights (**Annex 3.5**).

3.2.4 Quantification of life-forms and diversity

Cover values were seen as important for each species and used for the calculation of their life form and the diversity indices. (The assessment of the cover data ref. to Chapter 2.2).

The life-forms of herb layer in in the 3 community groups and in the 7 communities were analysed, following RAUNKIAER (1934), modified by CAIN (1950) and were based on the "Flora of Xiaolongshan Mountain of Gansu Province" (An 2001) and "Flora of China" (http://www.efloras.org).

The diversity indices (richness, evenness, Shannon index, Simpson index) in 4 vegetation layers of in the 3 community groups and in the 7 communities were analysed by the cover of vegetation. In order to characterise the stand structure of the forest communities, the species richness (α-richness) (GREIG-SMITH 1983) based on SHANNON & WEAVER (1949) in the 4 vegetation layers were calculated with the software PC-ORD 5 (MCCUNE & GRACE 2002), as well as the other 3 diversity indicies: evenness (based on Shannon index, PIELOU 1969), Shannon index (SHANNON & WEAVER 1949, modified by GREIG-SMITH 1983), Simpson index (SIMPSON 1949, modified by PIELOU 1969).

Species richness and evenness represent two different aspects of biodiversity. Therefore, they are both important for the evaluation of the results. It is useful for evaluation of biodiversity, proposed in the form of HAEUPLER (1982) to show them together, but separatel and not only combining them in a diversity index. The Shannon-index and the Simpson-index combined the species richness and the evenness, while in the Simpson-index weighted more evenness.

The 4 layers were 1^{st} tree layer (>10 m), 2^{nd} tree layer (5-10 m), shrub layer (1-5 m) and herb layer (<1 m) (ref. to Chapter 2.2), they give more structural details about different forest stands.

The 3 diversity indecies allow better description of the different forms and degrees (ratings) of mixed stands. The comparison of species numbers is not sufficient without information on the species composition and dominance relationships (evenness) in the vegetation for the evaluation of biodiversity (KIEHL 2000). The total species numbers of each communities and the species compositon of the 4 layers separate were described for the 7 communities (ref. to Chapter 2).

3.2.5 Data analysis

Non-parametric statistical tests (ZUUR et al. 2007), i.e. the Kruskal-Wallis H-test (KW-H-test, for comparisons on three community groups or seven communities), rep. the Mann-Whitney-U-test (MWU test, for pairwise comparisons) were used to compare the differences in the 3 community groups and in the 7 communities, i.e. to explore whether there was a difference between the of structural variables (structural attributes, e.g. density, basal area, volume, life-forms and diversity indices) by the different community groups or by the different communities.

The tested null-hypothesis of the KWH test and MWU test was: there was no difference in the median values of the structural attributes for the same community groups or for the same communities or between all the structural attributes seen in two or more community groups or in two or more communities.

For computations used the software Microsoft Excel and the statistical software package SPSS 20.0 (SPSS Inc., Chicago, IL, USA) were applied.

3.3 Results

3.3.1 Stand description

3.3.1.1 Density, basal area, volume and regeneration at forest level (120 plots)

A total of 56 tree species (dbh ≥5 cm) were identified and measured in 120 plots (Annex 3.6). 6 species of the 10 important tree species were most common in frequency, i. e. *Quercus aliena* var. *acutiserrata, Quercus mongolica, Betula platyphylla, Sorbus alnifolia, Corylus chinensis, Ulmus davidiana* var. *japonica* (**Table 3.4, Annex 3.7**). But the proportion of their density was between 20 % and 3 % of the total density, and the proportion of their volume ranged between 24 % and 2 % (**Table 3.4, Annex 3.7**).

There were 4 more diagnostic species (ref. to Chapter **2**) with less frequency, i. e. *Juglans mandshurica, Quercus dentata, Pinus armandii, Betula albosinensis*, with less density and volume (**Table 3.4, Annex 3.7**). These 6 plus 4 species represented 75 % of total volume and 50 % of total density. The forest type of the research area was named “oak forest” in the “field book” (Revierbuch) of the Forest Bureau of Xiaolongshan. The frequencies of the two *Quercus* species were confirmed the forests are oak forests, but the density and the volume of the two *Quercus* species showed the foroests arerather “mixed forests”.

Table 3.4: Frequency (%) of the tree species (dbh >5 cm) in 120 plots and their mean density, basal area, volume, and in percentage to total tree species in the 120 plots.

Species	Density		Basal area		Volume		Frequency
	trees ha^{-1}	%	m^2 ha^{-1}	%	m^3 ha^{-1}	%	%
Quercus aliena var. *acutiserrata*	**277**	*20*	**5**	*18*	**33**	*17*	62
Quercus mongolica	**123**	*8*	**6**	*20*	**44**	*24*	44
Betula platyphylla	**80**	*5*	**2**	*9*	**18**	*10*	33
Sorbus alnifolia	**97**	*6*	**1**	*3*	**5**	*2*	25
Corylus chinensis	**37**	*3*	**1**	*4*	**5**	*4*	23
Ulmus davidiana var. *japonica*	**33**	*4*	**<0.5**	*3*	**3**	*3*	23
Juglans mandshurica	**21**	*4*	**1**	*11*	**7**	*12*	13
Quercus dentata	**19**	*1*	**1**	*2*	**3**	*2*	11
Pinus armandii	**28**	*2*	**<0.5**	*1*	**1**	*1*	8
Betula albosinensis	**3**	*<0.5*	**<0.5**	*1*	**2**	*2*	4
Other species	**481**	*46*	**6**	*29*	**36**	*25*	96
Total	**1199**	*100*	**24**	*100*	**156**	*100*	

At forest level (120 plots), ***Quercus aliena* var. *acutiserrata*** was most abundant in naturally regenerated tree species (young trees with <5 cm dbh) among the 10 important tree species (**Annex 3.8**). ***Q. aliena* var. *acutiserrata*** showed more regrowth than other tree species, its mean density ranging from 1,773 trees/ha in height classes 0-20 cm to 359 trees/ha with height over 130 cm in the dbh class 4-5 cm. Its median density of regrowth was zero in any height classes and dbh classes. i.e. the regrowth was not evenly distributed in the forest area, i.e. in more than 50 % plots there was no regrowth at all, but in other plots there was high density (**Annex 3.8, Fig. 3.3**).

Othertree species of the remaining other 9 important species exceeded a density of 500 trees/ha (**Annex 3.8**). Interestingly, young growth of early successional tree species such as *Betula*, *Sorbus* and *Ulmus* was found in very low densities (<400 trees/ha). This might prove that there was less human disturbance in recent years, so closed canopies not offered regrowth for early succession species, like *Betula platyphylla*. This might also prove that not all the forest site was favourable for the regeneration of those species.

Besides the 10 tree important species, **natural regrowth** of all the **other 46 tree species together**, was close to 8,000 trees/ha (**Annex 3.8**). This, too, proved a high potential of regrowth for mixed forest with an abundance of species.

Annex 3.8, Fig. 3.2 shows the distribution of the regrowth (dbh <5 cm) of **all species** combined at forest level in the 3 height classes (0-20 cm, 20-50 cm, 50-130 cm), and in the 4 dbh classes with height over 130cm (1-2 cm, 2-3 cm, 3-4 cm, 4-5 cm). There was more regrowth with a height <130 cm, mean density ranging between 7,500 and 3,300 trees/ha. There was less regrowth with height over 130 cm (2,500-1,200 trees/ha), i.e. 1,200 trees/ha with dbh 4-5 cm showed a good natural regrowth capacity (**Annex 3.8, Fig. 3.2**).

There was more regrowth of all the **other species** combined (excluding the above 10 important species) in the all height classes <130 cm, and the two smallest dbh classes with height over 130 cm. Their mean density ranged between 5,000 trees/ha and 728 trees/ha. In the dbh classes 3-4 cm and 4-5 cm there was a varying density depending on the plots (**Annex 3.8, Fig. 3.4**).

3.3.1.2 Density, basal area, volume and regeneration at the community level

There were significant differences between the **3 community groups** in **density**, **basal area**, and **volume** of **all tree species combined** (**dbh ≥5 cm**) after KW-test, as well as MWU-test (**Fig. 3.5**). This confirms that on the different site units (ref. Chapter **2**) there are also differences, not only in vegetation, but also in the stand structures. The community groups QQ on dry sunny warm submontane-sites had a significantly higher density than the community group JC on moist shady warm submontane-sites. There was no significant difference in the density of the community SQ to the other community groups QQ and JC. But the basal area and the volume in the community group SQ on fresh sonny cold montane-sites were significantly higher than in the community groups QQ and JC (**Fig. 3.5**).

Between the **7 communities**, the **volume** and the **basal area** of **all tree species combined** (**dbh ≥5 cm**), showed significant differences after the KW H-test. There was, however, no difference in density (**Fig. 3.5, Table 3.5**). The community VuQa on warm sunny dry site had significantly lower basal area and volume than the community VcQa on similar sites (although in the same community group QQ).

Considering the **10 important tree species separately**, there was no such a trend in **the 7 communities and the 3 community groups**. **Volume**, **basal area** and also **density** of *Quercus aliena* var. *acutiserrata* (**Fig. 3.7**), *Quercus mongolica* (**Fig. 3.8**), *Betula platyphylla* (**Fig. 3.6**), *Sorbus alnifolia* (**Fig. 3.9**), *Corylus chinensis* (**Fig. 3.11**), *Ulmus davidiana* var. *japonica* (**Fig. 3.10**), *Juglans mandshurica* (**Fig. 3.12**), *Quercus dentata* (**Fig. 3.13**), *Betula albosinensis* (**Fig. 3.14**) and other species combined (excluding the 10 important species) (Fig. 3.15) varied significantly between the 7 communities and the 3 community groups . This confirms the differences in the vegetation analysis as to the different site units in Chapter **2**.

For *Betula platyphylla* and *Pinus armandii*, however, a different trend was observed. Interestingly, the density and the basal area *Pinus armandii* did not change significantly, either in the 7 communities or in the 3 community groups, but after the vegetation analysis in Chapter **2**, *Pinus armandii* was a diagnostic species of the community group QQ in sonny, dry, warm sites. For *Betula platyphylla* the differences in volume, basal area and density were found only between the 7 communities, but not in the 3 community groups (3 site units), i.e. not due to the sites, but maybe due to succession or disturbance (**Fig. 3.6**).

The density of **regrowth** (**dbh <5 cm**) of all species combined was remarkably high in all the **3 community groups** (**Fig. 3.16**). There was significantly more regrowth in the community groups QQ and JC on low altitude sites (13,000 and 14,000 trees/ha) than in the community group SQ in high altitude site (8,500 trees/ha).

The density of **regrowth** (dbh <5 cm) of the 10 important species were shown separately in the **3 community groups** (**Fig. 3.16**, **Fig. 3.17**, **Annex 3.9)**. Only *Quercus aliena* var. *acutiserrata* and *Ulmus davidiana* var. *japonica* showed differences in density of regrowth in the 3 community groups (**Fig. 3.16**).

There were differences of the regrowth of *Q. aliena* var. *acutiserrata*: significantly more in the community group QQ on warm dry site than in the community group JC on warm moist sites, less in the community group SQ on cool fresh sites.

There was more regrowth of *Ulmus davidiana* var. *japonica* in the community group JC on warm shady moist sites than in the community group QQ on warm sunny dry sites and in the community group SQ on cool sunny fresh sites.

For **all species combined**, **regrowth** (dbh <5 cm) was found in all the **7 communties**, their mean density ranged from 1,200 to 20,000 trees/ha (**Fig. 3.18** and **Annex 3.10**). There was significantly more regrowth in the community VuQa (C1) on warm dry site (19,400 trees/ha) and CrQa (C5) on warm but moist site (19,700 trees/ha), than in other communities: e.g. the community VcQa (C2) on warm dry site, and the communities AcQm (C3) and VpQm (C4) on cool fresh sites, and the communities OgJm (C6) and LbCc (C7) on warm moist sites. The least regrowth was in the community LbCc (1,200 trees/ha), i.e. maybe not due to the sites, but due to succession or disturbance.

Interestingly, only on low altitudes, on similar sites i.e. in the same community groups, there were significant differences of the regrowth for **all species combined** (**Fig. 3.18** and **Annex 3.10**): e.g. for the community group QQ on similar warm, sonny, dry sites, there was significantly more regrowth in the community VuQa than in the community VcQa. For the community group JC, on the similar warm, shady, moist sites, there was significantly more regrowth in the community CrQa than in the communities OgJm and LbCc. But for the community group SQ on high altitudes, cool, sonny, fresh sites, there were no significant differences of regrowth between the two communities AcQm and VpQm.

There was **regrowth of *Quercus aliena* var. *acutiserrata*** only in the 4 communities (**Fig. 3.18** and **Annex 3.10**): VuQa and VcQa on warm site, VpQm on cool site, CrQr on warm moist site. There was significantly more regrowth in the community VuQa on warm dry site, than in the community VcQa also on warm dry site, and in the community CrQa on warm but moist sites. But there were no significant differences in the communities VcQa and CrQa. The community CrQa was a community with *Q. aliena* var. *acutiserrata* as diagnostic species, but this species was not a dominant one on the moist sites any more. In the community VpQm there were *Q. aliena* var. *acutiserrata*, but the species was not dominant any more on the cool sites. There were significant differences in the *Quercus aliena* var. *acutiserrata* community group community group (QQ), between the 2 communities VuQa and VcQa, –the reason is not yet determined/obvious.

A good regrowth (mean density 1,000 trees/ha) of ***Sorbus alnifolia*** was found only in the community CrQa, but in the communities VcQa, AcQm, and VpQm only on single plots (**Fig. 3.19** and **Annex 3.10**), but *Sorbus alnifolia* was the diagnostic species for the commnities AcQm, and VpQm after the vegetation analysis in Chapter 2

In all the **7 communities**, regrowth was found for **other species combined** (excluding the 10 important species) (**Fig. 3.19** and **Annex 3.10**), i.e. a diversity of tree species in regeneration also. In the community CrQa on shady moist warm site, there was the most regrowth (14,800 trees/ha), significantly different with the other communities. In the community LbCc with a similar site condition, there was much less (1,200 trees/ha). The reason maybe not due to the sites, but due to succession or disturbance.

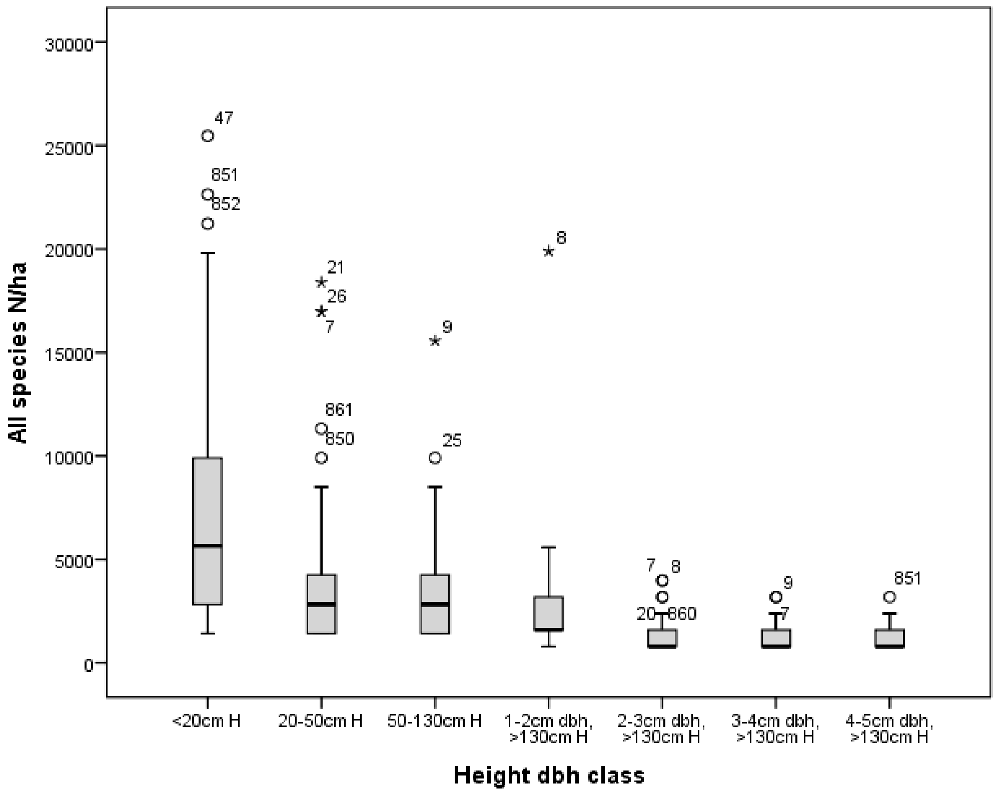


Fig. 3.2: Density (trees/ha) of regrowth of all the species combined in the height and dbh classes in 120 plots. Box plot with the smallest observation (sample minimum), lower quartile, median, upper quartile, and largest observation (sample maximum). The small circles (º) and the stars (*) with numbers are outliers and extreme values with plot numbers, respectively.

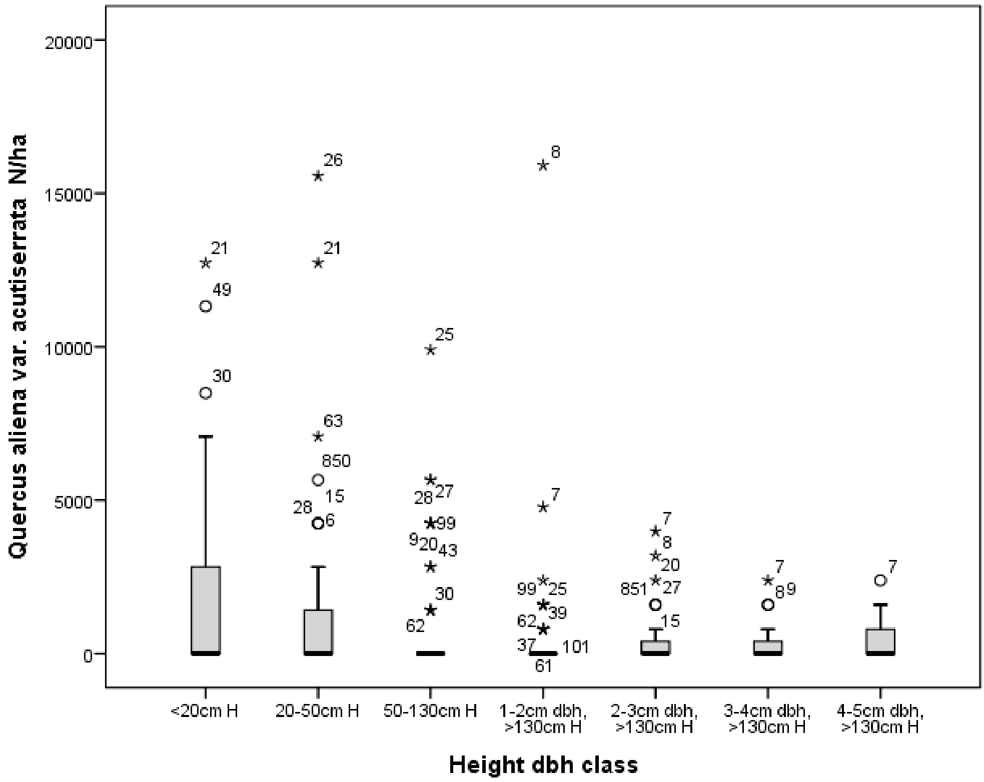


Fig. 3.3: Density (trees/ha) of regrowth of ***Quercus aliena* var. *acutiserrata*** as to **height and dbh classe** in 120 plots. Box plot with median, Q_{25} and Q_{75} (box), outliers and exterme values with their plot numbers.

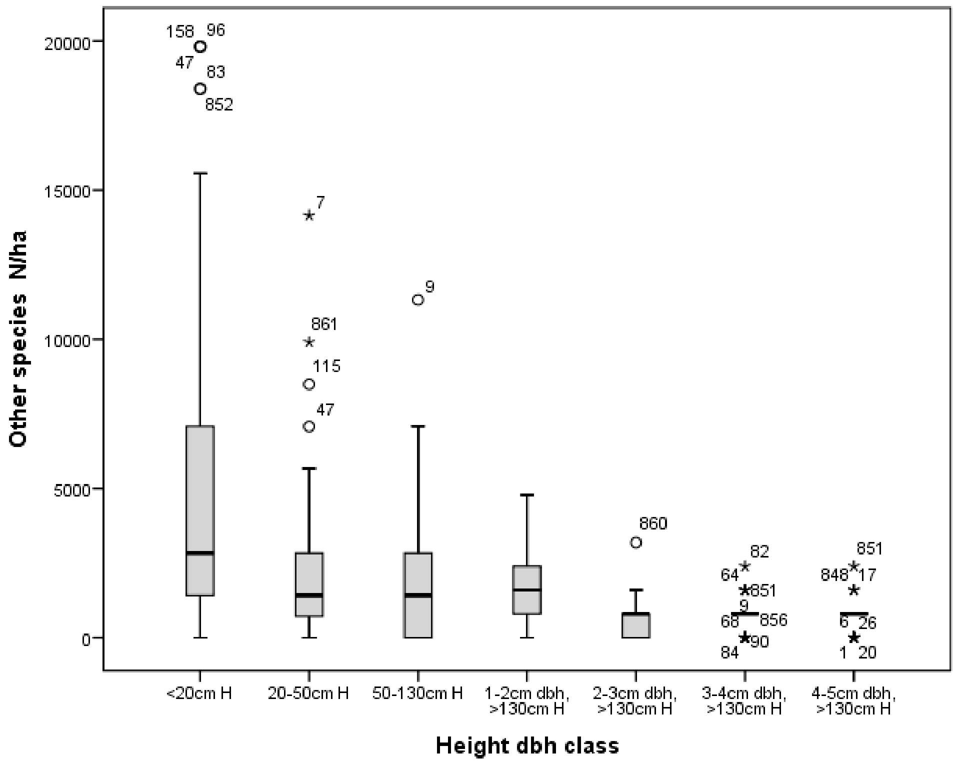


Fig. 3.4: Density (trees/ha) of regrowth of other species combined as to height- and dbh classe in 120 plots. Box plot with median, Q25 and Q75 (box), outliers and exterme values with their plot numbers.

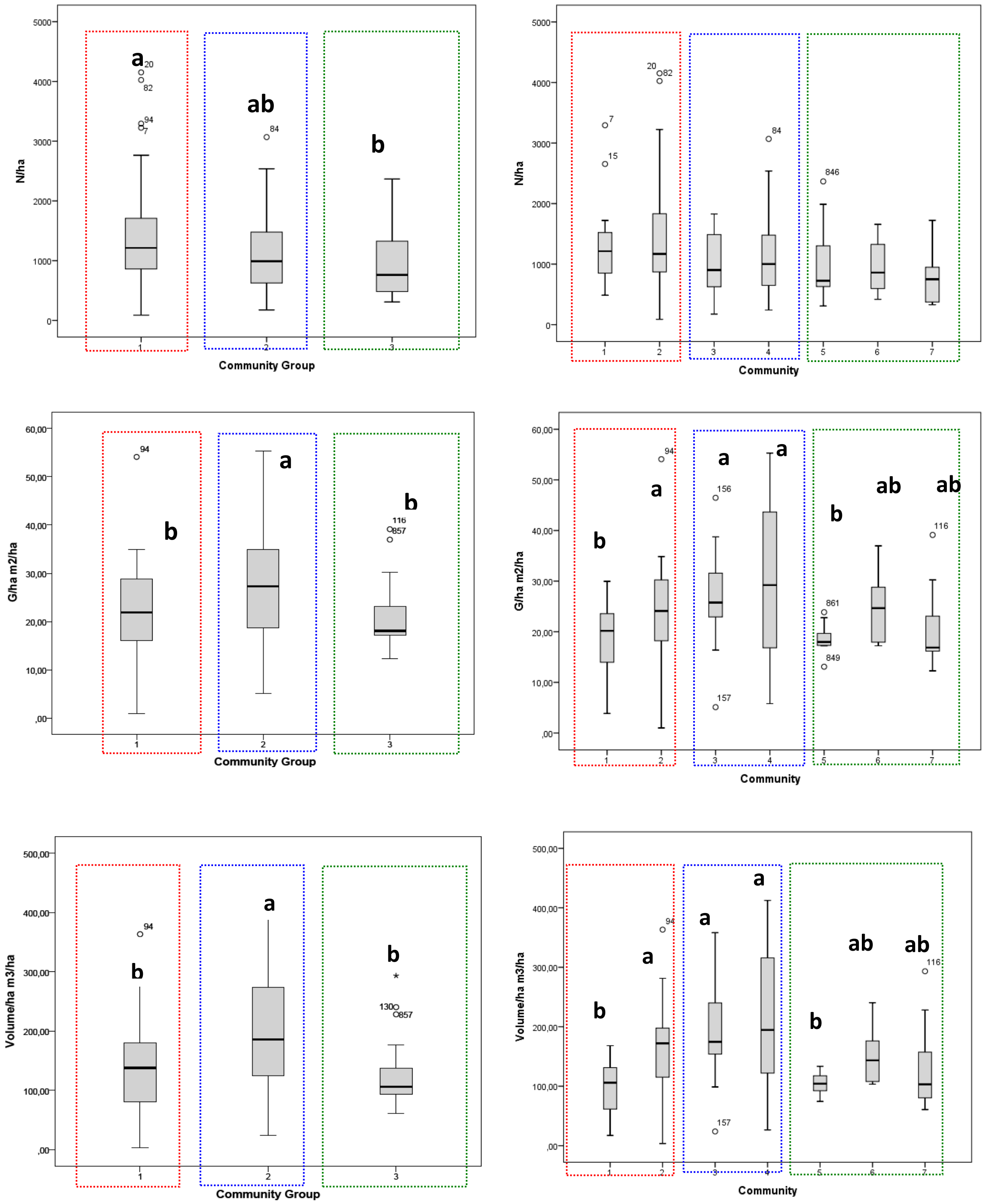


Fig. 3.5: Density (trees/ha), basal area (m^2/ha), and volume (m^3/ha) of the 3 community groups (1: QQ, 2: SQ, 3: JC) (left 3 figures) and the 7 communities (1: VuQa, 2: VcQa, 3: AcQm, 4: VpQm, 5: CrQa, 6: OgJm, 7: LbCc) (right 3 figures), sample size and abbrev. see Table 3.1. Values with different letters in superscript were significantly different based on pairwise comparisons with MWU-test. Box plot with median, Q_{25} and Q_{75} (box), outliers and exterme values with their plot numbers.

Table 3.5: Density (trees/ha), basal area (m^2/ha), and volume (m^3/ha) for the 7 different communities. (VuQa, VcQa, AcQm, VpQm, CrQa, OgJm, LbCc, abbrev. see Table 3.1) (based on trees with a dbh ≥5 cm, values reportet are mean), and in brackets their standard deviation. The differences were tested with KW H-test, *: p <0.05, **: p <0.01. Values with different letters in superscript were significantly different based on pairwise comparisons with MWU-test.

Community plots	**VuQa** **19**	**VcQa** **36**	**AcQm** **15**	**VpQm** **24**	**CrQa** **12**	**OgJm** **5**	**LbCc** **9**
Total (all species)							
Density--	**1301**	**1458**	**1024**	**1138**	**997**	**971**	**804**
	(702)	(932)	(513)	(680)	(645)	(513)	(502)
Basal area*	**18**^{b}	**24**^{a}	**27**^{a}	**30**^{a}	**19**^{b}	**25**^{ab}	**21**^{ab}
	(7)	(10)	(10)	(15)	(3)	(8)	(9)
Volume**	**97**^{b}	**158**^{a}	**190**^{a}	**211**^{a}	**105**^{b}	**154**^{ab}	**138**^{ab}
	(48)	(77)	(85)	(118)	(18)	(56)	(77)
Quercus aliena* var. *acutiserrata							
Density**	**819**^{a}	**360**^{b}	0^{d}	**74**^{c}	**226**^{b}	**4**^{cd}	**29**^{c}
	(770)	(682)		(127)	(301)	(10)	(33)
Basal area**	**12**	**7**	0	**3**	**6**	**<0.5**	**2**
	(8)	(9)		(4)	(4)	(1)	(3)
Volume**	**66**	**46**	0	**19**	**35**	**2**	**14**
	(46)	(64)		(28)	(26)	(4)	(18)
Quercus mongolica							
Density**	**21**^{bc}	**174**^{a}	**195**^{a}	**195**^{a}	0^{c}	0^{bc}	**56**^{ab}
	(81)	(290)	(268)	(246)			(91)
Basal area**	**<0.5**	**5**	**9**	**14**	0	0	**5**
	(1)	(7)	(11)	(16)			(9)
Volume**	**2**	**39**	**65**	**106**	0	0	**36**
	(6)	(53)	(86)	(124)			(69)
Betula platyphylla							
Density**	**21**^{c}	**156**^{ab}	**202**^{a}	**6**^{bc}	**31**^{a}	0^{bc}	0^{c}
	(91)	(296)	(279)	(20)	(33)		
Basal area**	**<0.5**	**4**	**7**	**<0.5**	**3**	0	0
	(2)	(7)	(8)	(1)	(3)		
Volume**	**2**	**30**	**52**	**3**	**16**	0	0
	(10)	(53)	(63)	(12)	(20)		
Sorbus alnifolia							
Density**	**9**^{c}	**120**^{bc}	**26**^{bc}	**259**^{a}	**15**^{ab}	0^{bc}	**39**^{bc}
	(40)	(376)	(75)	(438)	(22)		(118)
Basal area**	**<0.5**	**1**	**<0.5**	**2**	**1**	0	**<0.5**
	(<0.5)	(3)	(1)	(3)	(1)		(1)
Volume**	**1**	**4**	**3**	**12**	**4**	0	**1**
	(3)	(16)	(7)	(18)	(6)		(4)
Corylus chinensis							
Density**	0^{c}	**49**^{b}	**35**^{ab}	**44**^{a}	**72**^{a}	**31**^{ab}	**15**^{ab}
		(187)	(99)	(70)	(176)	(43)	(36)
Basal area**	0	**<0.5**	**1**	**2**	**1**	**2**	**1**
		(1)	(1)	(2)	(2)	(3)	(1)
Volume**	0	**1**	**4**	**11**	**6**	**16**	**4**
		(4)	(8)	(13)	(9)	(22)	(11)

Community plots	**VuQa** **19**	**VcQa** **36**	**AcQm** **15**	**VpQm** **24**	**CrQa** **12**	**OgJm** **5**	**LbCc** **9**
Ulmus davidiana* var. *japonica							
Density**	**60**[bc] (183)	**20**[bc] (69)	**1**[c] (6)	**2**[bc] (6)	**68**[a] (109)	**4**[bc] (10)	**138**[ab] (245)
Basal area**	**<0.5** (1)	**<0.5** (1)	**<0.5** (1)	**<0.5** (1)	**2** (3)	**<0.5** (1)	**1** (2)
Volume**	**1** (3)	**1** (3)	**1** (5)	**1** (3)	**14** (18)	**1** (3)	**6** (12)
Juglans mandshurica							
Density**	0[c]	**1**[c] (4)	0[c]	**2**[bc] (6)	**65**[b] (210)	**132**[a] (111)	**115**[a] (257)
Basal area**	0	**<0.5** (<0.5)	0	**<0.5** (<0.5)	**1** (2)	**13** (9)	**3** (3)
Volume**	0	**1** (4)	0	**1** (3)	**6** (12)	**92** (67)	**21** (25)
Quercus dentata							
Density**	**78**[a] (165)	**23**[ab] (68)	0[bc]	0[c]	0[bc]	0[abc]	0[bc]
Basal area**	**2** (4)	**1** (2)	0	0	0	0	0
Volume**	**11** (20)	**5** (16)	0	0	0	0	0
Pinus armandii							
Density--	**61** (145)	**48** (202)	**1** (6)	**18** (73)	0	0	0
Basal area--	**<0.5** (1)	**<0.5** (2)	**<0.5** (<0.5)	**<0.5** (1)	0	0	0
Volume--	**2** (4)	**3** (11)	**<0.5** (2)	**1** (5)	0	0	0
Betula albosinensis							
Density**	0[bc]	0[c]	**19**[a] (44)	0[bc]	0[abc]	0[abc]	**2**[ab] (7)
Basal area**	0	0	**2** (5)	0	0	0	**0** (1)
Volume**	0	0	**17** (44)	0	0	0	**2** (7)
Other species							
Density*	**233**[b] (322)	**507**[a] (697)	**543**[a] (380)	**539**[a] (432)	**521**[a] (643)	**800**[a] (461)	**409**[a] (192)
Basal area**	**2** (3)	**5** (6)	**8** (4)	**9** (5)	**5** (4)	**9** (5)	**9** (5)
Volume**	**13** (15)	**28** (33)	**48** (29)	**56** (34)	**23** (17)	**43** (30)	**51** (34)

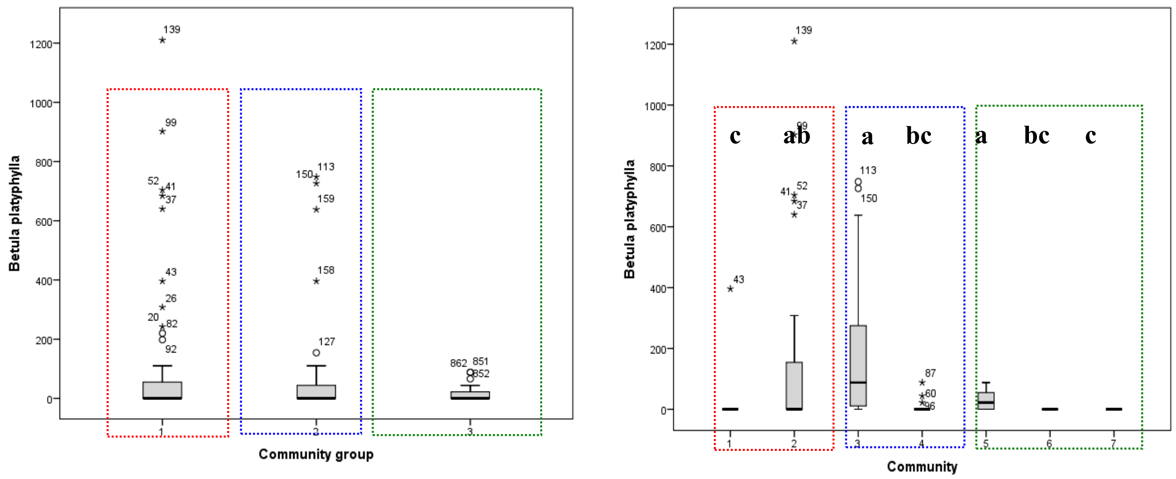


Fig. 3.6: Density (trees/ha) of trees (dbh ≥5 cm) of ***Betula platyphylla*** in the **3 community groups** (left) (1: QQ, 2: SQ, 3: JC) and the **7 communities** (right) (1: VuQa, 2: VcQa, 3: AcQm, 4: VpQm, 5: CrQa, 6: OgJm, 7: LbCc), sample size and abbrev. see Table 3.1. Values with different letters in superscript were significantly different based on pairwise comparisons with MWU-test. Box plot with median, Q_{25} and Q_{75} (box), outliers and exterme values with their plot numbers.

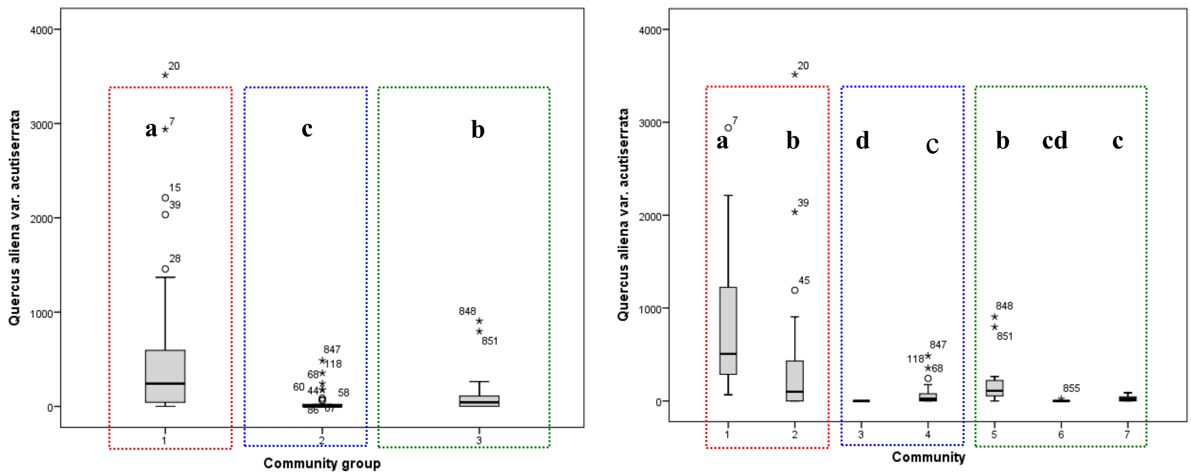


Fig. 3.7: Density (trees/ha) of trees (dbh ≥5 cm) of ***Quercus aliena* var. *acutiserrata*** in the **3 community groups** (left) (1: QQ, 2: SQ, 3: JC) and the **7 communities** (right) (1: VuQa, 2: VcQa, 3: AcQm, 4: VpQm, 5: CrQa, 6: OgJm, 7: LbCc), sample size and abbrev. see **Table 3.1**.

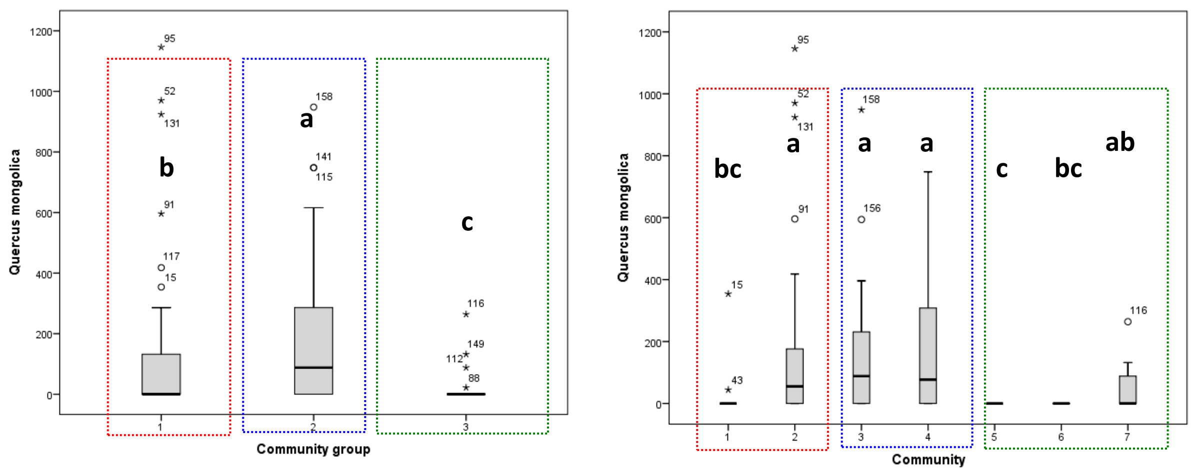


Fig. 3.8: Density (trees/ha) of trees (dbh ≥5 cm) of ***Quercus mongolica*** in the **3 community groups** (left) (1: QQ, 2: SQ, 3: JC) and the **7 communities** (right) (1: VuQa, 2: VcQa, 3: AcQm, 4: VpQm, 5: CrQa, 6: OgJm, 7: LbCc), sample size and abbrev. see Table 3.1**.**

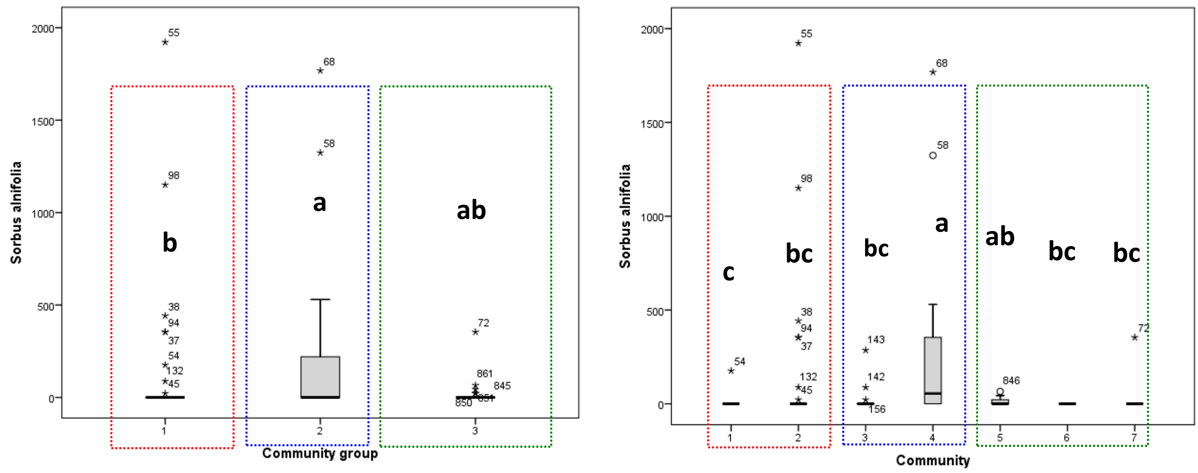


Fig. 3.9: Density (trees/ha) of trees (dbh ≥5 cm) of ***Sorbus alnifolia*** in the **3 community groups** (left) (1: QQ, 2: SQ, 3: JC) and the **7 communities** (right) (1: VuQa, 2: VcQa, 3: AcQm, 4: VpQm, 5: CrQa, 6: OgJm, 7: LbCc), sample size and abbrev. see Table 3.1. Values with different letters in superscript were significantly different based on pairwise comparisons with MWU-test. Box plot with median, Q_{25} and Q_{75} (box), outliers and exterme values with their plot numbers.

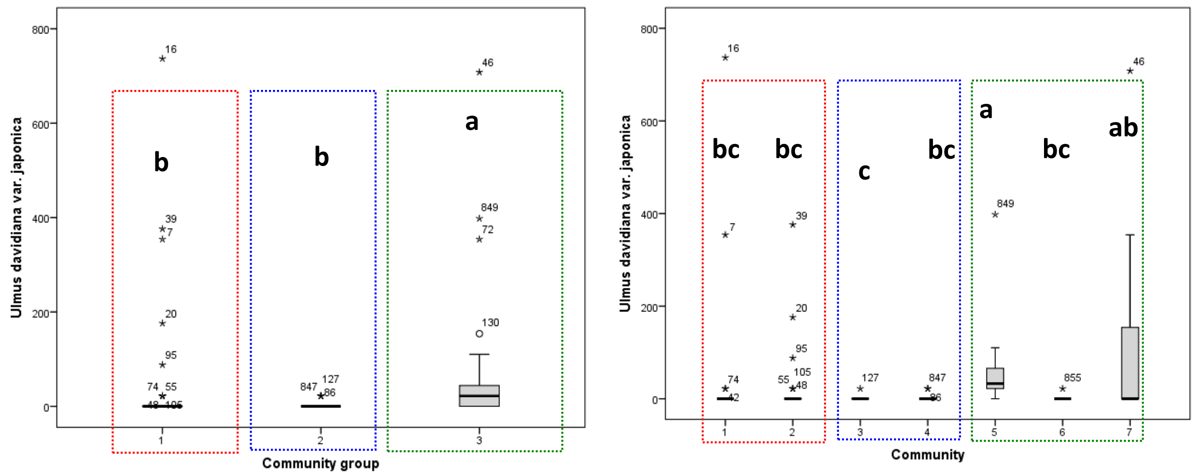


Fig. 3.10: Density (trees/ha) of trees (dbh ≥5 cm) of ***Ulmus davidiana* var. *japonica*** in the **3 community groups** (left) (1: QQ, 2: SQ, 3: JC) and the **7 communities** (right) (1: VuQa, 2: VcQa, 3: AcQm, 4: VpQm, 5: CrQa, 6: OgJm, 7: LbCc), sample size and abbrev. see Table 3.1**.**

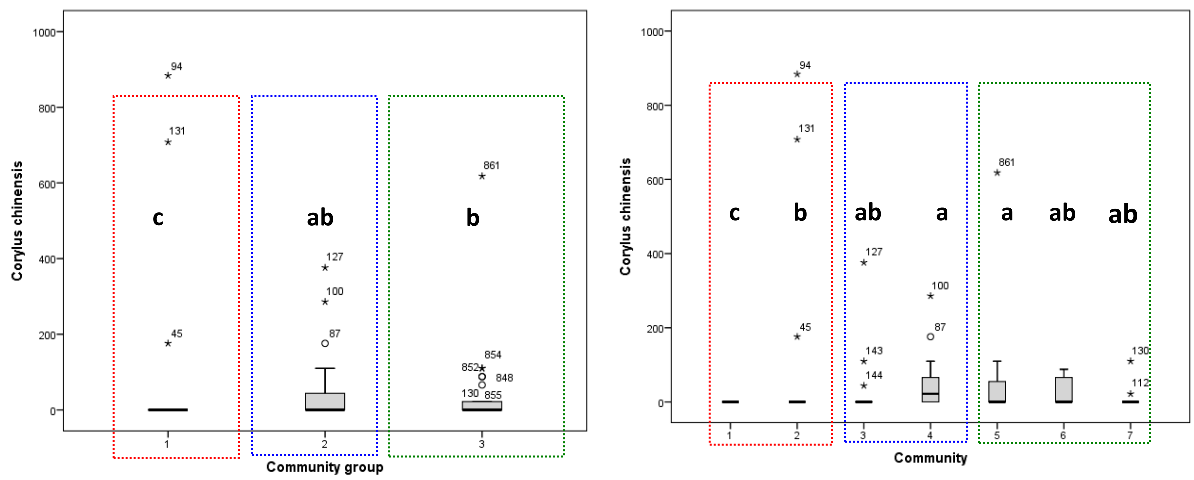


Fig. 3.11: Density (trees/ha) of trees (dbh ≥5 cm) of ***Corylus chinensis*** in the **3 community groups** (left) (1: QQ, 2: SQ, 3: JC) and the **7 communities** (right) (1: VuQa, 2: VcQa, 3: AcQm, 4: VpQm, 5: CrQa, 6: OgJm, 7: LbCc), sample size and abbrev. see Table 3.1**.**

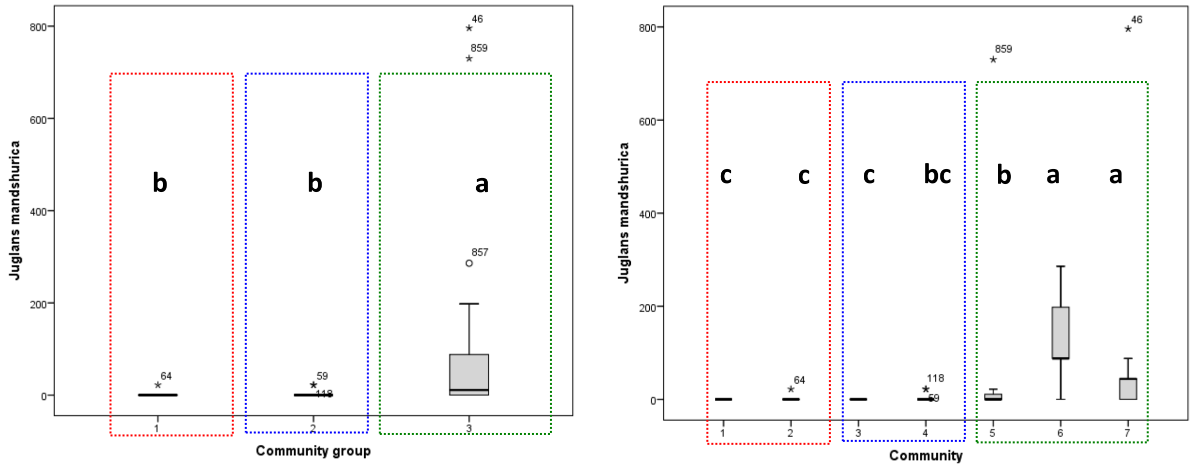


Fig. 3.12: Density (trees/ha) of trees (dbh ≥5 cm) of ***Juglans mandshurica*** in the **3 community groups** (left) (1: QQ, 2: SQ, 3: JC) and the **7 communities** (right) (1: VuQa, 2: VcQa, 3: AcQm, 4: VpQm, 5: CrQa, 6: OgJm, 7: LbCc), sample size and abbrev. see Table 3.1. Values with different letters in superscript were significantly different based on pairwise comparisons with MWU-test. Box plot with median, Q_{25} and Q_{75} (box), outliers and exterme values with their plot numbers.

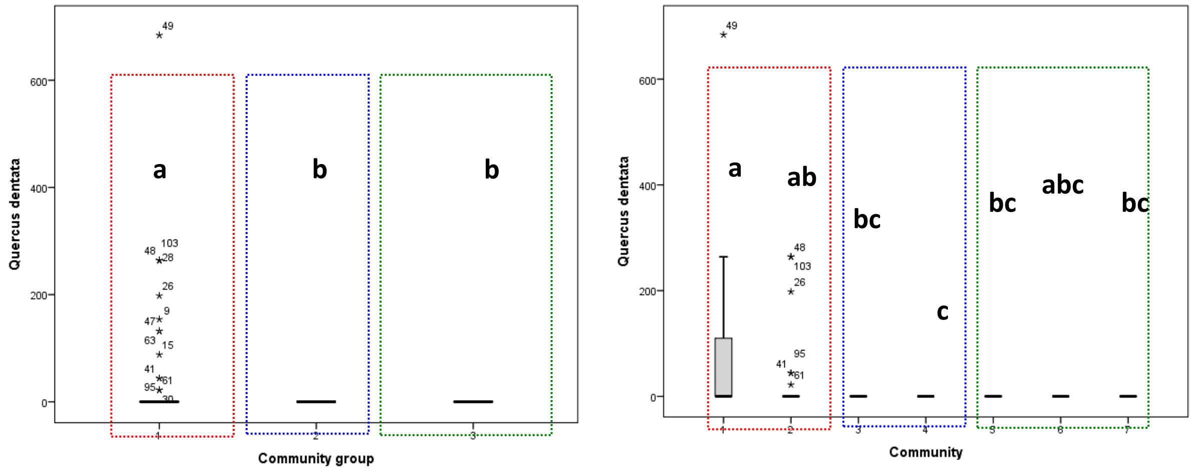


Fig. 3.13: Density (trees/ha) of trees (dbh ≥5 cm) of ***Quercus dentata*** in the **3 community groups** (left) (1: QQ, 2: SQ, 3: JC) and the **7 communities** (right) (1: VuQa, 2: VcQa, 3: AcQm, 4: VpQm, 5: CrQa, 6: OgJm, 7: LbCc), sample size and abbrev. see Table 3.1**.**

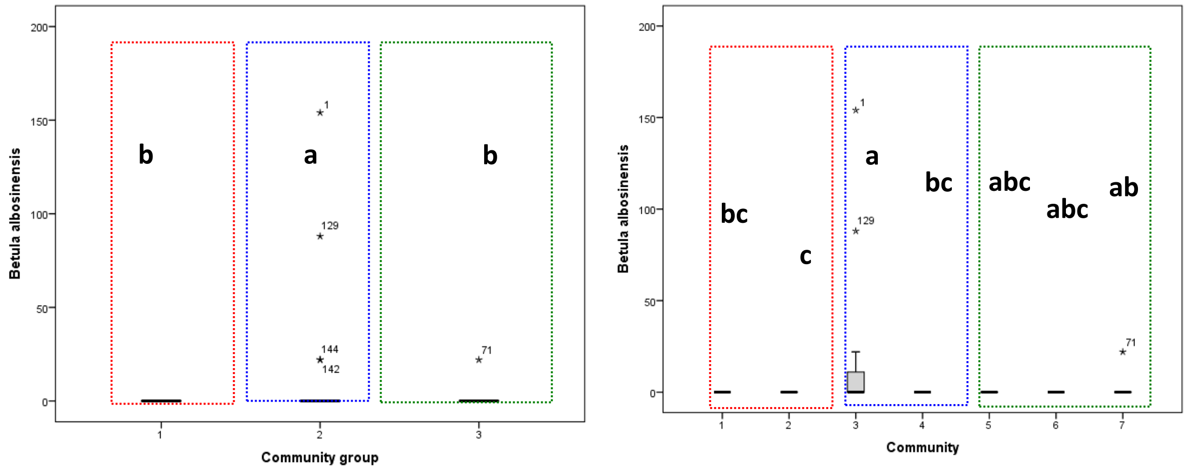


Fig. 3.14: Density (trees/ha) of trees (dbh ≥5 cm) of ***Betula albosinensis*** in the **3 community groups** (left) (1: QQ, 2: SQ, 3: JC) and the **7 communities** (right) (1: VuQa, 2: VcQa, 3: AcQm, 4: VpQm, 5: CrQa, 6: OgJm, 7: LbCc), sample size and abbrev. see Table 3.1**.**

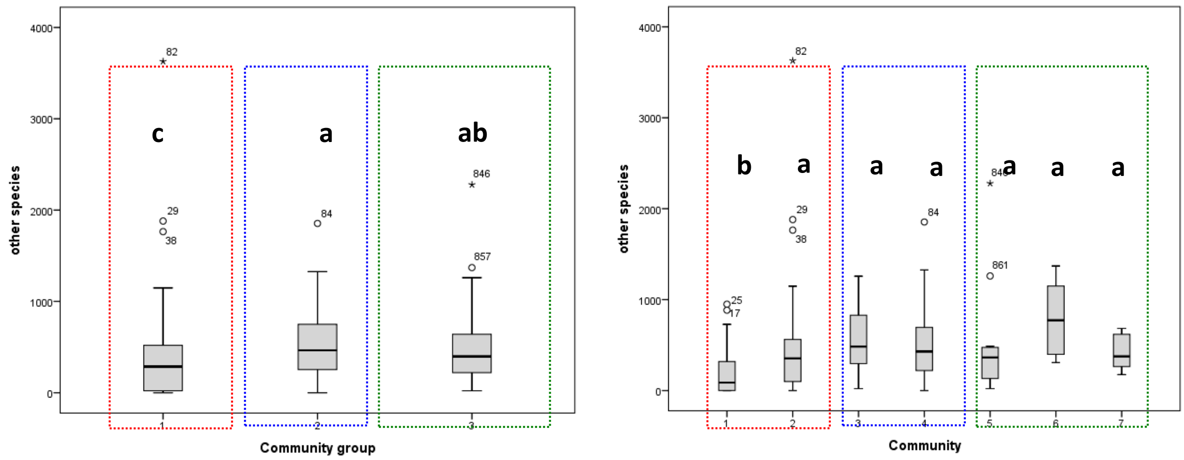


Fig. 3.15: Density (trees/ha) of trees (dbh ≥5 cm) of **other species combined** (excluding the 10 important species) in the **3 community groups** (left) (1: QQ, 2: SQ, 3: JC) and the **7 communities** (right) (1: VuQa, 2: VcQa, 3: AcQm, 4: VpQm, 5: CrQa, 6: OgJm, 7: LbCc), sample size and abbrev. see Table 3.1. Values with different letters in superscript were significantly different based on pairwise comparisons with MWU-test. Box plot with median, Q_{25} and Q_{75} (box), outliers and exterme values with their plot numbers.

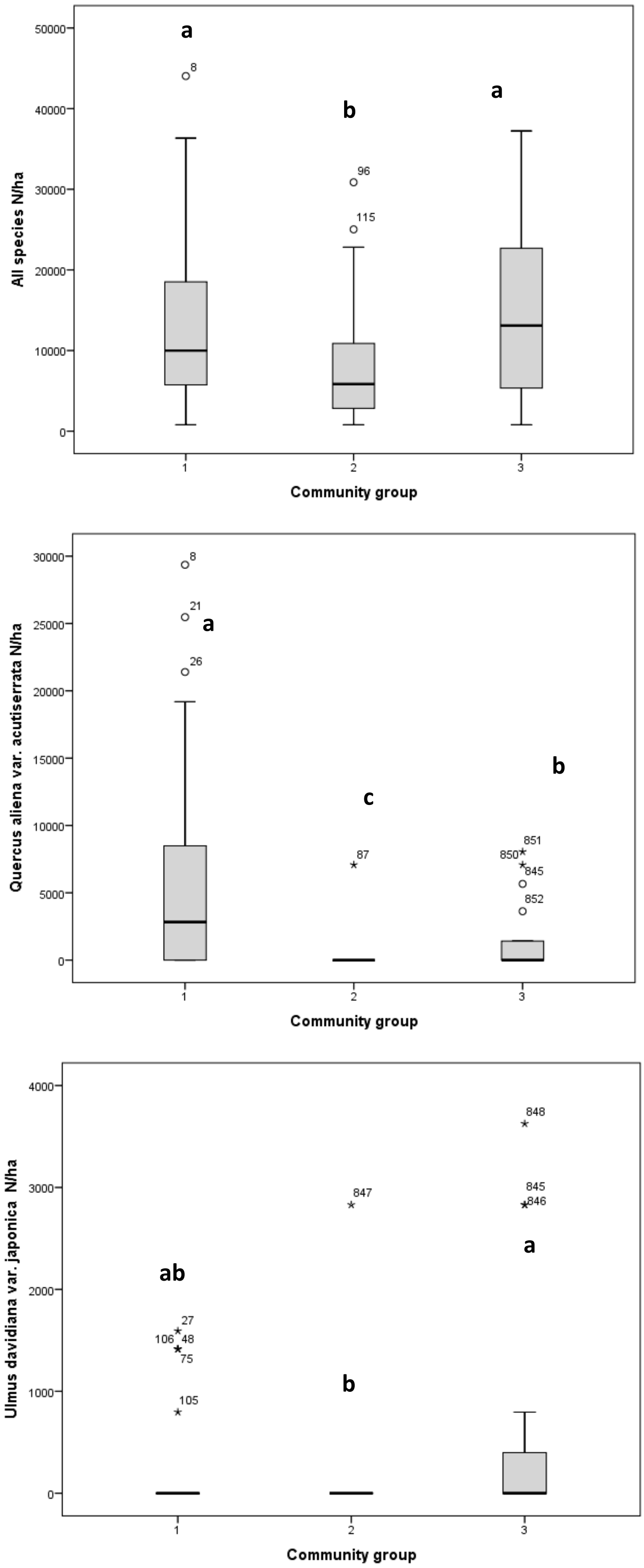


Fig. 3.16: Density (trees/ha) of regrowth (dbh <5 cm) of **all species** (above), ***Quercus aliena* var. *acutiserrata*** (middle), ***Ulmus davidiana* var. *japonica*** (below) in the **3 community groups** (1: QQ, 2: SQ, 3: JC), sample size and abbrev. see Table 3.1. Values with different letters in superscript were significantly different based on pairwise comparisons with MWU-test. Box plot with median, Q_{25} and Q_{75} (box), outliers and exterme values with their plot numbers.

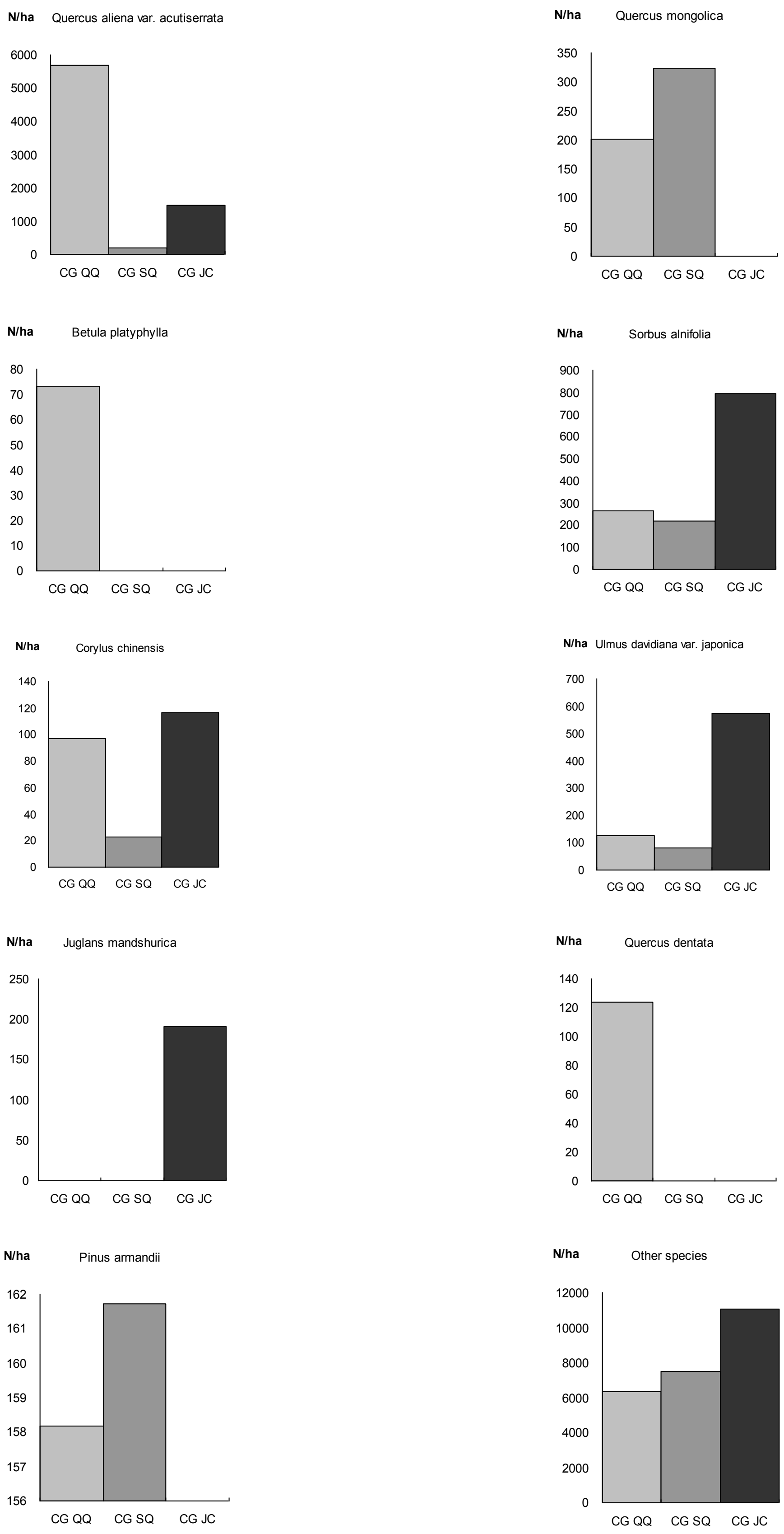
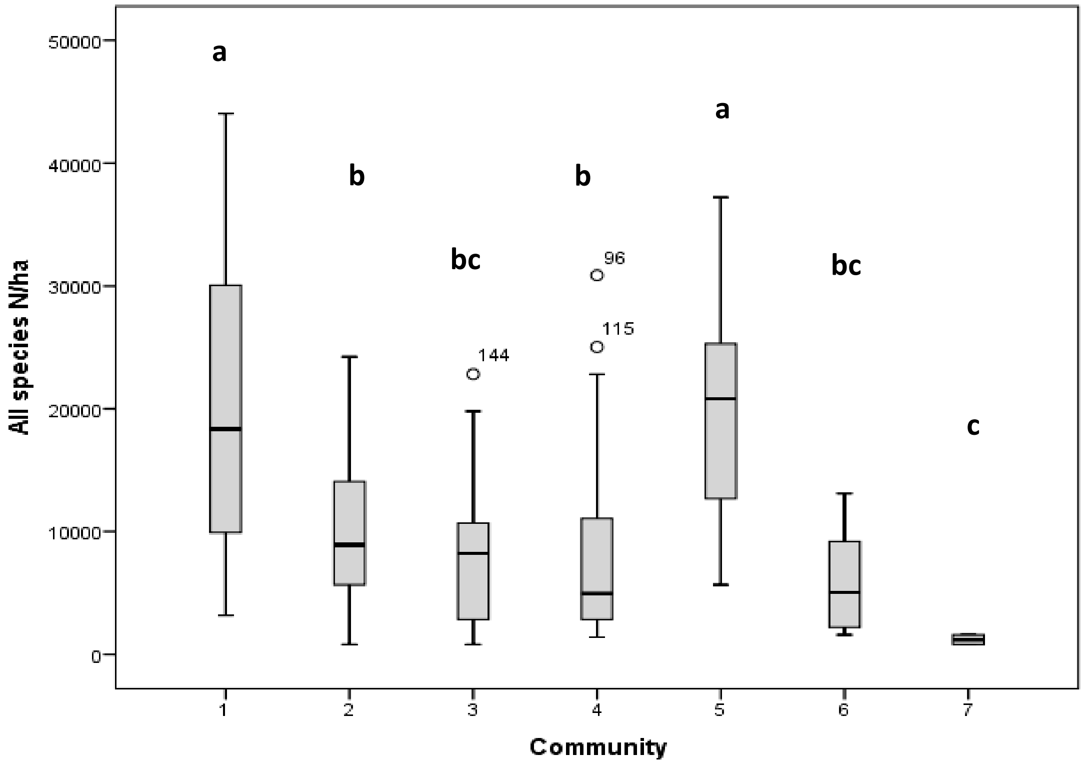


Fig. 3.17: Mean density of regrowth (dbh <5 cm) of the important species *Quercus aliena* var. *acutiserrata, Quercus mongolica, Betula platyphylla, Sorbus alnifolia, Corylus chinensis, Ulmus davidiana* var. *japonica, Juglans mandshurica, Quercus dentata, Pinus armandii,* other species in 3 community groups (CG QQ, CG SQ, CG JC) sample size and abbrev. see Table 3.1.



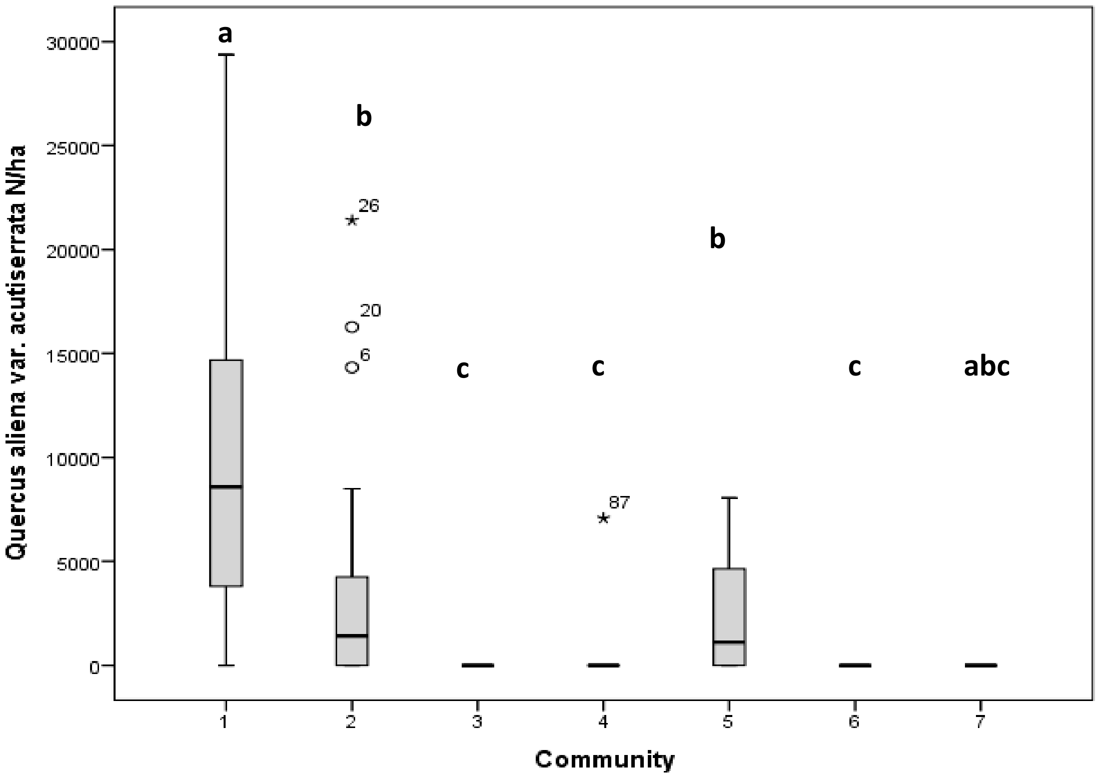


Fig. 3.18: Density (trees/ha) of regrowth (dbh <5 cm) of all species combined (above), *Quercus aliena* var. *acutiserrata* (below) in the 7 communities (**1**: VuQa, **2**: VcQa, **3**: AcQm, **4**: VpQm, **5**: CrQa, **6**: OgJm, **7**: LbCc) sample size and abbrev. see Table 3.1. Values with different letters in superscript were significantly different based on pairwise comparisons with MW U-test.made after KW H-test. Box plot with median, Q_{25} and Q_{75} (box), outliers and exterme values with their plot numbers.

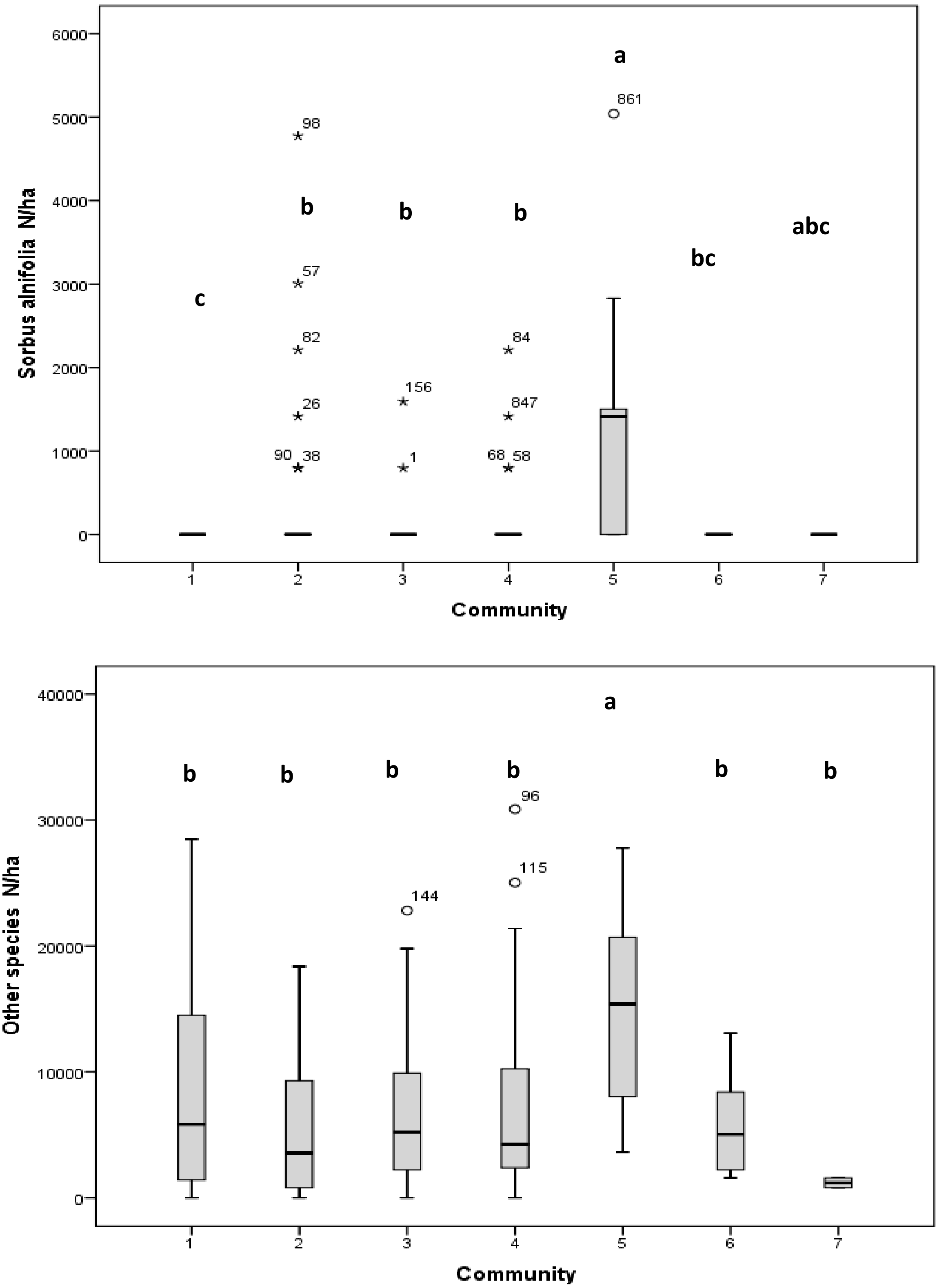


Fig. 3.19: Density (trees/ha) of regrowth (dbh <5 cm) of *Sorbus alnifolia* (above), other species combined (excluding the 10 important species) (below) in the 7 communities (**1**: VuQa, **2**: VcQa, **3**: AcQm, **4**: VpQm, **5**: CrQa, **6**: OgJm, **7**: LbCc) sample size and abbrev. see Table 3.1. Values with different letters in superscript were significantly different based on pairwise comparisons with MW U-test, made after KW H-test. Box plot with median, Q_{25} and Q_{75} (box), outliers and exterme values with their plot numbers.

3.3.2 Distribution of dbh classes of trees, height- and dbh classes of regrowth

The distribution of dbh classes of **all species combined** (dbh ≥5 cm) of the **7 communities** showed a similar trend (**Fig. 3.20**): Similarly there were many thinner trees, only few thick trees with dbh >20 cm, which means over-use, despite being a protected area since 1998. Thick trees offer more volumes than thinner ones. e.g. in the community OgJm there were few more trees with dbh 40-50 cm than in the community CrQa with dbh 40-50 cm, but OgJm had much more volume (ca. 70 m^3/ha) compared to CrQa with ca. 40 m^3/ha.

The **regrowth** (dbh <5 cm) of **all species combined** in all the 3 height classes (0-20 cm and 20-50 cm and 50-130 cm), and the 4 dbh classes with height over 130 cm (1-2 cm, 2-3 cm, 3-4 cm, 4-5 cm) were found in the following 6 (of the 7) communities (VuQa, VcQa, AcQm, VpQm, CrQa, OgJm) (**Fig. 3.21**); in the community LbCc there was less regrowth only in the dbh classes 1-2 cm and 2-3 cm and 3-4 cm (height >130 cm), no regrowth with height <130 cm. The reason may be not due to the sites, but due to human disturbance or animals.

The **10 important species** were evaluated separately by their varying present distribution of dbh classes in the **7 communities** (see **Fig. 3.22** to **Fig. 3.32**). This description also allows the assessment of stand dynamic development, and trend of succession.

Quercus aliena* var. *acutiserrata of all dbh classes (dbh ≥5 cm) was found in the communities VuQa and VcQa on sunny warm dry sites with higher density. In the communities CrQa on shady warm moist sites and in the community VpQm on sunny cool fresh sites with less of density (**Fig. 3.22**). The regrowth (dbh <5 cm) of *Q. aliena* var. *acutiserrata* in all height classes and dbh classes was found in the communities VuQa and VcQa, in the community CrQa there was less regrowth and not all the classes represented (**Fig. 3.22**). In the community VpQm there was only few regrowth in the height class 0-20 cm. *Q. aliena* var. *acutiserrata* had more potential in the communities VuQa and VcQa on the sunny dry sites than in the community CrQa on the shady moist site and in the community VpQm on cool sunny fresh sites.

Quercus mongolica in the higher dbh classes (>20 cm) was found in the communities AcQm and VpQm (diagnostic tree, cool sunny fresh site) with high density and in the community VcQa (warm sunny dry site), and, less in the community LbCc (warm shady moist site) (**Fig. 3.23**). In the communities VpQm and LbCc there was no regrowth with dbh class 5-10 cm. The regrowth (dbh <5 cm) of *Quercus mongolica* in few height classes and dbh classes was found in the communities VuQa and VcQa and AcQm and VpQm. In the community AcQm there was more regrowth, in 2 height classes (0-20 cm and 50-130 cm), i.e. here more potential for *Q. mongolica* than in other communities VuQa, VcQa and VpQm (**Fig. 3.23**).

Betula platyphylla in the higher dbh classes was found with high density in the community AcQm (cool sunny fresh site), in the community VcQa (warm sunny dry site), and with less density in the community CrQa (warm shady moist site) (**Fig. 3.24**). Thinner trees in the dbh class 5-10 cm were found in the community VcQa, but not in the community AcQm. In the height class (50-130 cm) and the dbh class (1-2 cm), regrowth of *Betula platyphylla* was found only in the community VcQa (**Fig. 3.24**), i.e. in the community VcQa may by due to more disturbance favoured *Betula platyphylla* as a pioneer species.

The ***Quercus dentata*** (dbh ≥5 cm) was found only in the communities VuQa and VcQa (warm dry sunny sites) in most dbh classes (**Fig. 3.25**), confirmed as diagnostic species (ref. to Chapter 2). Its regrowth (dbh <5 cm) was found in both communities in few height- or dbh classes (**Fig. 3.25**), no trees or regrowth in the other communities.

Sorbus alnifolia in the smaller dbh classes (5-10 cm and 10-20 cm) was found with higher density in the community VpQm (cool sunny fresh site), less density in the community VcQa (warm sunny dry site), and in the community LbCc (warm shady moist site) (**Fig. 3.26**). Only one dbh classe 10-20 cm was found with low density in the communities AcQm (cool sunny fresh site) and CrQa (warm shady moist site). Its regrowth (dbh <5 cm) in more height classes and dbh classes was found in the communities VcQa and AcQm and VpQm and CrQa, especally in the community AcQm most regrowth was found in the dbh classe 4-5cm (**Fig. 3.26**).

Corylus chinensis in the higher dbh classes was found with higher density in the community VpQm (cool sunny fresh site), and in the communities on warm shady moist sites (CrQa and OgJm and LbCc) (**Fig. 3.27**). There was less density in the communities VcQa (warm sunny dry site), and in the community AcQm (cool sunny fresh site). The dbh class 5-10 cm was found with higher density in the communities VcQa and AcQm and CrQa. Its regrowth (dbh <5 cm) was found only in few height- and dbh-classes in the communities VcQa and VpQm and CrQa) (**Fig. 3.27**).

Ulmus davidiana* var. *japonica in the dbh class 5-10 cm was found with high density in the community LbCc (warm shady moist site) (**Fig. 3.28**). There were more dbh classes but with low density in the community CrQa (similar warm shady moist site), in the communities on warm sunny dry sites (VuQa and VcQa). The regrowth (dbh <5 cm) of *Ulmus davidiana* var. *japonica* in more classes was found in the communities VuQa, VcQa, CrQa, Ogjm, and in the community VpQm on cool sunny fresh site (**Fig. 3.28**).

Juglans mandshurica in more dbh classes was found with higher density in the communities on warm shady moist sites (OgJm and LbCc), in the community CrQa on similar site it was found in only two dbh classes (5-10 cm and 30-40 cm) (**Fig. 3.29**). Its regrowth (dbh <5 cm) was found in 2 classes (height 20-50 cm, and dbh 2-3 cm with height over 130 cm) only in the community CrQa (**Annex 3.8, Annex 3.10**).

Betula albosinensis in higher dbh classes (20-30 cm and 30-40 cm and 40-50 cm) was found in the community AcQm (cool sunny fresh site), only one dbh class (40-50 cm) in the community LbCc (warm shady moist site) (**Fig. 3.30**). Its regrowth (dbh <5 cm) was not found in any community.

Pinus armandii had a much smaller density in the dbh classes of the 7 communities, despite being a locally important species for timber, with drought tolerance, fast growth, straight stem form (**Fig. 3.31**). Its regrowth (dbh <5 cm) in more classes was found in the communities on warm sunny dry sites (VuQa and VcQa), and in the communities on cool sunny fresh sites (AcQm and VpQm) (**Fig. 3.31**).

The distribution of dbh classes of the **other species** combined (excluding the 10 important species) in the 7 communities was similar. There were more trees with dbh class 5-10 cm, less trees with dbh >20 cm (**Fig. 3.32**). Their regrowth (dbh <5 cm) in all height classes (0-20 cm and 20-50 cm and 50-130 cm), and all dbh classes (1-2 cm and 2-3 cm and 3-4 cm and 4-5 cm), height over 130 cm was found in 6 communities (VuQa, VcQa, AcQm, VpQm, CrQa, OgJm), but in the community LbCc on cool sunny fresh sites, only less regrowth was found in the dbh classes (1-2 cm and 2-3 cm and3-4 cm), and none in the dbh class 4-5 cm (**Fig. 3.32**).

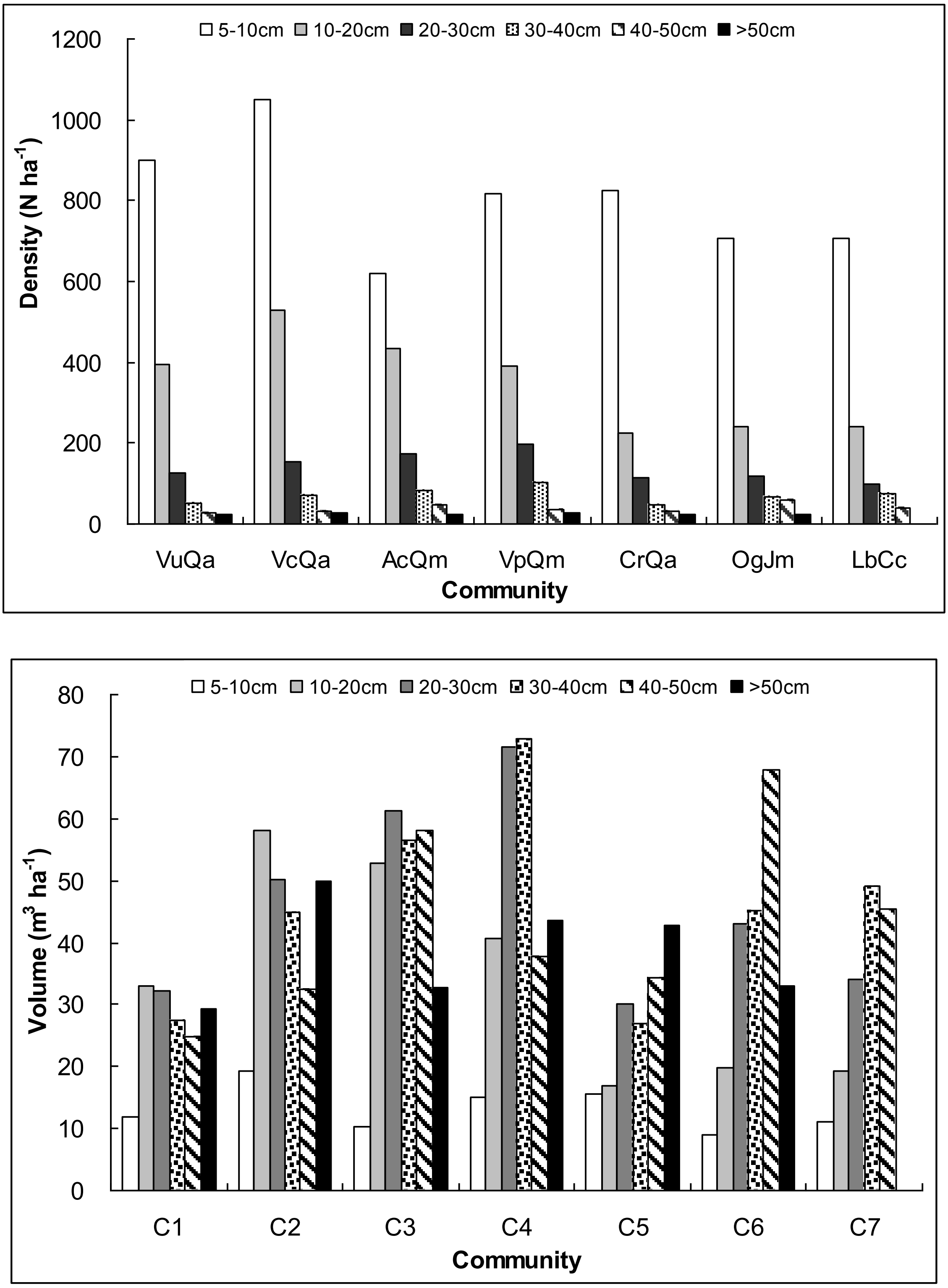


Fig. 3.20: Mean density (trees/ha, above) and volume (m^3/ha, below) of dbh classes (cm) of all species combined of the 7 communities (**C1**: VuQa, **C2**: VcQa, **C3**: AcQm, **C4**: VpQm, **C5**: CrQa, **C6**: OgJm, **C7**: LbCc) sample size and abbrev. see Table 3.1.

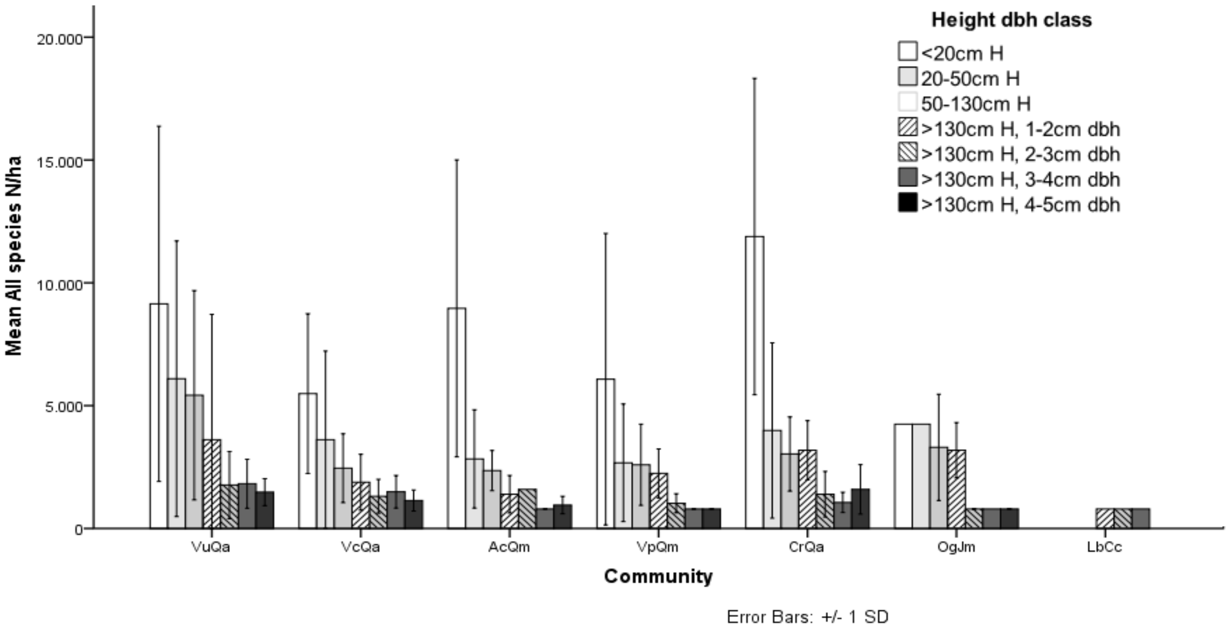
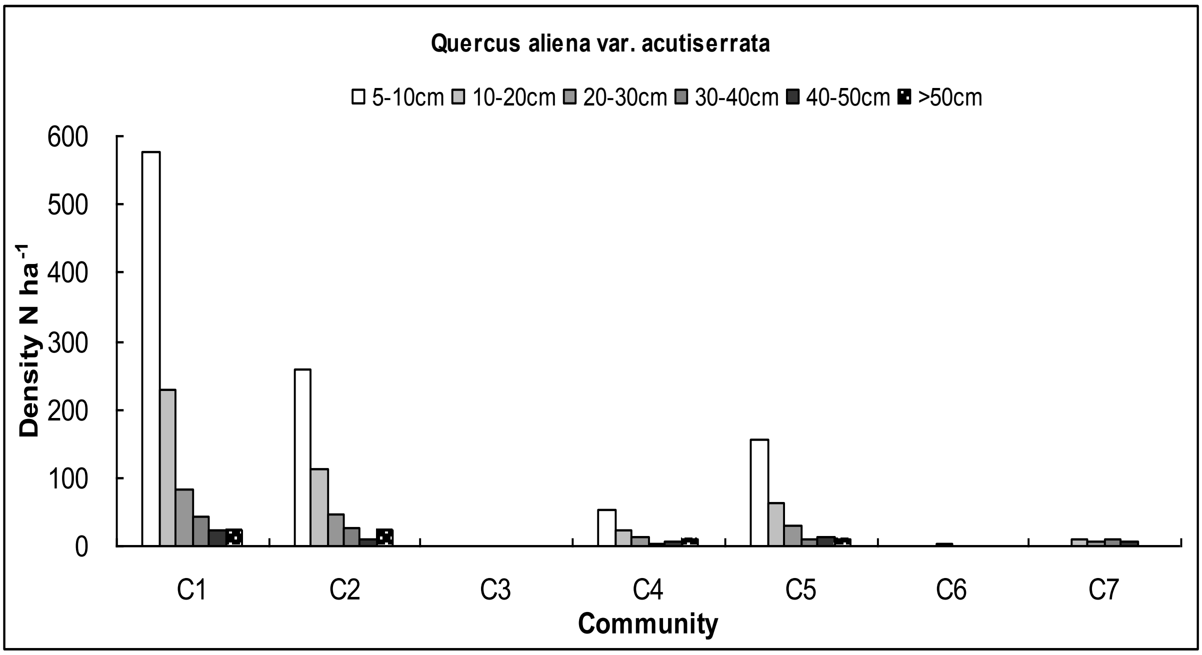


Fig. 3.21: Density (trees/ha) of regrowth (dbh <5 cm) of **all species** in the **height classes** (0-20 cm, 20-50 cm, 50-130 cm), and the dbh classes (1-2 cm, 2-3 cm, 3-4 cm, 4-5 cm, height >130 cm) in the 7 communities (**C1**: VuQa, **C2**: VcQa, **C3**: AcQm, **C4**: VpQm, **C5**: CrQa, **C6**: OgJm, **C7**: LbCc), sample size and abbrev. see Table 3.1.



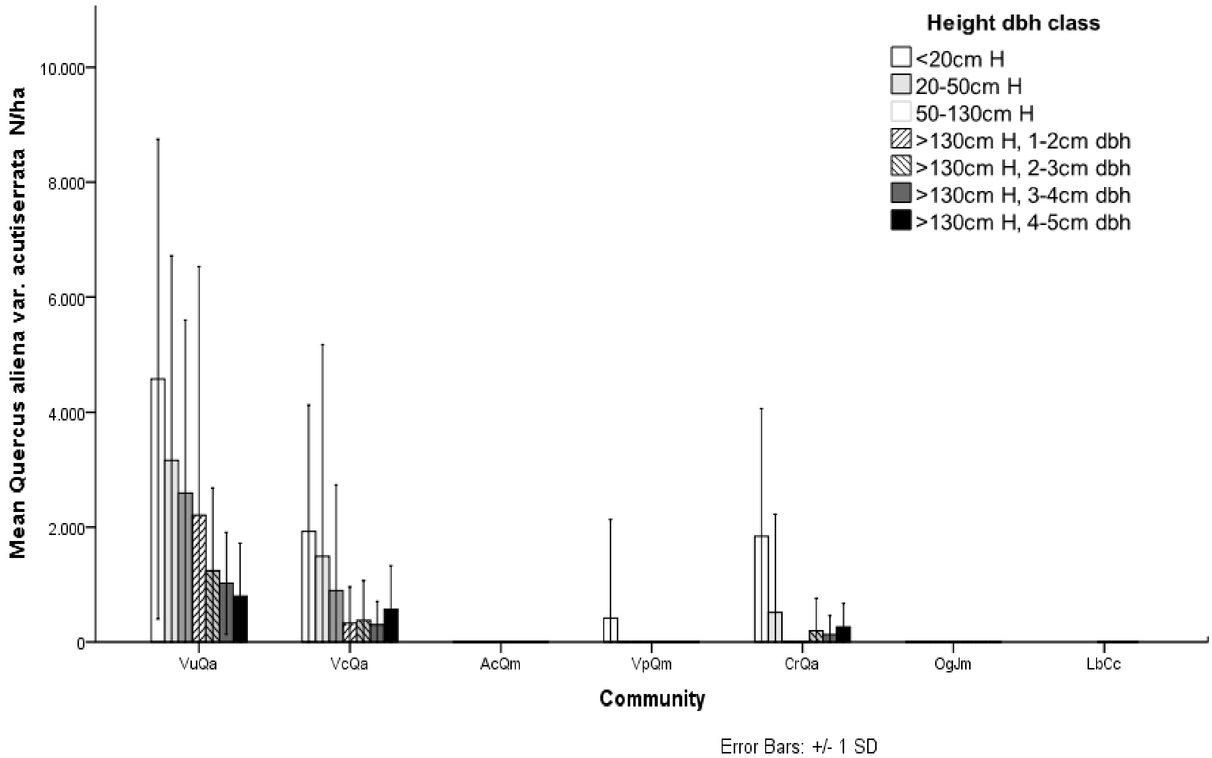
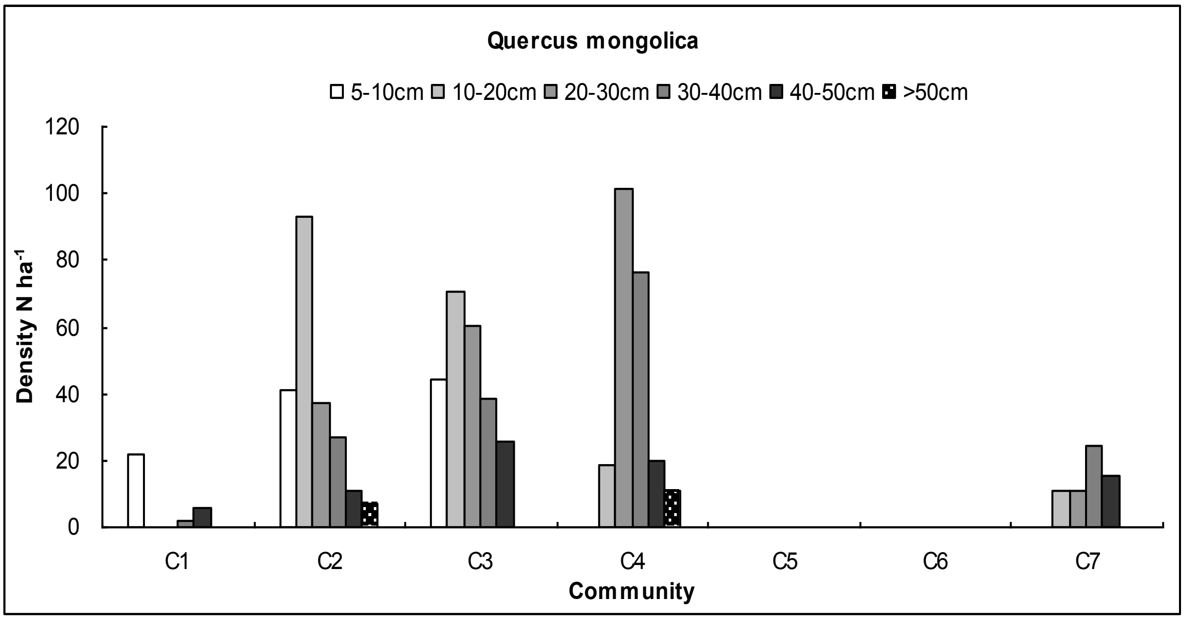


Fig. 3.22: Density (trees/ha) of trees (dbh ≥5 cm) in **dbh classes** (above) and density (trees/ha) of regrowth (dbh <5 cm) (below) of ***Quercus aliena* var. *acutiserrata*** in the height classes (0-20 cm, 20-50 cm, 50-130 cm), and the dbh classes (1-2 cm, 2-3 cm, 3-4 cm, 4-5 cm, height >130 cm) in the 7 communities (C1: VuQa, C2: VcQa, C3: AcQm, C4: VpQm, C5: CrQa, C6: OgJm, C7: LbCc) sample size and abbrev. see Table 3.1.



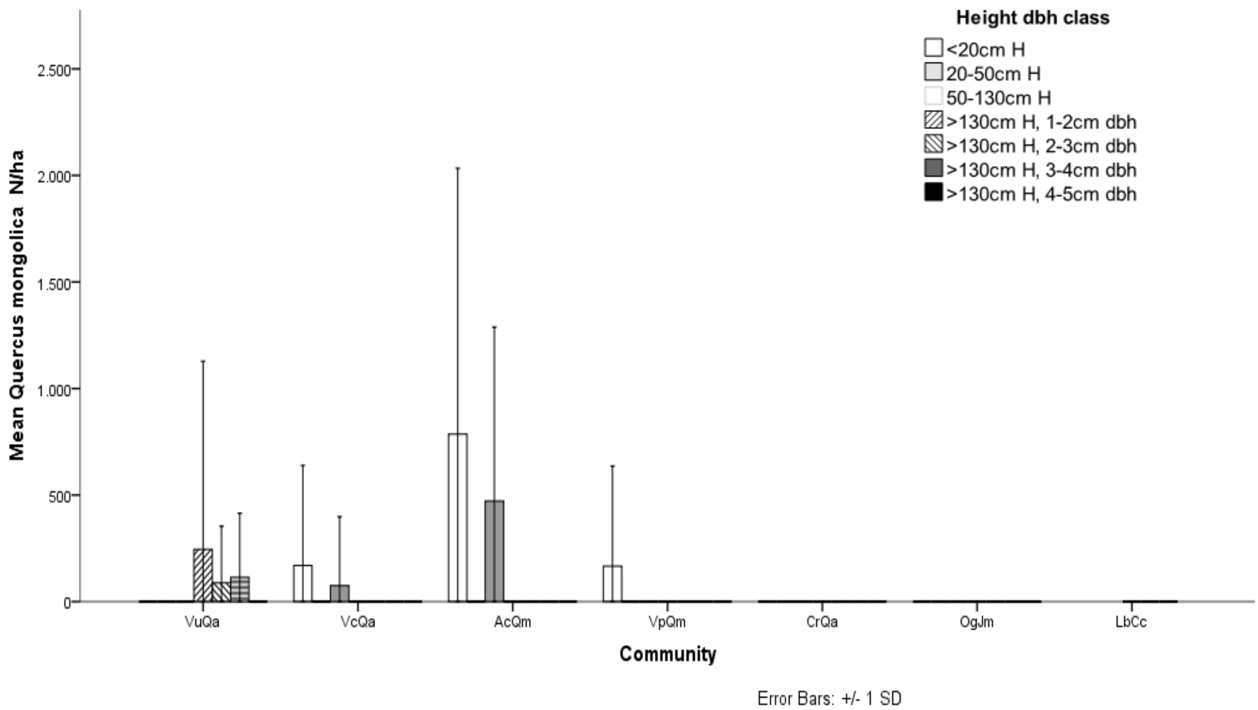
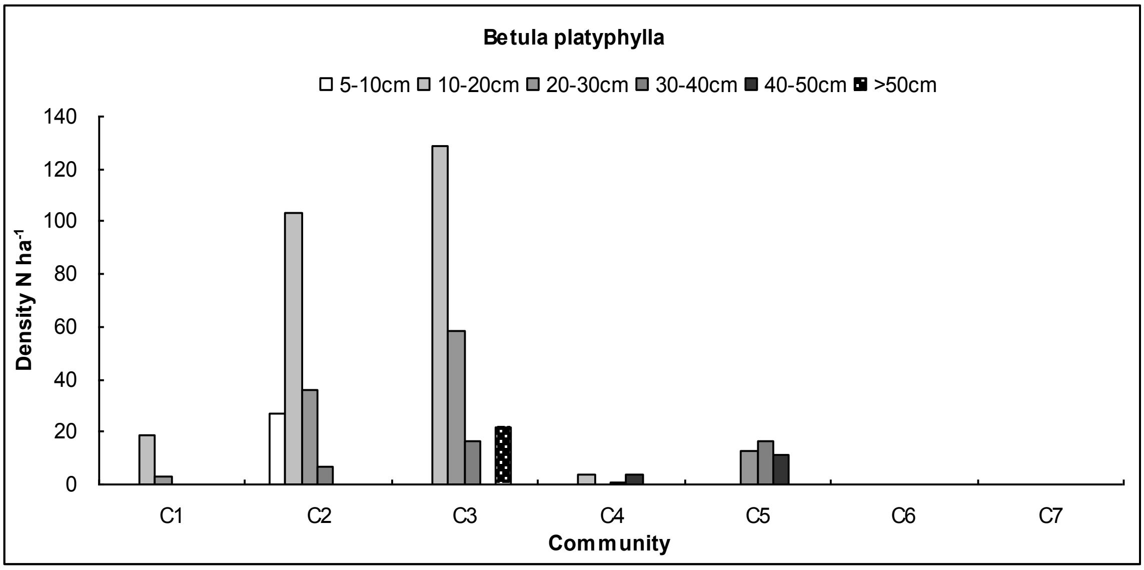


Fig. 3.23: Density (trees/ha) of trees (dbh ≥5 cm) in **dbh classes** (above) and of regrowth (dbh <5 cm) (below) of ***Quercus mongolica*** in the **height classes** (0-20 cm, 20-50 cm, 50-130 cm), and the **dbh classes** (1-2 cm, 2-3 cm, 3-4 cm, 4-5 cm, height >130 cm) in the 7 communities (**C1**: VuQa, **C2**: VcQa, **C3**: AcQm, **C4**: VpQm, **C5**: CrQa, **C6**: OgJm, **C7**: LbCc) sample size and abbrev. see Table 3.1.



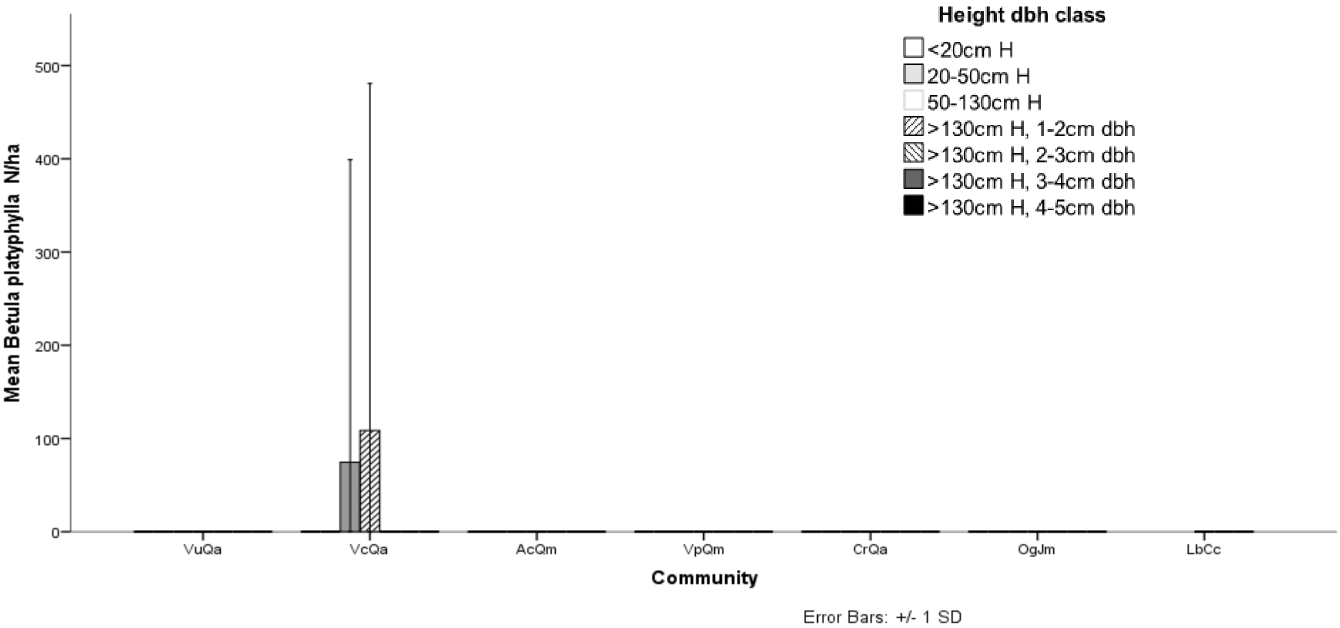
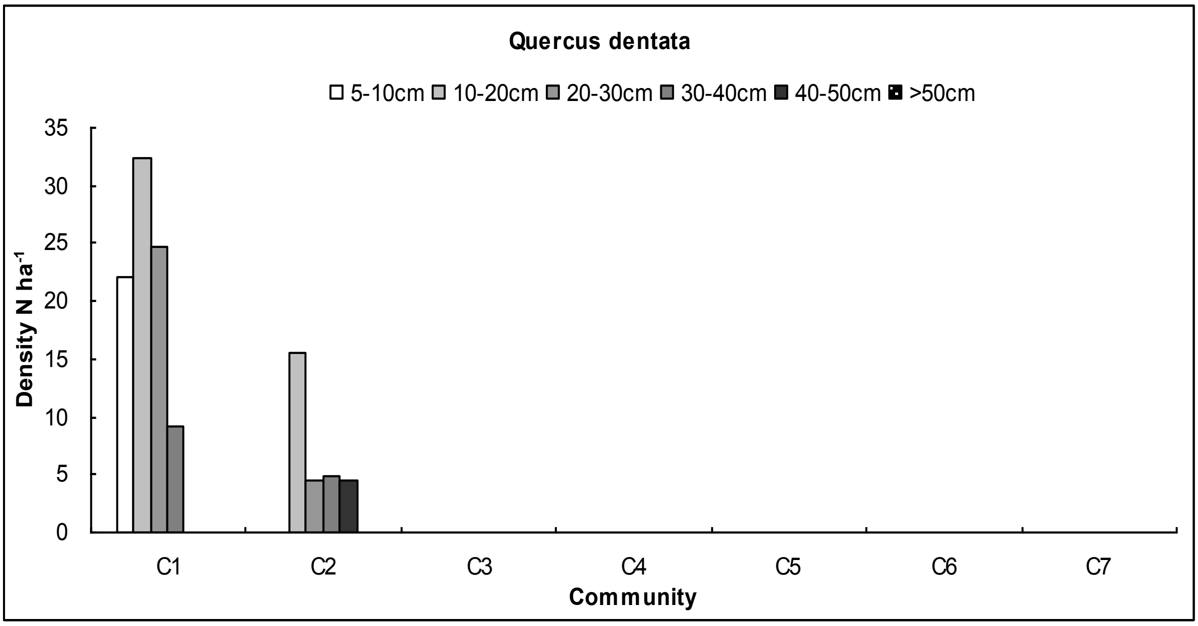


Fig. 3.24: Density (trees/ha) of trees (dbh ≥5 cm) in **dbh classes** (above) and of regrowth (dbh <5 cm) below) of ***Betula platyphylla*** in the **height classes** (0-20 cm, 20-50 cm, 50-130 cm), and the **dbh classes** (1-2 cm, 2-3 cm, 3-4 cm, 4-5 cm, height >130 cm) in the 7 communities (C1: VuQa, C2: VcQa, C3: AcQm, C4: VpQm, C5: CrQa, C6: OgJm, C7: LbCc) sample size and abbrev. see Table 3.1.



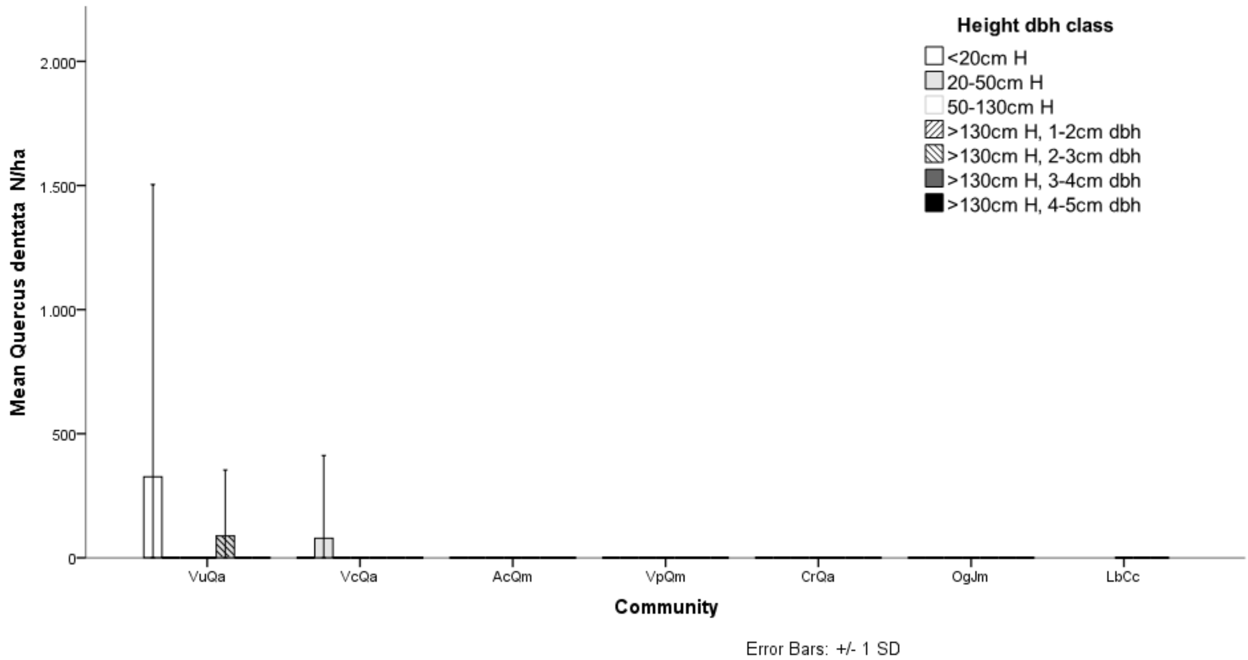
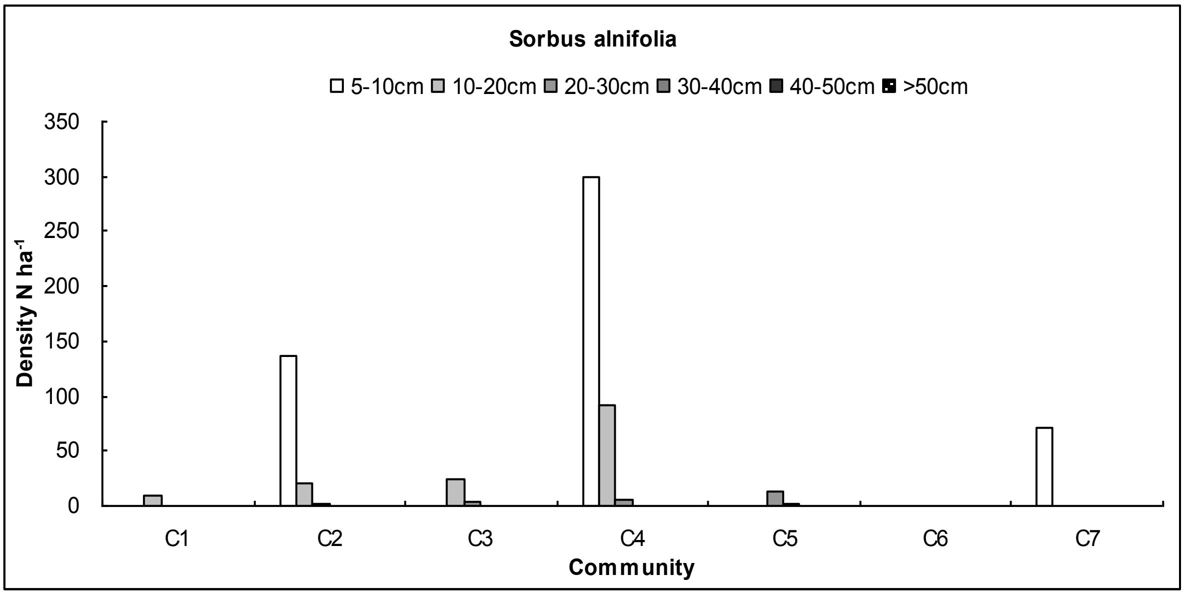


Fig. 3.25: Density (trees/ha) of trees (dbh ≥5 cm) in **dbh classes** (above) and of regrowth (dbh <5 cm) (below) of ***Quercus dentata*** in the **height classes** (0-20 cm, 20-50 cm, 50-130 cm), and the **dbh classes** (1-2 cm, 2-3 cm, 3-4 cm, 4-5 cm, height >130 cm) in the 7 communities (C1: VuQa, C2: VcQa, C3: AcQm, C4: VpQm, C5: CrQa, C6: OgJm, C7: LbCc) sample size and abbrev. see Table 3.1.



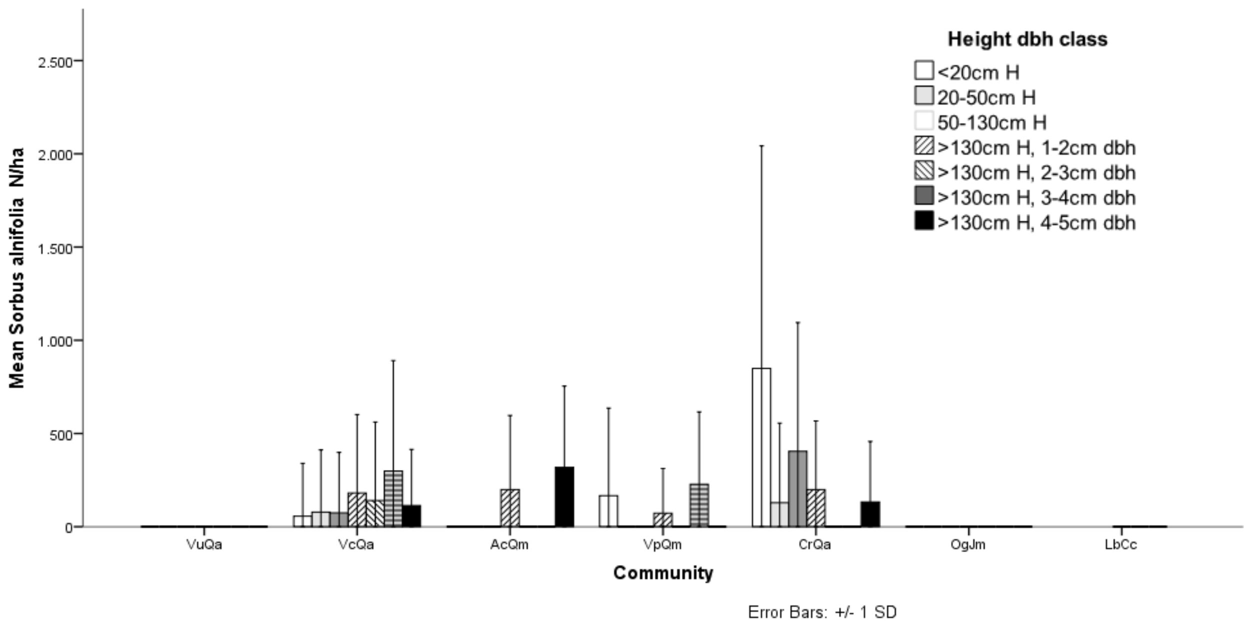
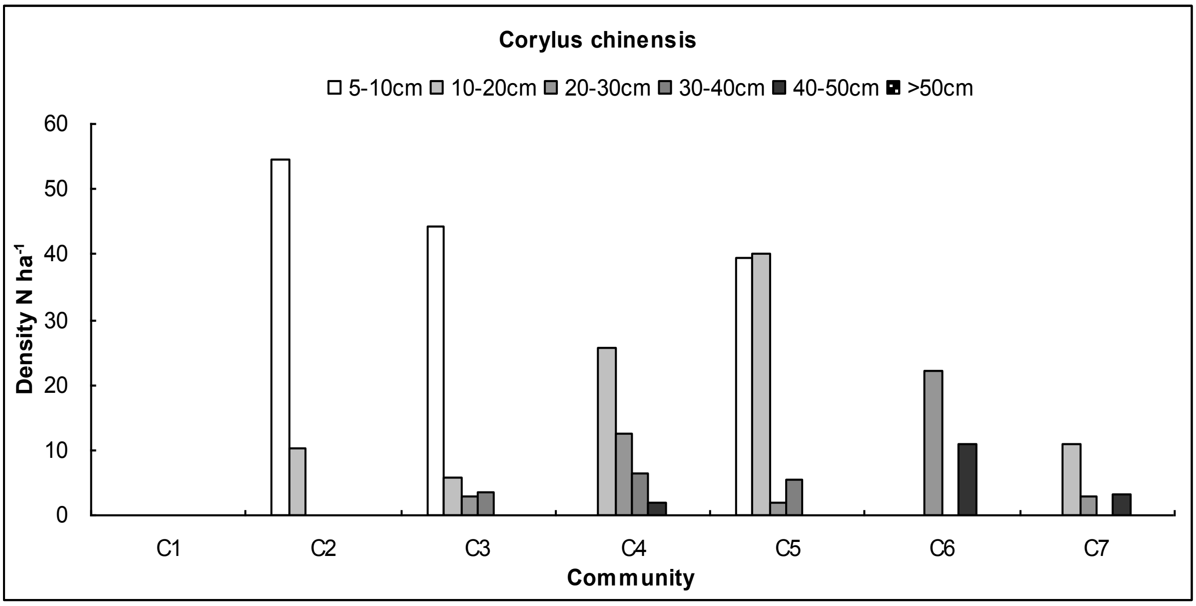


Fig. 3.26: Density (trees/ha) of trees (dbh ≥5 cm) in **dbh classes** (above) and of regrowth (dbh <5 cm) (below) of ***Sorbus alnifolia*** in the **height classes** (0-20 cm, 20-50 cm, 50-130 cm), and the **dbh classes** (1-2 cm, 2-3 cm, 3-4 cm, 4-5 cm, height >130 cm) in the 7 communities (C1: VuQa, C2: VcQa, C3: AcQm, C4: VpQm, C5: CrQa, C6: OgJm, C7: LbCc) sample size and abbrev. see Table 3.1.



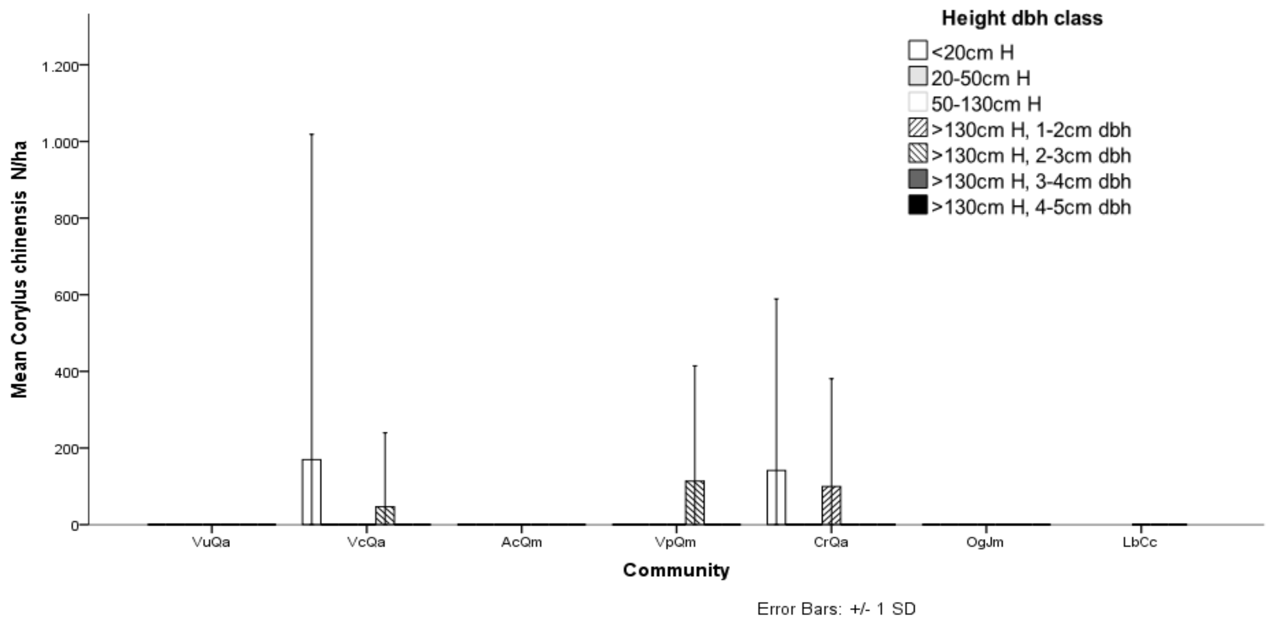
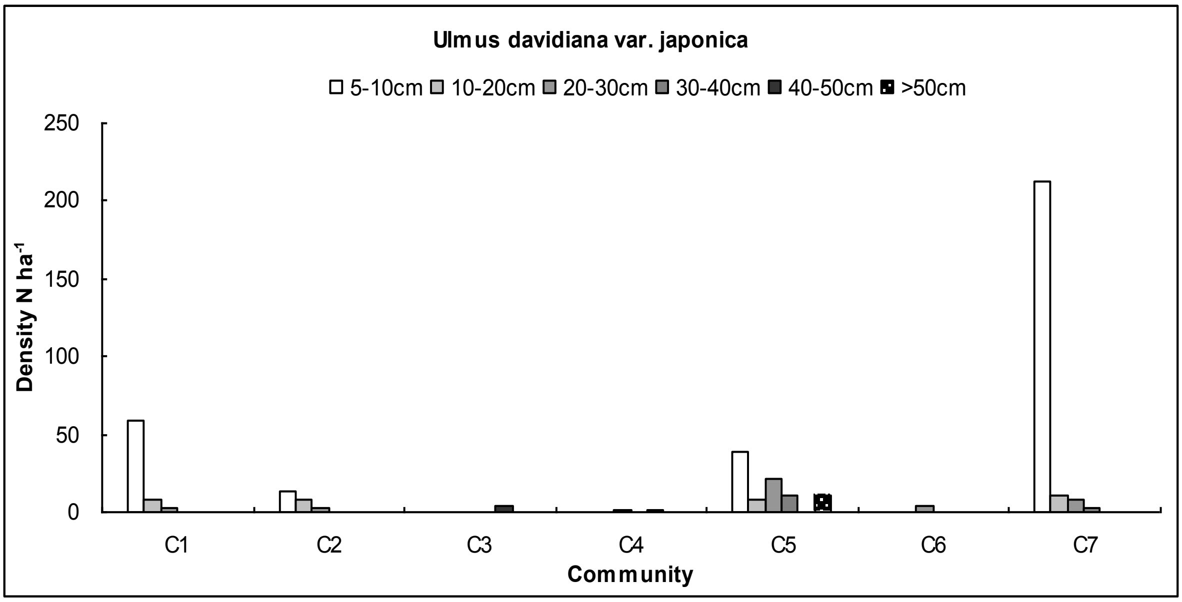


Fig. 3.27: Density (trees/ha) of trees (dbh ≥5 cm) in **dbh classes** (above) and of regrowth (dbh <5 cm) (below) of ***Corylus chinensis*** in the **height classes** (0-20 cm, 20-50 cm, 50-130 cm), and the **dbh classes** (1-2 cm, 2-3 cm, 3-4 cm, 4-5 cm, height >130 cm) in the 7 communities (C1: VuQa, C2: VcQa, C3: AcQm, C4: VpQm, C5: CrQa, C6: OgJm, C7: LbCc) sample size and abbrev. see Table 3.1.



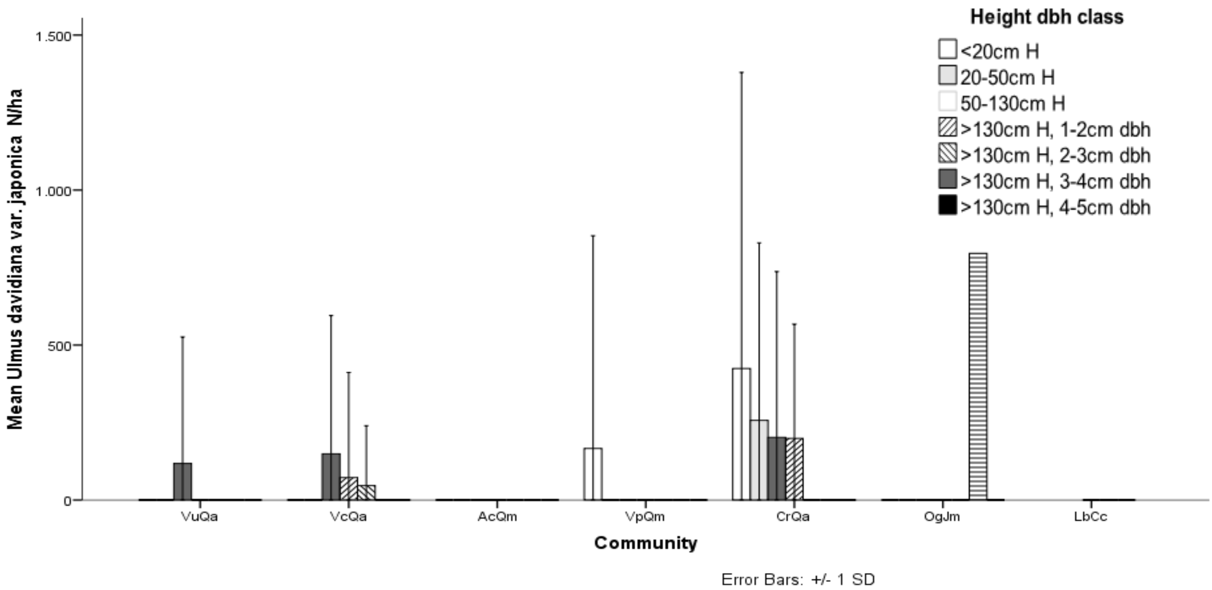


Fig. 3.28: Density (trees/ha) of trees (dbh ≥5 cm) in **dbh classes** (above) and of regrowth (dbh <5 cm) (below) of ***Ulmus davidiana* var. *japonica*** in the **height classes** (0-20 cm, 20-50 cm, 50-130 cm), and the **dbh classes** (1-2 cm, 2-3 cm, 3-4 cm, 4-5 cm, height >130 cm) in the 7 communities (C1: VuQa, C2: VcQa, C3: AcQm, C4: VpQm, C5: CrQa, C6: OgJm, C7: LbCc) sample size and abbrev. see Table 3.1.

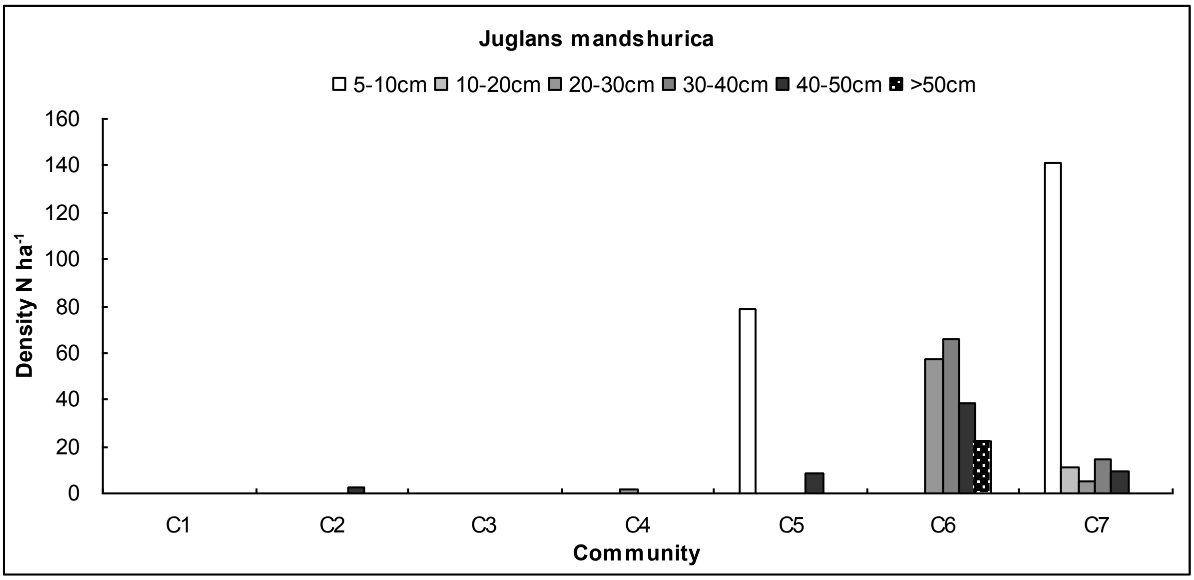


Fig. 3.29: Density (trees/ha) of trees (dbh ≥5 cm) in **dbh classes** of ***Juglans mandshurica*** in the 7 communities (C1: VuQa, C2: VcQa, C3: AcQm, C4: VpQm, C5: CrQa, C6: OgJm, C7: LbCc) sample size and abbrev. see Table 3.1.

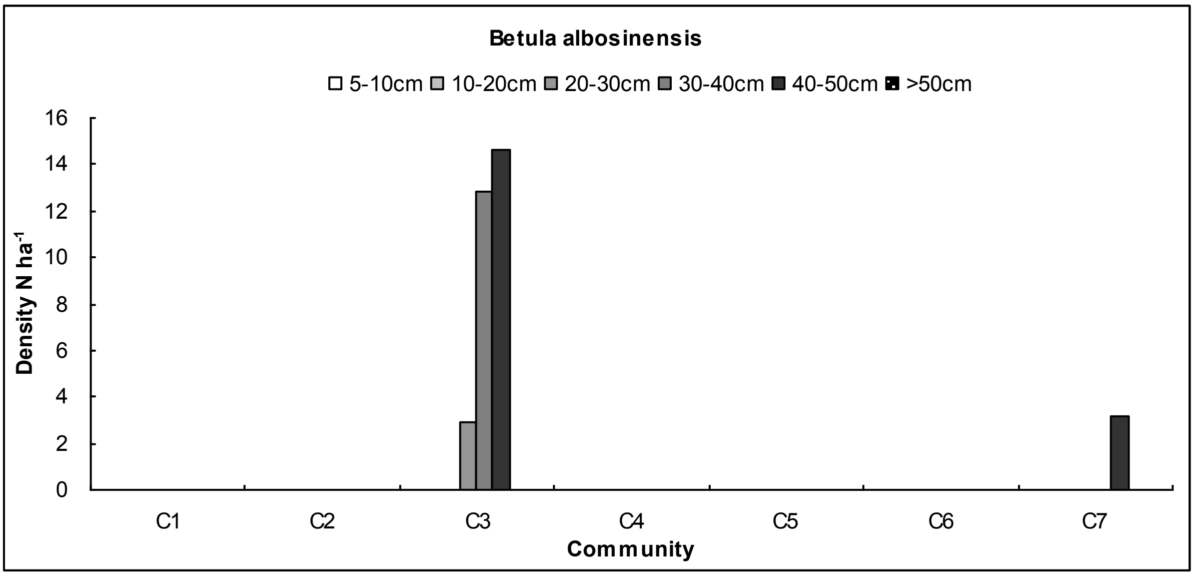
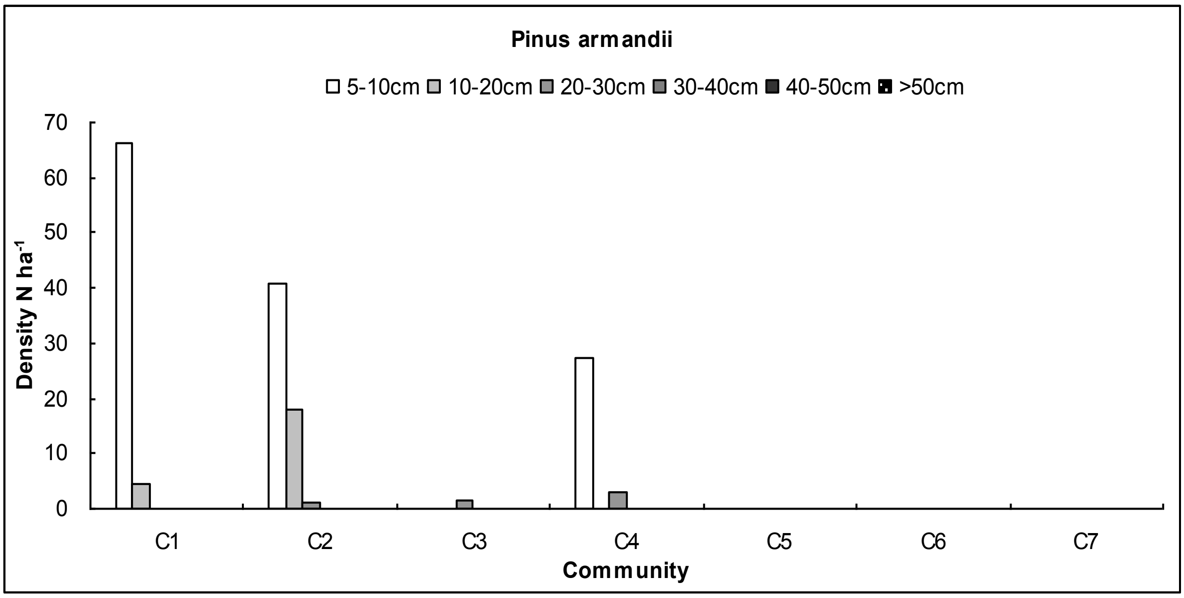


Fig. 3.30: Density (trees/ha) of trees (dbh ≥5 cm) in **dbh classes** of ***Betula albosinensis*** in the 7 communities (C1: VuQa, C2: VcQa, C3: AcQm, C4: VpQm, C5: CrQa, C6: OgJm, C7: LbCc) sample size and abbrev. see Table 3.1.



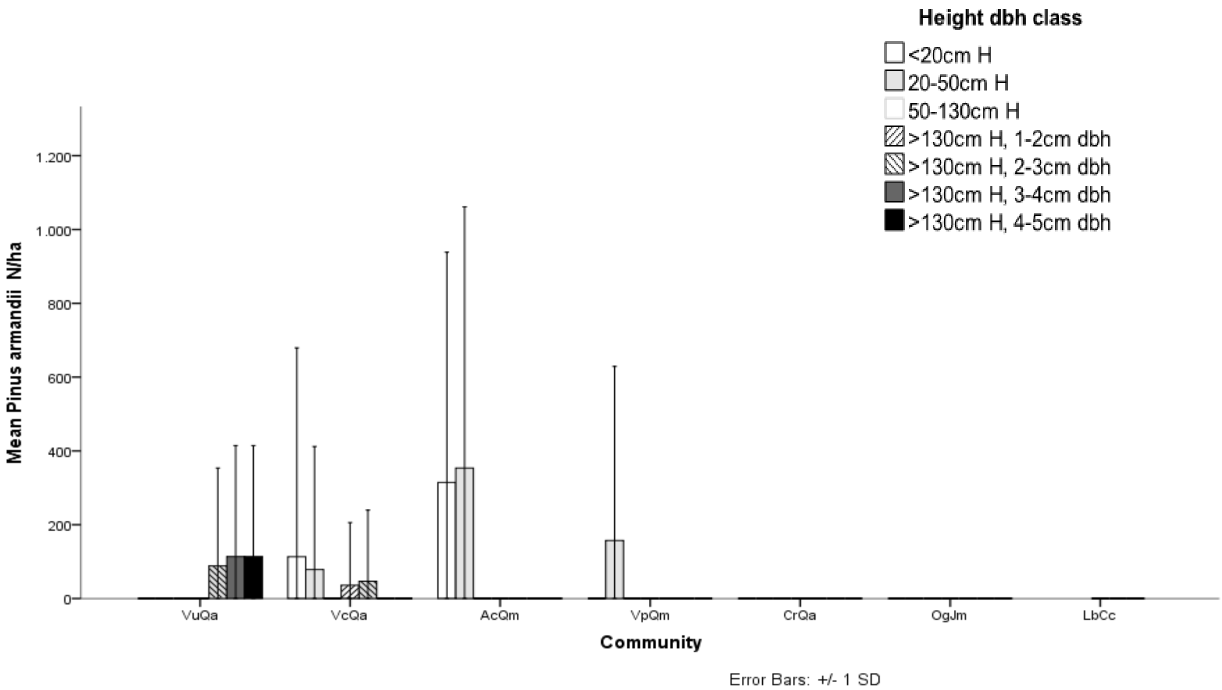
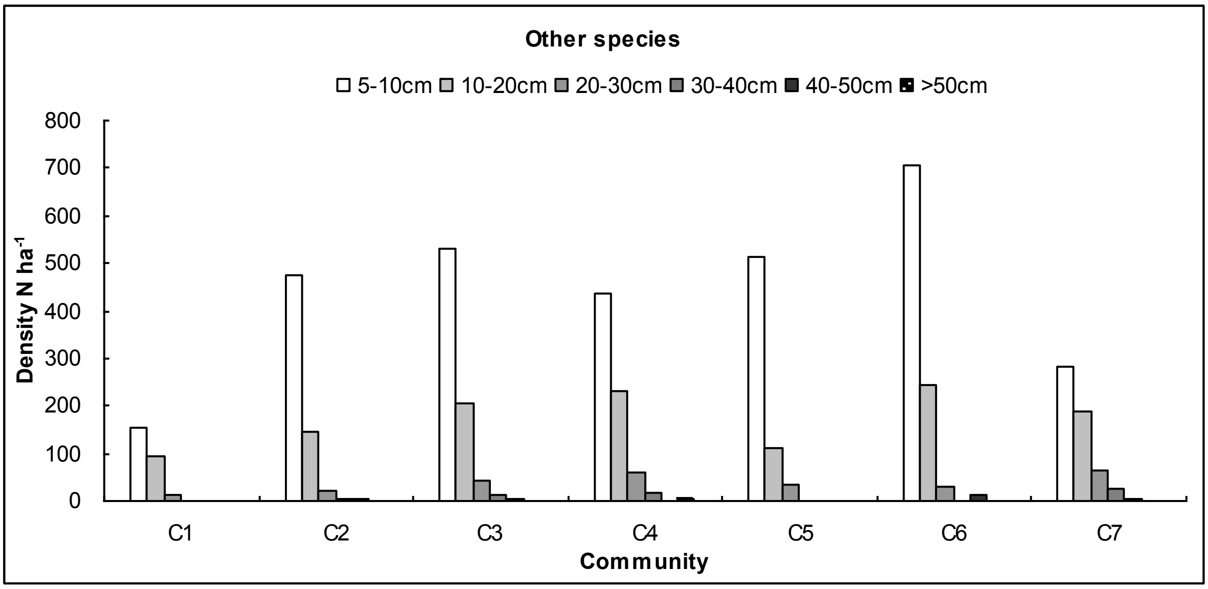


Fig. 3.31: Density (trees/ha) of trees (dbh ≥5 cm) in **dbh classes** (above) and of regrowth (dbh <5 cm) (below) of ***Pinus armandii*** in the **height classes** (0-20 cm, 20-50 cm, 50-130 cm), and the **dbh classes** (1-2 cm, 2-3 cm, 3-4 cm, 4-5 cm, height >130 cm) in the 7 communities (C1: VuQa, C2: VcQa, C3: AcQm, C4: VpQm, C5: CrQa, C6: OgJm, C7: LbCc) sample size and abbrev. see Table 3.1.



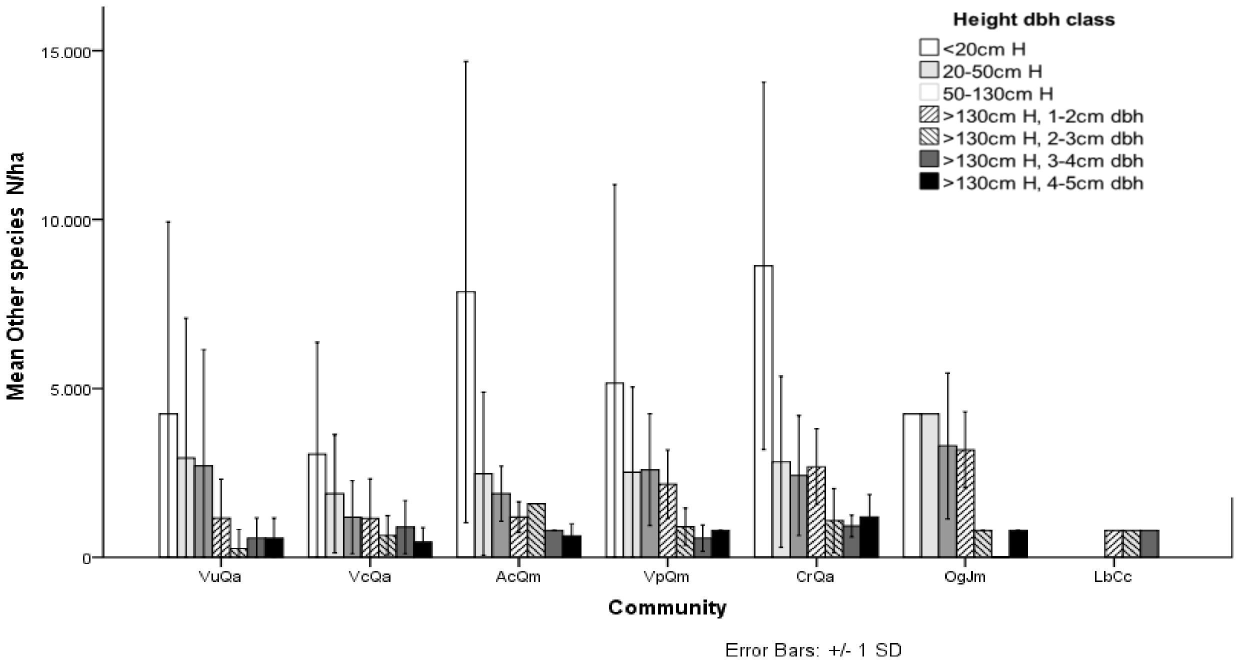


Fig. 3.32: Density (trees/ha) of trees (dbh ≥5 cm) in **dbh classes** (above) and of regrowth (dbh <5 cm) (below) of **other species** in the **height classes** (0-20 cm, 20-50 cm, 50-130 cm), and the **dbh classes** (1-2 cm, 2-3 cm, 3-4 cm, 4-5 cm, height >130 cm) in the 7 communities (C1: VuQa, C2: VcQa, C3: AcQm, C4: VpQm, C5: CrQa, C6: OgJm, C7: LbCc) sample size and abbrev. see Table 3.1.

3.3.3 Tree top height of 3 species groups on the 3 main site units

The age-height relation of dominant trees in 3 tree species groups, the *Quercus* species, the broad-leaf tree species, and the *Betula/Populus* species, were calculated as indicator for site productivity (Standort-Bonität) (ref. to Chapter 3.2.3). It shows the distribution of the top heights and their trendlines in the ages of the 3 tree species groups in the 3 community groups QQ and SQ and JC (the 3 main site units) (**Fig. 3.33**, **Fig. 3.34**, **Fig. 3.35**). The trendlines with logarithmic function shows the covariance relations between top heights and ages of 3 species groups, and the coefficient of determination (R^2) measures the fit. Only the coefficient of determination of higher top heights of *Quercus* species of the community group SQ is more than 0.7 (**Fig. 3.33**), the other R^2 are less, especially by the trendlines of the to top heights of *Populus-Betula* tree species (**Fig. 3.35**).

In the community group **SQ** on cool sunny fresh sites on higher altitudes, there were higher dominant-heights of all 3 tree species groups (the *Quercus* species, and the broad-leaf tree species, and the *Betula/Populus* species) than other community groups (QQ and JC). In the community group **QQ** (warm sunny dry sites) and in the community group **JC** (warm shady moist site) there were similarities of site qualities for the 3 tree species groups.

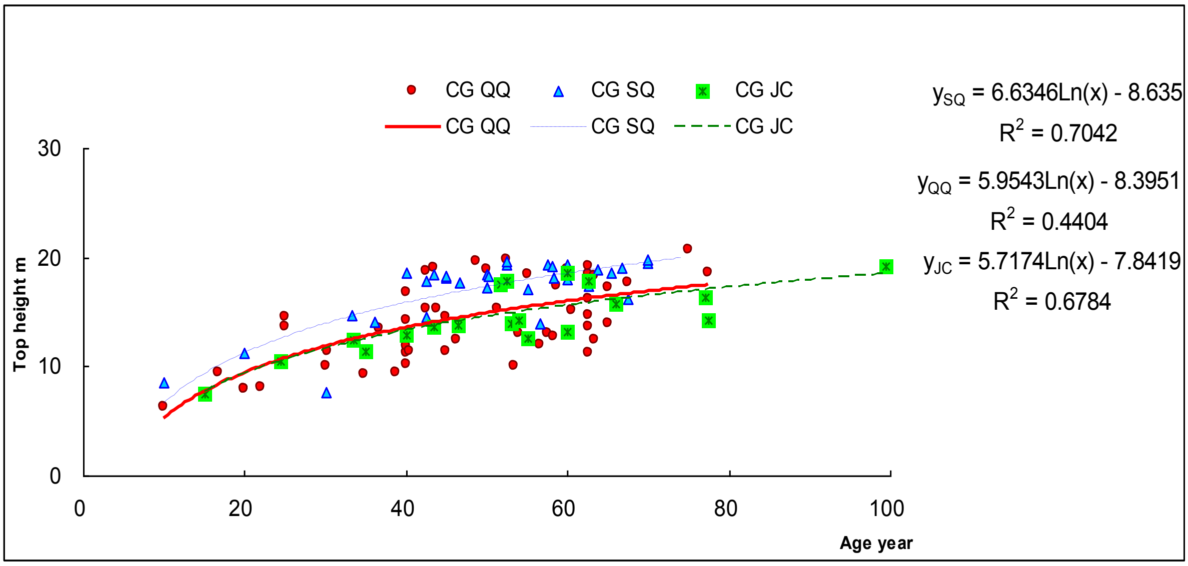


Fig. 3.33: Top height in relation to age and their trendlines of the *Quercus* species groups in the 3 community groups: **CG QQ**: solid red line, **CG SQ**: dashed blue line, **CG JC**: dashed green line (sample size and abbrev. see Table 3.1).

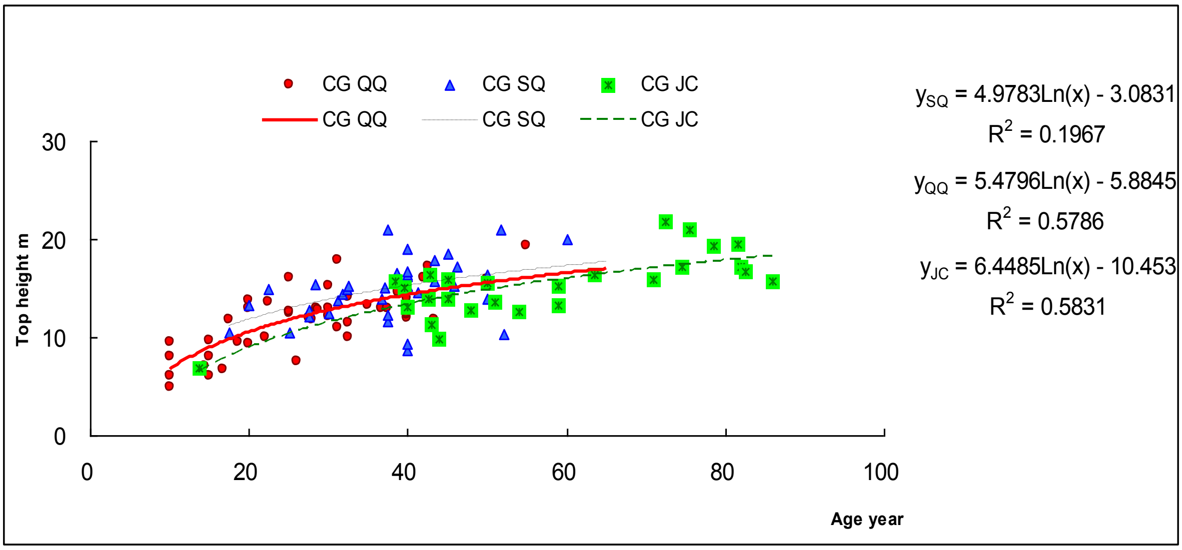


Fig. 3.34: Top height in relation to age and their trendlines of the broad-leaved tree species groups in the 3 community groups: **CG QQ**: solid red line, **CG SQ**: dashed blue line, **CG JC**: dashed green line (sample size and abbrev. see Table 3.1).

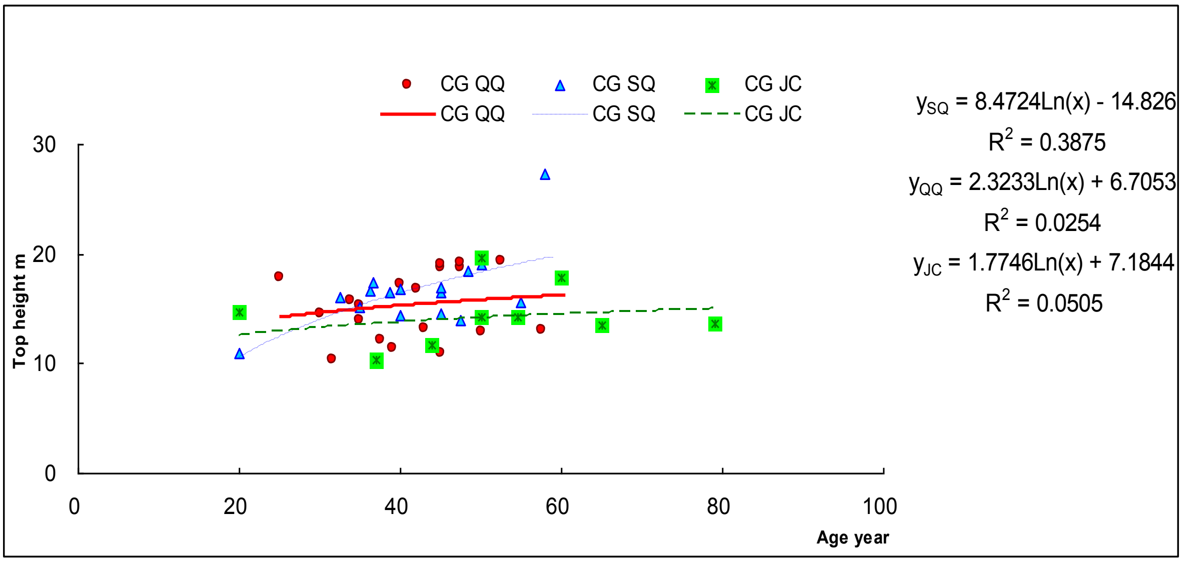


Fig. 3.35: Top height in relation to age and their trendlines of *Populus-Betula* species group in the 3 community groups: **CG QQ**: solid red line, **CG SQ**: dashed blue line, **CG JC**: dashed green line (sample size and abbrev. see Table 3.1).

3.3.4 Life forms and diversity

The **life forms** of the **herb layer**, and the **diversity indexes** of all the **4 layers** were particularly pointed out as structural characteristic besides density, basal area and volume, as well as their distribution of dbh classes of trees, and the distribution of height- and dbh classes of regrowth. The differences of the life forms (**Table 3.6**, **Table 3.7**), and of the diversity indexes between the 3 community groups and the 7 communities were graphically illustratived (**Fig. 3.36, Fig. 3.37, Fig. 3.38**).

3.3.4.1 Life forms of the herb layer

The herb layer includes the vegetation layer (height up to 1 m) with herb, grass, dwarf-shrub (hemicryptophyte, geophyte, therophyte, and chamaephyte), and also seedling of woody plants, i.e. trees and shrubs (phanerophyte) (ref. to Chapter 2). **Table 3.6** shows the ranges of mean cover (%, 100 m^2, std. deviation, minimum, maximum) of life forms in the herb layer of the 3 different **community groups**. There were significant differences in phanerophytes, chamaephytes, hemicryptophytes, therophytes between the 3 community groups, but no significant difference in geophytes.

Table 3.6: Life forms (%, 100 m^2) of herb layer for the 3 community groups (QQ, SQ, JC), abbrev. see Table 3.1. Values reported are mean and range, and their standard deviation in brackets. The differences were tested with KW H-test, *: p <0.05, **: p <0.01. Values with different letters in superscript were significantly different, based on pairwise comparisons with MW U-test.

Community group / plots / Life form	QQ	SQ	JC
plots	55	39	26
Phanerophyte**	**42**^{a}	**38**^{a}	**13**^{b}
	(21)	(20)	(10)
	4-95	0-93	1-37
Chamaephyte**	**1** ^{a}	**1**^{b}	**<0.5**^{b}
	(2)	(4)	(0.2)
	0-14	0-20	0-1
Hemicryptophyte**	**14**^{b}	**14**^{b}	**56**^{a}
	(10)	(15)	(36)
	1-53	0-72	8-1681
Geophyte--	**20**	**20**	**24**
	(15)	(15)	(19)
	1-72	2-53	2-83
Therophyte**	**1**^{b}	**3**^{b}	**13**^{a}
	(3)	(6)	(19)
	0-20	0-24	0-63

The community groups QQ (dry, sunny, warm, submontane sites) and SQ (fresh, sunny, cool, montane-sites) had a significant higher cover of phanerophytes and less of hemicryptophytes and of therophytes (**Table 3.6**).

In the community group JC (moist, shady, warm, submontane sites in valleys or lower-slopes), in comparison, there was less cover of phanerophytes, however, the highest cover of hemicryptophyte and also of therophytes, i.e. there was less regrowth of trees and shrubs, but mostly herbs and grass of the perennial plants with perennating buds situated at the soil surface or just below, and also mostly herbs and grass of annual plants. This may be due mostly to natural disturbance (flood, debris flow, mudflow), or by human or animal impacts.

Table 3.7 shows variations of mean cover (%, 100 m^2) of life forms in the herb layer of the **7 communities**. The KW H-test confirmed in general differences in all the life forms between the 7 communities. The pairwise comparisons with MW U-test showed the differences between different communities in the same community group.

The communities VuQa and VcQa, both on dry sunny warm submontane-sites, were significantly different in the cover of chamaephytes and therophytes (**Table 3.7**) in the community VuQa there was a heigher cover of chamaephytes, i.e. more dwarf-bushes and herbaceous perennials with buds either at or near the soil surface; but less therophytes (annual herb and grass) than in the community VcQa.

The communities AcQm and VpQm, both on fresh sunny cool montane-sites, were significantly different in the phanerophytes, the hemicryptophytes, and the geophytes (**Table 3.7**): in the community AcQm, in comparson to community VpQm, there was less cover of the phanerophytes, i.e less regrowth of trees and shrubs, but heigher cover of the hemicryptophytes, and the geophytes, i.e. more herbs and grass of the perennial perennating buds situated at or under the soil surface. The regrowth of trees also meantioned in the Chapter **3.3.1.2** with their density.

The communities CrQa, OgJm and LbCc, all on moist shady warm submontane-sites, were significantly different in the phanerophytes, the geophytes and the therophytes (**Table 3.7**). In the community CrQa there was a heigher cover of phanerophytes, i.e. more regrowth of trees and shrubs, than in the communities OgJm and LbCc. In the community OgJm there was a heigher cover of therophytes, i.e. more annual herb and grass. In the community LbCc there was a heigher cover of geophytes, i.e. more herbaceous perennating their buds situated below ground. The regrowth of trees in each community also meantioned in the Chapter **3.3.1.2** with their density. The communities VcQa (dry, sunny, warm, submontane-sites) and VpQm (fresh, sunny, cool, montane-sites) had the highest cover of phanerophytes (**Table 3.7**), i.e. there were the most seedlings of trees and shrubs. The community VuQa had the significantly highest cover of the chamaephytes, i.e. there were the most dwarf-bushes and herbaceous perennials their buds either at or near the soil surface. The communities CrQa, OgJm, and LbCc, all on moist, shady, warm, submontane-sites on valleys or under slopes, had the highest cover of hemicryptophytes. The community LbCc had the highest cover of geophytes, i.e. herbaceous perennating their buds below ground as rhizome, tuber, bulb, or corm. The community OgJm has the highest cover of therophytes, its value was extrem.

Table 3.7: Life forms (%, 100 m^2) of herb layer for the 7 communities (VuQa, VcQa; AcQm, VpQm, CrQa, OgJm, LbCc), abbrev. see Table 3.1. Values reported are mean, and their standard deviation in brackets. The differences were tested with KW H-test, *: p <0.05, **: p <0.01. Values with different letters in superscript were significantly different, based on pairwise comparisons with MW U-test.

Community / Life form	VuQa	VcQa	AcQm	VpQm	CrQa	OgJm	LbCc
plots	19	36	15	24	12	5	9
Phanerophyte**	**36^{ab}**	**46^{a}**	**26^{bcd}**	**45^{a}**	**20^{c}**	**4^{e}**	**8^{de}**
	(21)	(20)	(19)	(17)	(9)	(4)	(7)
Chamaephyte**	**7^{a}**	**$<0.5^{b}$**	**3^{bc}**	**$<0.5^{c}$**	**$<0.5^{bc}$**	**0^{cd}**	**$<0.5^{bc}$**
	(3)	(1)	(6)	(<0.5)	(<0.5)		(<0.5)
Hemicryptophyte**	**12^{c}**	**15^{c}**	**23^{bc}**	**9^{d}**	**54^{a}**	**50^{a}**	**61^{a}**
	(66)	(11)	(18)	(11)	(48)	(17)	(25)
Geophyte*	**23^{ab}**	**18^{bc}**	**27^{ab}**	**15^{c}**	**21^{bc}**	**16^{bc}**	**31^{a}**
	(16)	(15)	(18)	(11)	(23)	(7)	(15)
Therophyte**	**$<0.5^{d}$**	**1^{c}**	**5^{bc}**	**1^{cd}**	**7^{b}**	**44^{a}**	**5^{b}**
	(<0.5)	(4)	(9)	(2)	(12)	(19)	(6)

3.3.4.2 Diversity in the 4 vegetation layers

The **diversity indexes** (richness, evenness, Shannon index, Simpson index) in the 4 vegetatio layers (1st tree layer, 2nd tree layer, shrub layer, herb layer) of the forest stands were analyzed with parameter coverage and number of species (ref. to Chapter **3.2.4**).

There were significant differences (tested with KW-test) in most diversity indexes of the 4 layers between the 3 community groups (**QQ, SQ, JC**), there were no significant differences: in the evenness of the 1st tree layer and the shrub layer, and in the species richness of the herb layer (**Fig. 3.36**, **Fig. 3.37**).

In the **community group QQ** (dry, sunny, warm, submontane-sites), there was the least species richness of the 1st tree layer, less species richness of the 2nd tree layer, but high species richness of the shrub layer (**Fig. 3.36**, **Fig. 3.37**). There was a similar trend in the Shannon-index, which took into account the two components of diversity (the species richness and evenness, the equal distribution of the species). Similar trend was also in the Simpson index, its calculation was used also with the species richness and the evenness, but evenness ccounted more. In the community group QQ, the evenness of the 1st tree layer, of the 2nd tree layer and of the shrub layer were similarly high like in the other 2 community groups. The evenness of the herb layer was less. i.e. there were less tree species in the dominant layer and the sub dominant layer, but distribution of all the species was similar; there were more species of shrubs and obviously of regrowth of trees (height 1-5 m); there was a similar high diversity of species (30-40 species) in the herb layer.

In the **community group SQ** (fresh, sunny, cool, montane-sites) there was a high species richness of the 1st tree layer, of the 2nd tree layer, and also of the shrub layer (**Fig. 3.36**, **Fig. 3.37**). There was a similar trend in the Shannon-index and the Simpson-index. There was a high evenness in the 2nd tree layer and the herb layer. i.e. in the community group SQ, there was a high diversity in alle 4 layers; distribution of all the species was similar in the sub dominant tree layer and the herb layer.

In the **community group JC** (moist, shady, warm, submontane-sites) there was a high species richness in the 1st tree layer, middle in the 2nd tree layer, but less in the shrub layer (**Fig. 3.36**, **Fig. 3.37**). In the 1st tree layer of the community group JC, however, there was no similar trend in the Shannon-index and in the Simpson index, both indexes were significantly lower, despite a high species richness. i.e. there were more tree species in the dominant and sub dominant tree layers, but less shrub species or regrowth of tree species (hight 1-5 m). In the 2nd tree layer and herb layer, evenness was smaller, i.e. in the sub dominant tree layer and herb layer, a few species were dominant, like*Meliosma cuneifolia*, *Chrysosplenium biondianum*.

There were significant differences (tested with KW-test) of all diversity indexes of the 4 layers between the **7 communities** (**Fig. 3.38**).

Mean species **richness** of the **1st tree layer** in the 7 communities ranged between 3 species (in the community VuQa, warm, sunny, dry sites) and 6 species (in VpQm, cool, sunny, fresh sites). Mean **evenness** ranged between 0.33 (in OgJm, warm, shady, moist sites) and 0.85 (in LbCc, also warm, shady, moist sites). Mean **Shannon index** ranged between 0.38 (in OgJm) and 1.35 (in VpQm). Mean **Simpson index** ranged between 0.21 (in OgJm) and 0.68 (in VpQm) (**Fig. 3.38)**.

Mean species richness of the **2nd tree layer** in the 7 communities ranged between 5 species (in VuQa, warm, sunny, dry sites) and 8 species (in CrQa, warm, shady, moist sites). Mean evenness ranged between 0.47 (in CrQa, significant difference to other 6 communities) and 0.72 (in LbCc, also warm, shady, moist sites). Mean Shannon index ranged between 0.91 (in VuQa) and 1.39 (in AcQm, cool, sunny, fresh sites). Mean Simpson index ranged between 0.47 (in CrQa) and 0.69 (in AcQm) (**Fig. 3.38**).

Mean species richness of the **shrub layer** in the 7 communities ranged between 12 species (in OgJm, warm, shady, moist sites) and 24 species (in VcQa, warm, sunny, dry sites). Mean evenness ranged between 0.57 (in OgJm) and 0.71 (in VcQa). Mean Shannon index ranged between 1.42 (in OgJm) and 2.25 (in VcQa, significant difference to other 6 communities). Mean Simpson index ranged between 0.56 (in OgJm) and 0.83 (in VcQa) (**Fig. 3.38**).

Mean species richness of the **herb layer** in the 7 communities ranged between 23 (in OgJm, warm, shady, moist sites) to 45 (in CrQa, also warm, shady, moist sites). Mean evenness ranged between 0.59 (in OgJm) and 0.71 (in VpQm, cool, sunny, fresh sites). Mean Shannon index ranged between 1.86 (in OgJm, significant difference to other 6 communities) and 2.8 (in VpQm). Mean Simpson index ranged between 0.77 (in OgJm) and 0.9 (in AcQm, cool, sunny, fresh sites) (**Fig. 3.38**).

The community VcQa had a significantly higher diversity in all layers than the community VuQa, but both on warm sunny dry sites. The community VcQa had a higher species richness, Shannon index, Simpson index in the 1st tree layer; a higher Shannon index and Simpson index in the 2nd tree layer; a higher evenness, Shannon index and Simpson index in the shrub layer, and a higher Simpson index in the herb layer.

The communities AcQm and VpQm, both on cool sunny fresh sites, were significantly different only in the species richness of the 1st tree layer: the community VpQm had a higher species richness (even the highest in the 7 communities), i.e. there was the highst α-diversity in the dominant tree layer.

The communities CrQa, OgJm and LbCc, all on warm shady moist sites, were significantly different in the diversity of the 1st tree layer, of the shrub layer and of the herb layer. The communities CrQa had the highst species richness, but low evenness in the 2nd tree layer and in the herb layer. The community OgJm had low diversity: lowest evenness, Shannon index and Simpson index in the 1st tree layer, low species richness, but high in the 2nd tree layer, and the lowest species richness and evenness and Shannon index and Simpson index in the herb layer. In the herb layer of the community OgJm, there were few species, but some of them, obviously hemicryptophytes or therophytes (see above Life Forms **3.3.4.1**, **Table 3.7**) like*Chrysosplenium biondianum*, were dominant. The community LbCc had high evenness in the 1st tree layer and in the 2nd tree layer.

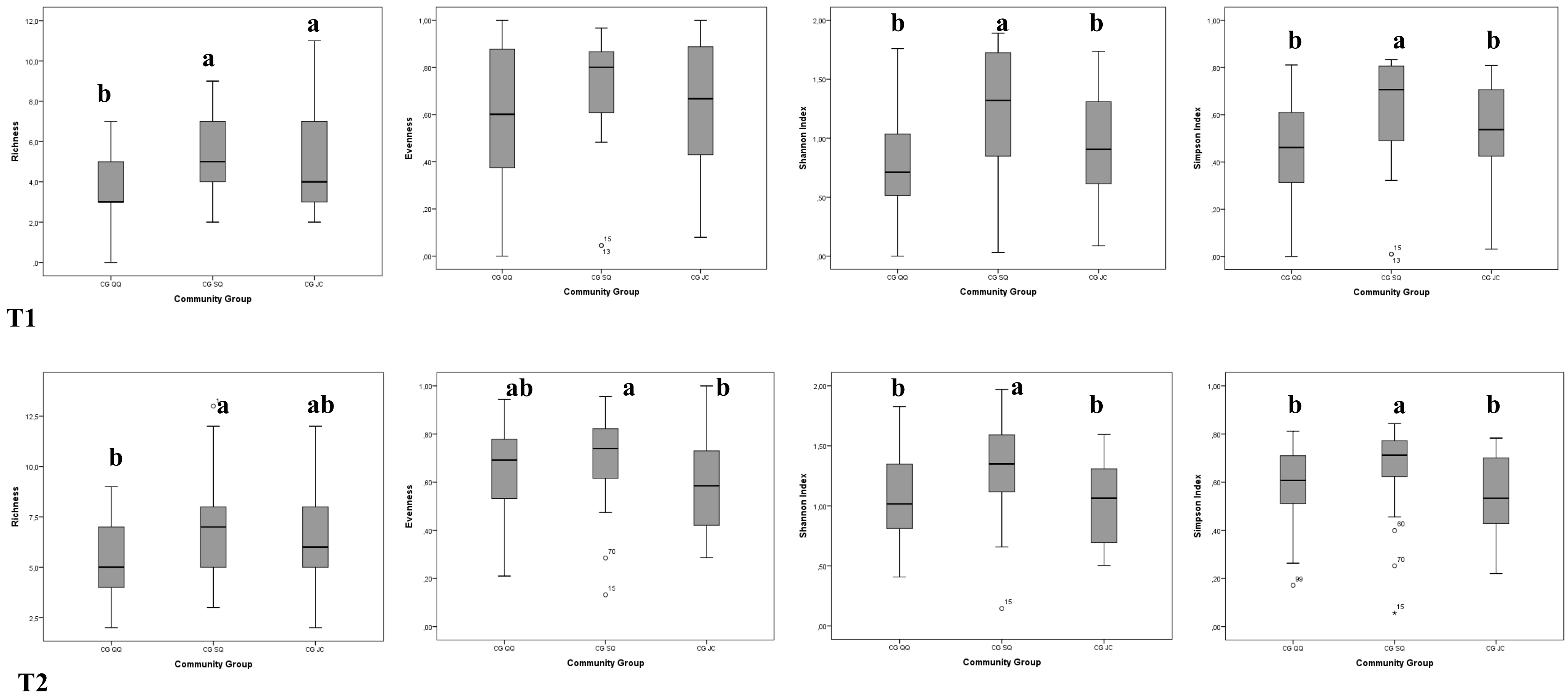


Fig. 3.36: Diversity (richness, evenness, Shannon index, Simpson index) in the **1st tree layer** (T1) (above), **2nd tree layer** (T2) (below) of **3 community groups** (CG **QQ**, CG **SQ**, CG **JC**), sample size and abbrev. see Table 3.1. Values with different letters in superscript were significantly different, based on pairwise comparisons with MW U-test. Box plot with median, Q_{25} and Q_{75} (box), outliers and exterme values with their plot numbers.

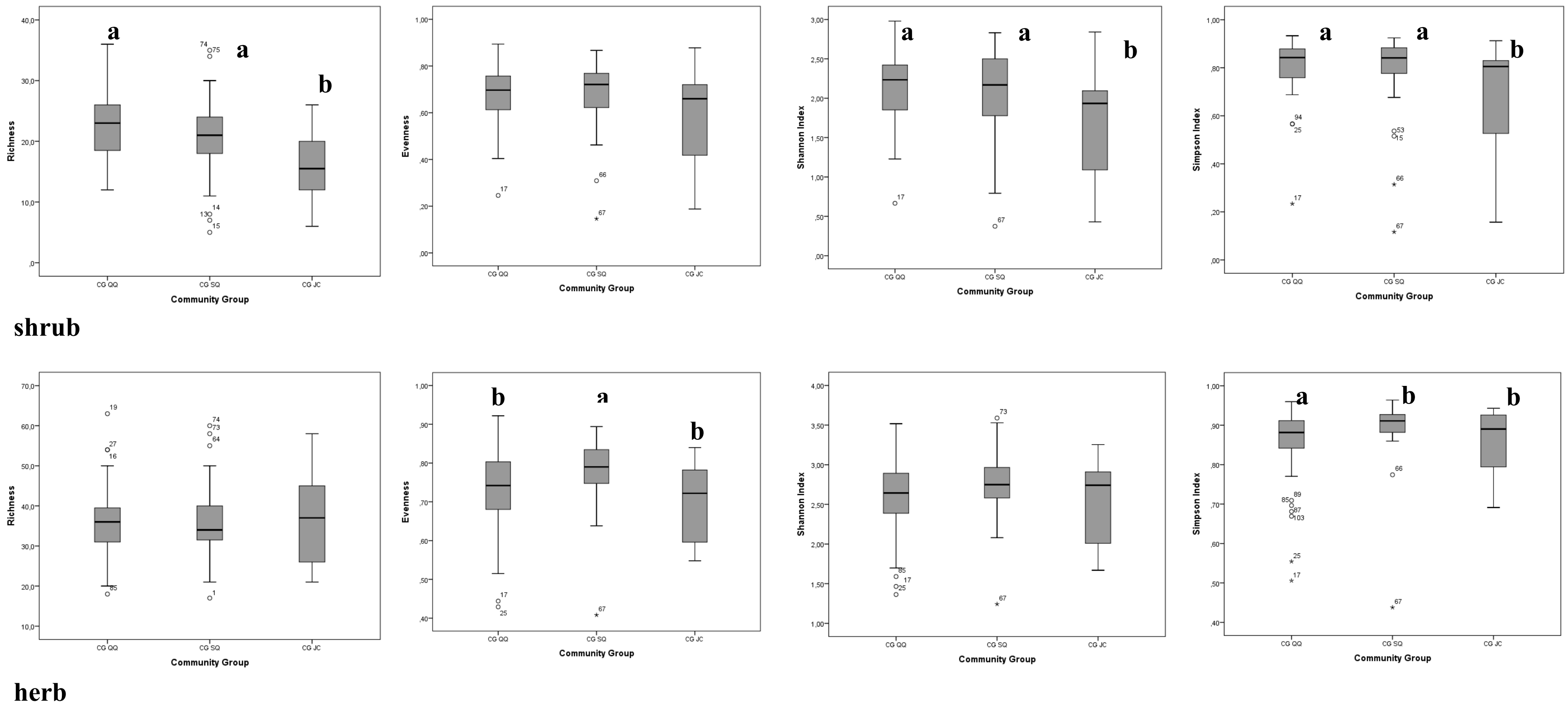


Fig. 3.37: Diversity (richness, evenness, Shannon index, Simpson index) in the **shrub layer** (above) **and herb layer** (below) of **3 community groups** (CG **QQ**, CG **SQ**, CG **JC**), sample size and abbrev. see Table 3.1. Values with different letters in superscript were significantly different, based on pairwise comparisons with MW U-test. Box plot with median, Q_{25} and Q_{75} (box), outliers and exterme values with their plot numbers.

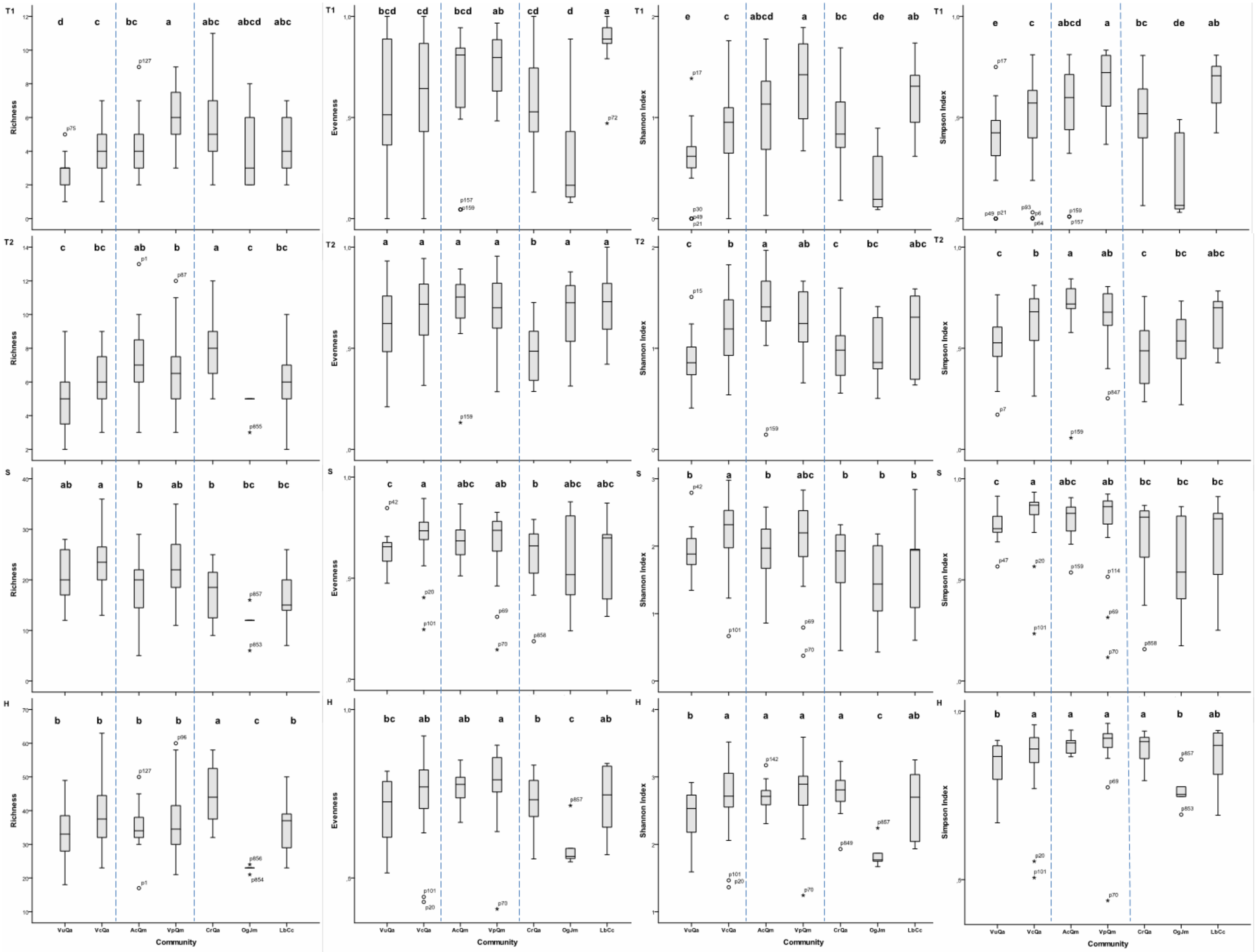


Fig. 3.38: Diversity (richness, evenness, Shannon index, Simpson index) of 1st tree layer (T1), 2nd tree layer (T2), shrub layer (S), herb layer (H) in the 7 communities (VuQa, VcQa, AcQm, VpQm, CrQa, OgJm, LbCc), sample size and abbrev. see Table 3.1. Values with different letters in superscript were significantly different, based on pairwise comparisons with MW U-test. Box plot with median, Q25 and Q75 (box), outliers and exterme values with their plot numbers.

3.4 Discussion

The aim of the 2nd part of this thesis (Chapter **3**) was describe to the stand structure of 3 forest community groups and 7 forest communities with regard to dynamic and forest site quality. These community groups and communities were the result of the vegetation classification in the first part of this thesis. The results of this study showed the different situations of the stand structure, of the regrowth of tree species, as well as of the trends succession in the community groups and the communities. Silvicultural measures should be differentiated and further optimised on the basis of forest site, and their succession, for conserving the combination and diversity of species and diversity of stand structure.

3.4.1 Stand structure

The majority of the world forests is influenced by humans. The intensity of these infuences depend upon socio-cultural status, upon dense population, and upon historical land-use (UNEP et al. 2009). In China, with her thousand years of cultural history and prolonged wars, the high human pressure has had an immense impact on the forests. As a result of this anthropogenic pressure, primeval forests in China have mostly disappeared. Many forests, however, still represent a good floristic reflection on natural site conditions even after human intervention and they still can be categorised as "semi-natural" after DIERSCHKE (1994: 66-73). Such forest stands are mostly composed of native species adapted to the site conditions.

In the Western Qinling Mts. the remaining oak forests still tend clearly towards "semi-natural" ones, where the forests were selectively cut and thinned at short intervals in the past. The mixed mountain forests in the research area were rich in structure and species. Obviously they are in a transition phase between pioneer forest and late succession forest.

The study of ZHAO et al. (2008) showed that in the *Quercus aliena* var. *acutiserrata* dominated “natural forest” (0.4 ha) in the Western Qinling Mts., as they named it, there are site adapted native deciduous broad-leaf tree species still present. This confirms the present study made in the neighbourhood.

There were mostly trees with smaller diameters (dbh <20 cm), fewer trees with bigger diameters. ZHAO et al. (2003) mentioned that in the *Quercus aliena* var.

acutiserrata dominanted forest stands in Qinling Mts. there were 81 % trees of *Q. aliena* var. *acutiserrata* with a dbh <22 cm. The present research showed a similar character of forest stand structure in the *Quercus* forests of the Qinling Mts, probably the results of an over-use in the past.

The mixed mountain forests in the research area were characterised by many young trees and very few old ones. The volume of stands here was bigger than the average of the volume in the older stands, as stated by the Forest Bureau of Xiaolongshan (ref. to Chapter **1.6**). Nevertheless, this low volume is not sufficient as a basis for increase of stand volume in general. Judging from a silvicultural point of view, it would be, therefore, better to implement further protective measures for the much needed increase of stand volume.

3.4.2 Stand dynamics

With time the community **VuQa** will be dominated by more *Quercus aliena* var. *acutiserrata* and by less *Quercus dentata*, accompanied by some of the other broad-leaf tree species. The conifer species *Pinus armandii* will develop slowly. Only if the site condition is dryer and opener, this species will have more chance to develop.

With time, the community **VcQa** will be mixed with more *Quercus aliena* var. *acutiserrata*, *Quercus mongolica, Betula platyphylla*, and with less *Quercus dentata, Corylus chinensis, Sorbus alnifolia*, accompanied for long time by some of the other broad-leaf tree species. But *Betula platyphylla* as a pioneer species will persist no longer than other mid-successional species and late-successional species.

With time, the community **AcQm** will persist with more *Quercus mongolica, Betula platyphylla*, and with less *Corylus chinensis, Betula albosinensis.* Some other broad-leaf tree species will accompany them for long time. The long-lived species *Betula albosinensis* will persist longer than short-lived species *Betula platyphylla*, while both species have no small dbh class (5-10 cm) trees and no regrowth in the community.

The community **VpQm** will persist with time with more *Quercus mongolica*, *Corylus chinensis*, and with less *Corylus chinensis*. More *Corylus chinensis* will develop in to bigger dbh classes. Some of other broad-leaf tree species will mix also for long time.

With time, the community **CrQa** will be mixed with *Quercus aliena* var. *acutiserrata, Betula platyphylla, Corylus chinensis*, *Ulmus davidiana* var. *japonica*, *Juglans mandshurica*, and with some of other broad-leaf tree species. *Betula platyphylla* will not persist longer than the other early successional species like *Ulmus davidiana* var. *japonica*, while *Betula platyphylla was* different to *Ulmus davidiana* var. *japonica* and had no small dbh class and no regrowth (ref. to Chapter **3.3.2**).

With time, the community **OgJm** will be mixed with *Juglans mandshurica, Corylus chinensis*, and with some of other broad-leaf tree species. The regrowth of *Juglans mandshurica* was missing, so this species will not persist very long time.

The community **LbCc** with time will be mixed with more *Quercus mongolica*, *Juglans mandshurica, Ulmus davidiana* var. *japonica*, with less *Quercus aliena* var. *acutiserrata*, *Sorbus alnifolia*, *Corylus chinensis*, *Betula albosinensis* and with less of some of other broad-leaf tree species.

The reason for the different dynamic in the communities of the same cmmunity group might be more human disturbance in the past than the difference of site condition. There are still detailed differences in site conditions for the different communities of the same community group, like steeper or flatter slopes, with more or less sun, with more or less good soil conditions and moisture to allow or to hinder the growth.

The distribution of *Betula platyphylla* is less connected to its site conditions, like altitude, because the 3 community groups with high density of this species were on sites with great difference in altitudes. The difference in density and basal area for *Betula platyphylla* were only found between the 7 communities, but not in 3 community groups (see **Fig. 3.6** and **Fig. 3.24**). This is shown in detail: in the community **AcQm** (C3) from 1990 m to 2080 m, the community **VcQa** (C2) mostly between 1500 m to 1900 m, the community **CrQa** (C5) only between 1600 m and 1700 m. The distribution of this pioneer species (the early successional species) *Betula platyphylla* might probably be influenced, more or less, by human disturbances. However, the distribution of the dbh classe of *Betula platyphylla* was varying in those different communities. The other early successional species like *Ulmus davidiana* var. *japonica* in the dbh class 5-10 cm was found in the community LbCc with high density, there were more dbh classes in the communities CrQa, VuQa, VcQa (**Fig. 3.28**). The regrowth of *Ulmus davidiana* var. *japonica* was found in the communities (VuQa, VcQa, VpQm, CrQa, Ogjm) (ref. to Chapter **3.3.2**). Obviously they might have been more exposed to human disturbance and activities. However, the early succession species have also been important for diversity.

3.4.3 Site Quality

To evaluate the site quality of the 3 community groups, the top heights in this study were compared to the site indices with absolute top heights of the Forest Bureau of Xiaolongshan (FOREST BUREAU OF XIAOLONGSHAN 1982b) (**Annex 3.5**). **Fig. 3.39** shows the trend lines of top heights of the 3 community groups (**QQ**, **SQ** and **JC**) in the curve diagram of the site index with absolute top heights for "*Quercus* species group" and for "broad-leaf tree species group".

The site quality of the community group **QQ** compared to the site index for *Quercus* species group is similar to site index 14 (**Fig. 3.39**). The same applies to the community group **SQ** (site index 16) and **JC** (site index 14). The site quality of the community groups QQ and JC can be regarded as medium site quality for *Quercus* species. The site quality of the community group SQ is better for *Quercus* species.

The site quality of the community group **QQ** compared to the site index for broad-leaved tree species group is similar to site index 14 (**Fig. 3.39**). The same applies to the community groups **SQ** (site index 15) and **JC** (site index 14). The site quality of QQ, SQ and JC can be regarded as medium site quality for broad-leaved tree species.

Using the top heights as a means of evaluation of site quality showed that site of the *Sorbus alnifolia–Quercus mongolica* community group (upper slopes or ridge between 1900 to 2000 m) was better for oak trees than the sites of the other two community groups. The site of the *Juglans mandshurica-Corylus chinensis* community group in valleys, shadow slopes and lower altitudes, however, was favorable for other broad-leaved tree species e.g. *Corylus chinensis* and *Juglans mandshurica*. Thus the diagnostic species from the vegetation analyses (see Chapter 2) could be an indicator for the site types as well as an indicator for the site quality, e.g. the diagnostic species *Viola phalacrocarpa, Stellaria palustris* in community group SQ are an indicator for a site with higher quality for the oak species *Quercus mongolica*. The diagnostic species *Viola unijuga, Saussurea pectinata* in community group QQ are an indicator for a site with medium quality for the oak species *Quercus aliena* var. *acutiserrata*. The diagnostic species *Aconitum sungpanense, Sanicula chinensis* in community group JC are an indicator for a site with medium to higher quality for the broad-leaved tree species e.g. *Corylus chinensis* and *Juglans mandshurica*.

The determination of age for top heights was not done by counting the year rings of each measured tree, but by referring to secondary sources ("field book", Revierbuch), by counting the year rings of trunks nearby, by counting the whorls on branches of coniferous trees and by estimating the age while considering site growth dynamics (FVA 2004). But the determination of age in these unevenly-aged mixed stands is prone to mistakes when employing the above-mentioned methods. In the forest stands there were only many rather young trees, no stands with old trees. There were insufficient data for all the species (or species groups). However, this was a primary attempt to integrate site quality with vegetation and site classification, while the top height site quality in this present study was based on a rough estimation only. Further studies, e.g. with the help of a permanent inventory, would have to be carried out in order to verify these results.

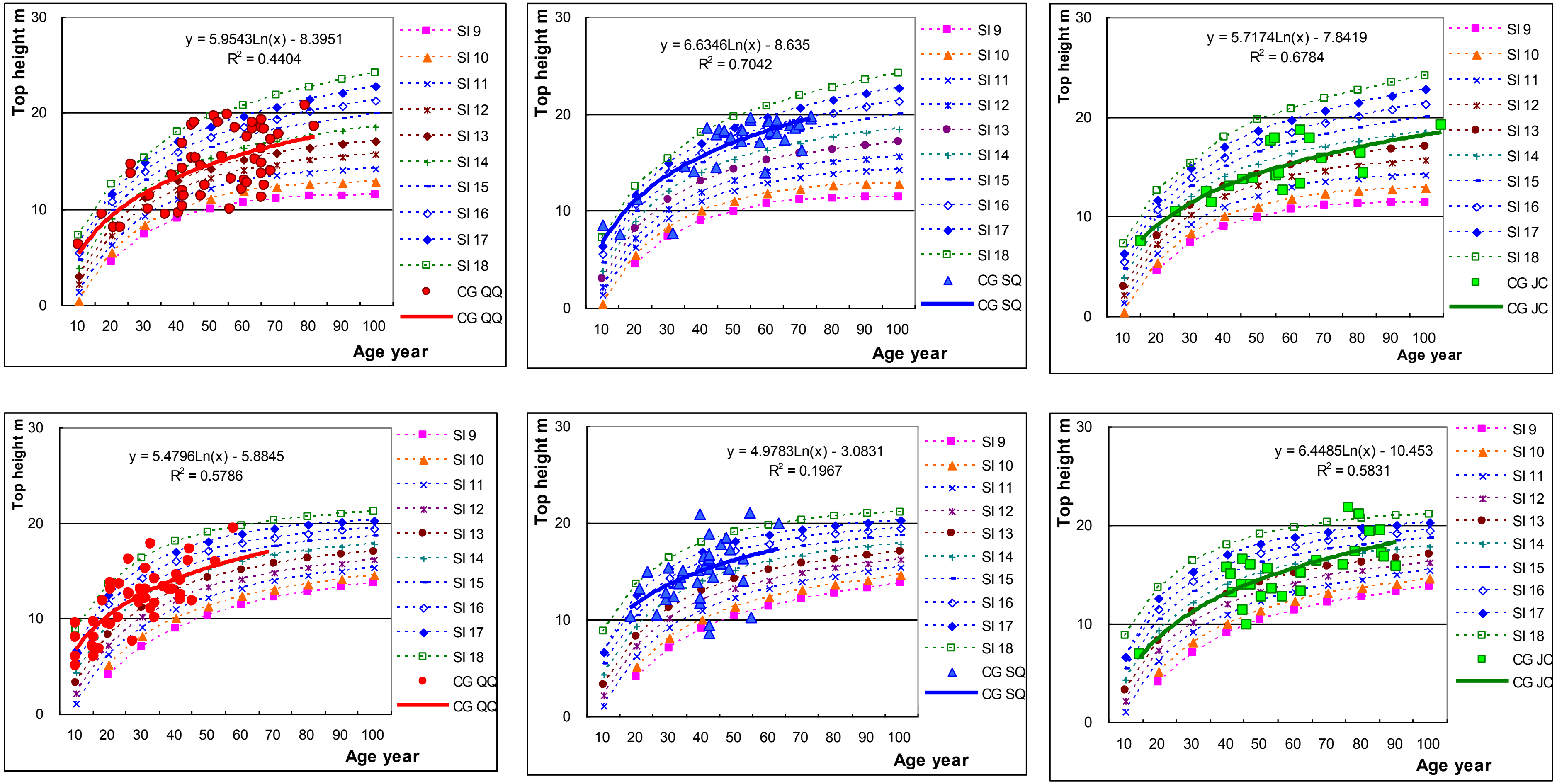


Fig. 3.39: Top heights and their trend lines of 3 community group: **QQ** (CG QQ) (left), **SQ** (CG SQ) (middle) and **JC** (CG JC) (right) (sample size and abbrev. see Table 3.1) and site index (SI) with absolute top heights for Oak tree species (above) and for broad-leaved tree species (below) **adapted from** (Forest Bureau of Xiaolongshan 1982b) (see Annex 3.5).

3.4.4 Life forms and diversity

The **life forms** of the herb layer in the different stands reflect human disturbance, e.g. theophytes, occur on opened areas (MCINTYRE et al. 1995). Especially in the community **OgJm** (on warm shady moist sites on valley or under slopes), there was a high cover of theophytes. These are indicators of disturbance proving that this community suffered natural disturbance (flood, debris flow, mudflow) or human and animal disturbance by cutting timber, by laying trails (trailing), or by grazing animals. The ground layer consists of native species adapted to the site conditions, but also of numerous light- and semi-shade-tolerant species which naturally occur mostly outside of forests or in the forest borders.

All **diversity** indexes varied in the 4 different layers between the 3 community groups and the 7 communities. The reason may be not only due to the sites, but also due to human disturbance or animals.

The low diversity of the dominant tree layer and the high diversity of the sub-dominant tree layer, shrub layer and herb layer proved that this community suffered from human disturbance, of forest use in history. The high diversity of more layers showed also the forests were rich in species and rich in stand structure.

In all the communities and their forest site types **rare species** could also found (ref. to Chapter **2**) in national rare species list (SFA 1999, CAI et al. 2003). e.g. the shrub species ***Paeonia suffruticosa* var. *papaveracea*** in the communities VuQa and VcQa on warm, sunny, dry sites; or the tree species ***Euptelea pleiosperma*** in the community VpQm on cool, sunny, fresh sites; or ***Corylus chinensis, Juglans mandshurica*** in the community group JC on warm, shady, moist sites, or the species ***Cephalotaxus sinensis*** in the community OgJm on warm, shady, moist sites.

The reason for the small number of trees with bigger diameters (dbh >20 cm) and the low diversity in the dominant tree layer might be due to the disturbance by humans (historic use). In order to clearly identify the real cause for this, it is necessary to perform further research of the forest dynamics in a setting where as experiments one part of the area is characterised by total protection and another part by controlled use.

Despite the fact that the mixed mountain forests in the research area had a low volume, they were, however, rich in structure and species. Their potential resistance against changes of climate and forest site is high.

3.5 Conclusion and management implications

As shown above the stand structure in the research area is diverse and its species richness is great. The forests are in transition between the pioneer succession phases and late succession forest phases, characterised by intermediate forest growth and low volume.

The site quality of the community groups could be considered medium for oak species in the community groups **QQ** and **JC,** and better site quality for oak species was in the community group **SQ**. The site quality for broad-leaf tree species was medium in the community groups **QQ, SQ,** and better site quality was in the community group **JC**.

Taking all the above-mentioned facts into account, the objectives for the Forest Bureau in this water reserve of the Western Qinling Mts. should be conservation and sustainable forest management.

This can be attained by ways of three different approaches. The most important and sustainable approach would be to continue pursuing the logging ban and thereby enhancing water quality and preventing erosion in the designated forest protection areas of semi-natural forests.

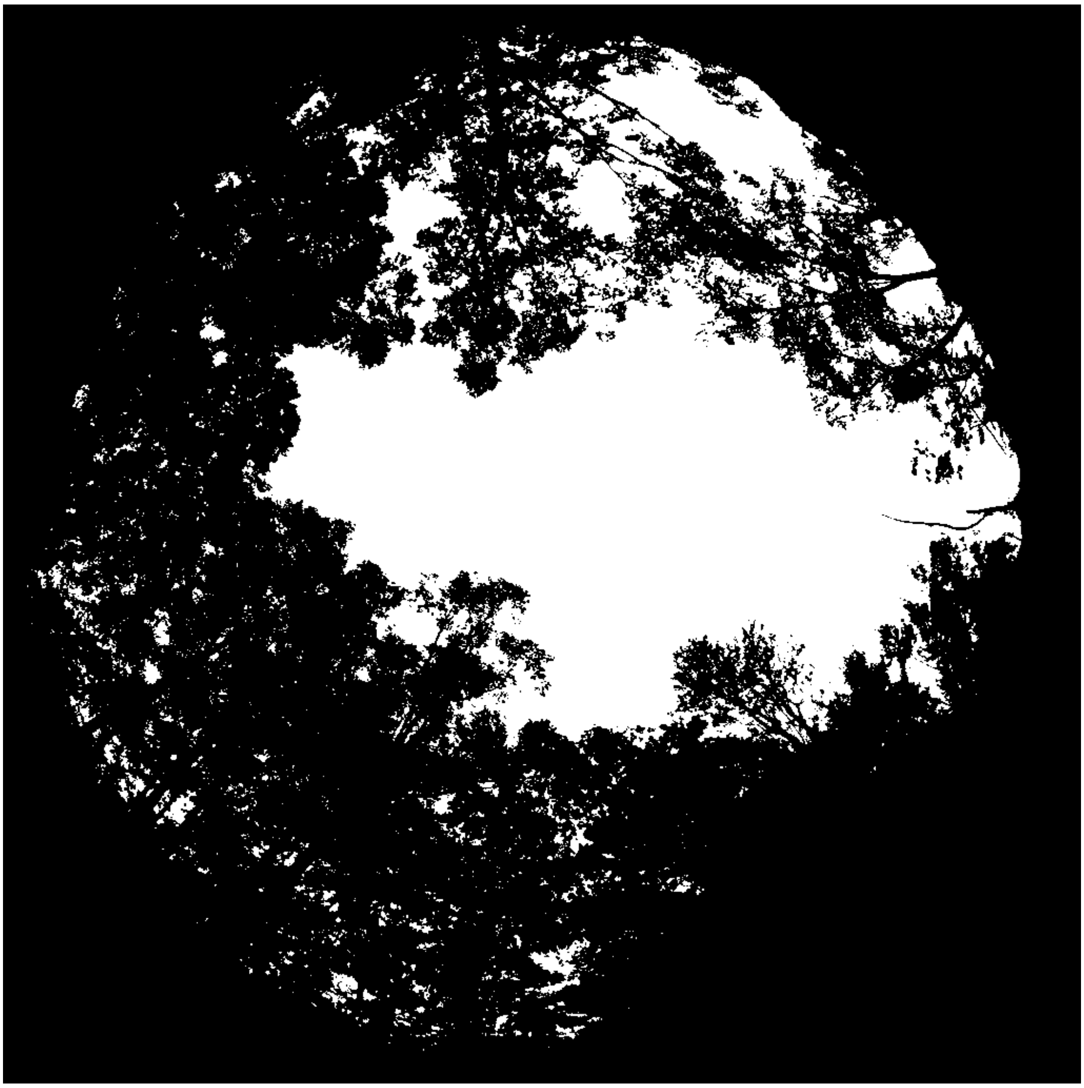
Considering the great demand of timber, on the one hand, and the insufficient governmental funds for the forest authorities, on the other hand, a permanent logging ban, might be a difficult task to realise. Therefore, certain compromises are inevitable. One could think of a second approach, e.g. a "multi-level protection". This would mean protecting a "key area" situated along water courses, also on the steep slopes (to prevent erosion) and covering all the forest site types and their communities as well as a conservational habitat for rare species e.g. the rare shrub species *Paeonia suffruticosa* var. *papaveracea* in the communities VuQa and VcQa on warm, sunny, dry sites; or *Euptelea pleiosperma* in the community VpQm on cool, sunny, fresh sites; or *Corylus chinensis, Juglans mandshurica* in the community group JC on warm, shady, moist sites, or *Cephalotaxus sinensis* in the community OgJm on warm, shady, moist sites. At the same time one would need a "buffer zone" between the protection area, on the one hand,

and densely populated and highly frequented areas, such as villages and roads on the other hand. This "buffer zone" would be characterised by richness of structure and species including pioneer species. Certain activities, such as collecting fire wood and non-timber products, as well as grazing of animals, would be allowed, but should be controlled in order to assess/evaluate the effects of human and animal interference on those areas as compared to the "key area".

The third approach would be a more future-oriented measure: to start a sustainable silvicultural management with site-adapted tree species in the different sites, wherever advisable, adapting e.g. a close-to-nature forest concept. (may be no sooner than in 30 to 50 years!) The advantages are obvious, i.e. automatical, biological processes with minimal changes regarding the natural processes under control of forest dynamics providing for natural regeneration. Site-adapted silvicultural management nees also less as possible human intervention (BURSCHEL & HUSS 2003). At least, this would mean to safeguard the production potential by using site adapted species. The silvicultural measures should be differentiated and further optimised on the basis of forest site as well as caring for succession, and thus to conserve the combination and diversity of species. The plan for the silvicultural measures should be considering the different situations of the structure of stands, of the regeneration of species as well as of the succession of the forest community groups and the forest communities, which this thesis shows.

There are, however, also a few reserves that can be denied at present. Favorable economics and political conditions are as important as enough well-trained forest bureau officials and forest workers to carry out the work. If all this comes together in the research area, it might take approximately 30 to 50 years for the mixed forests to increase substantially via the young stands and to result in potential future crop trees to be selected and provided for. At last, a professional training of the above-mentioned manpower in the local forestry will also need time.

4 Effects of canopy structure and light on regeneration of *Quercus aliena* var. *acutiserrata* in an oak forest in Western Qinling Mountains, China



A hemispherical photo in a gap of an oak forest (expanded gap size 103 m^2)

(Photography: CHUNLING DAI, 2008)

4.1 Introduction

Oak forests are considered one of the important natural forest types in the Qinling Mountains in Central China (ref. to Chapter 1.6). *Q. aliena* var. *acutiserrata* dominated forests can be found between altitudes of 1400-1800 m (WU 1980) and has a wide niche compared to other tree species (ZHAO et al. 2004). The Qinling Mountains (Mts.) are the central distribution area of this oak species (ZHU 1983). These oak forests are important for timber and firewood production (AN 2001), ca. 39 % of the forest area is dominated (>60 % tree layer) by *Q. aliena* var. *acutiserrata* and 36 % of their stand volume in the entire Qinling Mts. (YANG et al. 1994). These oak forests also provide valuable services, for example, soil and water conservation in the watershed region of the Yangtze and Yellow rivers (WANG 1984, YANG et al. 1991, LIU et al. 2002, DUAN et al. 2009). Therefore it is important to keep these forests alive by natural regeneration.

Taking advantage of natural regeneration of tree species is assumed to be a most economical method for the conservation of diversity and for a sustainable forest management (RÖHRIG et al. 2006, FUKUSHIMA et al. 2008). Such knowledge about ecological requirements (such as light and competition) for successful oak regeneration is necessary for local forest managers in order to pursue successful conservation of oak forests in this region of the water conservation.

Several abiotic factors (e. g. frost, water and nutrient availability, light availability etc.) and biotic factors (e. g. competitive and facilitative tree interactions, browsing, present stand structure and past history, human disturbance, and damage by rodents etc.) influence regeneration of oaks (DAHLGREN et al. 1997, BUCKLEY et al. 1998, LI & MA 2003, WANG & GAO 2006, GUO et al. 2011, YAN et al. 2011, 2012). Light availability is one of the most important factors that determine successful regeneration establishment, particularly for shade intolerant, and pioneer tree species (DENSLOW et al. 1998, KAELKE et al. 2001). Oak species like *Quercus aliena* var. *acutiserrata* is considered a shade-intolerant species (HE et al. 1999, LI & MA 2003).

The regeneration of *Q. aliena* var. *acutiserrata* has been studied in the sub-tropical climate zone, e. g. in mixed forests with *Q. serrata* in the plateau monsoon climate (WANG & GAO 2005, 2006), and in mixed forests with *Fagus engleriana* on Shennongjia Mts. (HE et. al. 1999). According to HE et al. (1999), *Q. aliena* var. *acutiserrata* is a shade-intolerant species, and its regeneration strategies consist in producing a relatively large amount of seeds, and in establishing seedlings growing in large gaps. WANG & GAO (2005) study, showed that *Q. aliena* var. *acutiserrata* is indeed shade-tolerant in the seedling phase. The fact that there are two different sets of results in the same climate zone shows that more field studies should be carried out in order to understand if gaps are needed for regeneration of this species in the temperate zone.

ZHAO et al. (2003a) say that *Q. aliena* var. *acutiserrata* regenerates naturally in an altitude between 1400-1800 m in the Qinling Mts. Recently, KANG et al. (2012) have studied seedlings regeneration of trees and shrubs species in *Q. aliena* var. *acutiserrata* dominated forests, under the aspect of different stand density, of slopes and of altitudes in the central parts of the Qinling Mts. But still the relationship between regeneration and the gaps is unknown for *Q. aliena* var. *acutiserrata*. The majority of studies about oak forests in the **Western Qinling Mts**. only focus on the vegetation classification of dominant tree species, biomass estimation, and diversity (ZHU 1983, WANG 1989, SUO et al. 2005, ZHAO et al. 2008).

The aim of this chapter is to study the influence of light availability under different canopy conditions (the influence of forest gaps and the solar radiation transmittance below canopies) on the natural regeneration of *Q. aliena* var. *acutiserrata* in the study area of the Western Qinling Mountains. Specifically, how does the natural regeneration of this oak species change with light and canopy openness. In the course of the study, three **questions** arose:

1. What are the differences in solar radiation between gaps and areas below the canopy?
2. How does the regeneration of *Q. aliena* var. *acutiserrata* differ in gaps and below canopies?
3. Is there a relationship between solar radiation and the regeneratio of *Q. aliena* var. *acutiserrata*?

4.2 Material and Methods

4.2.1 Study area

We recorded the positions of the gaps during a systematical inventory for vegetation and stand structure in the study area in 2007 (ref. to Chapter 2.2.1). There were no available satellite or airplane photos for this area to help us finding all the existing gaps.

The inventory of regeneration of trees and the hemispherical photographs were taken afterwards in 2008 in the *Q. aliena* var. *acutiserrata* dominated forest stands.

4.2.2 Gaps

After RUNKLE (1992), a gap was formed by the death (absence from the canopy) of at least one-half of a tree. The **gaps** were defined as closed when the regeneration within them was dominated by stems ≥5 cm diameter at breast height (dbh). Because 5 cm dbh is the standard cutoff for saplings in the international forestry literature (RUNKLE 1992), and also in the Chinese forest inventory (SFA 2003). The **expanded gap** was defined the area of the bases of canopy trees bordering the gaps RUNKLE (1992), the trees were with stems dbh ≥5 cm.

4.2.3 Sampling design with transects

A transect design for sampling was used after MEYER et al. (2001). The sampling for the inventory and for the hemispherical photographs were taken on transects along the gradients of canopy closure. Total 44 plots (11 gaps, 11 gap borders, 11 gap-forest transitions and 11 closed forests) were taken in the *Q. aliena* var. *acutiserrata* dominated forest stands, each from south to north, beginning in the centre of 11 gaps (**Fig. 4.1**).

4.2.4 Inventory of natural regeneration

The parameters of forest inventory (species, height, dbh, etc. refer to Chapter 3.2.2) after (FVA 2004) were recorded in the 44 plots of concentric cycles (radius 1.5-12 m, area size up to 452 m^2), in order to assess the regeneration and stand structure. The number of seedlings and saplings were counted with species information, and with height and dbh classes in the 2 smaller cycles (radius 1.5-2 m, area size up to 12.6 m^2) (**Table 4.1**).

The geographical parameters like latitude and longitude (for calculation of solar radiation under canopy with hemispherical photographs), relief, slope, slope direction, sky view factor (for direct solar radiation) were recorded for each plot. This means, slopes, too, were taken into consideration for their effects on regeration.

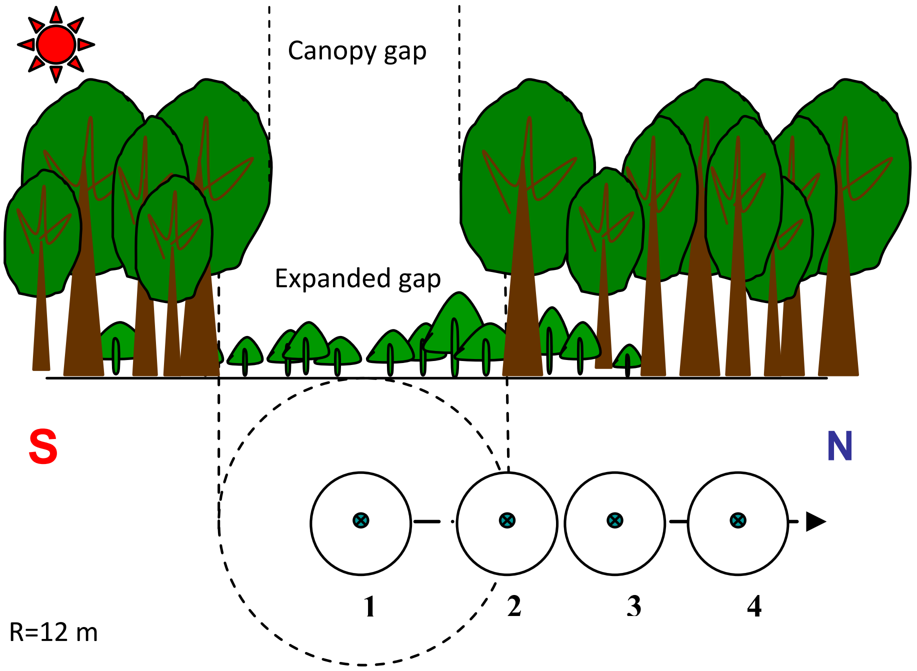


Fig. 4.1: Transect design for sampling: Plots of inventory of regeneration (r=2 m) and hemispherical photographs at ca. 1.3 m in the 4 gap compartments, each from south to north (**1:** inside gaps, **2:** gap borders, **3:** gap-forest transitions, **4:** closed forest). The cycle with radius 12 m is for calculating the size of the expanded gap.

Table 4.1: Regeneration size classes

Regeneration classes	Height and dbh class
R1	height <0.2 m
R2	height 0.2-0.5 m
R3	height 0.5-1.3 m
R4	height ≥1.3 m, dbh 1-1.9 cm;
R5	height ≥1.3 m, dbh 2-2.9 cm;
R6	height ≥1.3 m, dbh 3-3.9 cm;
R7	height ≥1.3 m, dbh 4-4.9 cm

4.2.5 Estimation of solar radiation and gap size

The light was estimated for 44 plots by hemispherical photos (**Fig. 4.4**) in the oak forests. For each photo the values were calculated using Winphot (TER STEEGE 1997) as relative values concerning the radiation quantity above the canopy, in percent above and below canopy light (direct solar radiation, diffuse solar radiation, openness, in percent during the growing season April to Oct.).

To estimate the intensity of the solar radiation on the forest ground, hemispherical photographs were taken after WAGNER et al. (2004) in the center of the 44 plots (**Fig. 4.1**) at ca. 1.3 m height. A compass helped to find the direction (of sky, south to north) for the camera. The photos were taken under homogeneous overcast sky or shortly before sunset. This measure guaranteed the uniform light of sky, important for correct results of the evaluation by software Winphot 5.0 (TER STEEGE 1997). Exposure was measured by a lens of 50 mm directed to the zenith, aimed at finding the best contrasts between canopy and sky. For each plot 3-5 photos were taken, and one photo with the best quality was used for analysis.

The negative films were scanned. The photos were first cut by Adobe Photoshop 3.0, and then converted in black and white information. The threshold for the transformation of grey of each pixel in to black or white (canopy or sky) was estimated visually by comparing extracts of different threshold with the original photos. Winphot 5.0 was used for the estimation of solar radiation (direct solar radiation, diffuse solar radiation, openness in percent) from the digital photos.

The software Winphot 5.0, developed by TER STEEGE (1997) was used for assessment of the photos, which has high precision for quantification of quantity and quality of solar radiation. This program was originally developed for the tropics, but it also offers reliable results for temperate latitudes (PROMIS 2009, PROMIS et al. 2011). After the input of the coordinates, altitude, and deviation from the magnetic north, this program calculates the orbit of the sun over the horizon for every single day of the vegetation period (TER STEEGE 1997).

Winphot 5.0 can be used only with 12 definite points for the vegetation period, but the results of the evaluation of solar radiation didn’t show any significant differences with 3 other softwares, like HemiView, Gap Light Analyzer, hemIMAGE, which can be used with more than 12 definite dates (PROMIS 2009). In this study the 12 definite dates were given during the vegetation period from 1st April to 30th September: 1st April, 15th April, 1st May, 15th May, 1st June, 15th June, 1st July, 15th July, 1st August, 15th August, 1st September und 30th September.

The character of gap varies by its surface (**gap size**), its form, its aperture (LAWTON & PUTZ 1988), and the height of the trees standing around (RUNKLE 1992). The surface (gap size) is most important. There are 2 forms of gap size: **canopy gap** and **expanded gap**.

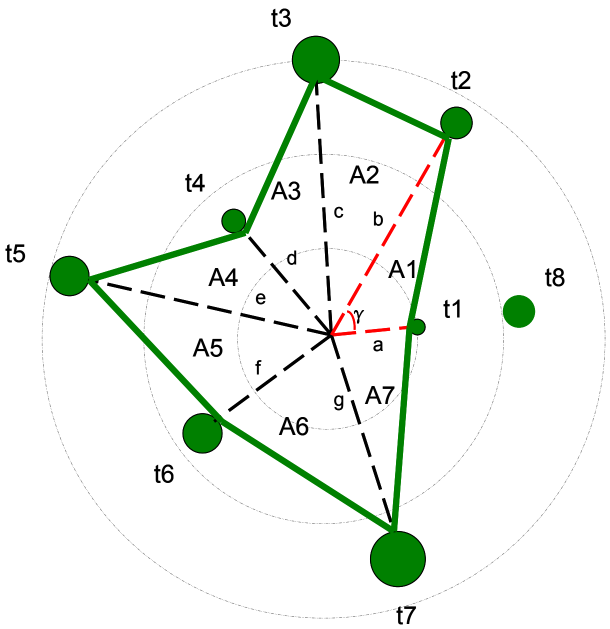


Fig. 4.2: Illustration of the method to measure **expanded gap** size. The total **expanded gap** area of an irregularly shaped gap was obtained by summing the areas of all triangles used to fit the polygon ($A_{gap} = A_1 + A_2 + ... + A_n$). The area of the triangle (A_1) was expressed as: $A_1 = ½\, \boldsymbol{ab} \sin \boldsymbol{\gamma}$. (***a*** and ***b*** are the triangle's sides, ***γ*** is the interior angle between line ***a*** and line ***b***). The line ***a*** and line ***b*** (also line c, d, e, f, g) were measured as the horizontal distances in metres from the centre of the plot to centres of the tree stems. The angle ***γ*** was calculated from the azimuths in degrees from the plot centre to the position of the tree stem t1 and the tree stem t2. The shortest distance (e.g. ***a***) was used for the calculation, if there are two tree stems with the same azimuths like t1 and t8. The three concentric circles were the sample plots with radius 3 m, 6 m, and 12 m after FVA 2004.

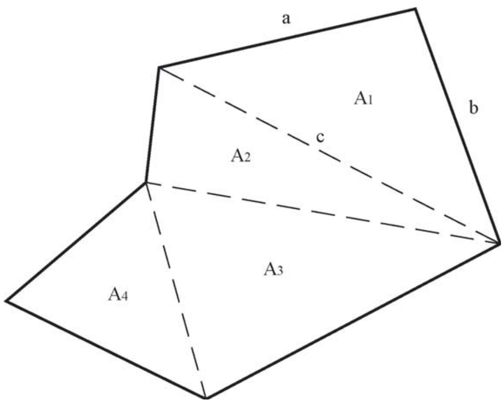


Fig. 4.3: Illustration of the method proposed by DE LIMA (2005) to measure **expanded gap** size. Continuous lines represent the sides of the polygon (gap limits) and dashed lines represent the diagonal of the polygon. Capital letters indicate the area of each triangle and small letters its sizes.

The **expanded gap** consisted of the canopy gap plus the adjacent area extending to the bases of canopy trees surrounding the canopy gap (WAGNER et al. 2004). **Irregularly**

shaped gaps can be subdivided into smaller sections, each section measured, and the total gap size of the **expanded gap** can be calculated (BROKAW 1982), (GREEN 1996), (FERREIRA DE LIMA 2005). FERREIRA DE LIMA (2005)'s 'triangles' method consists in dividing gap area in triangles, measuring the sides of each triangle and summing the area of all triangles used to fit the polygon (**Fig. 4.3**). In this study, the calculation of the size of the **expanded gap** was used during the forest inventory after FVA (2004). We developed the de Lima's method (FERREIRA DE LIMA 2005) to calculate the size of the **expanded gap** with inventory data of each gap (**Fig. 4.2**). For the calculation of the **expanded gap**, the trees next to the centre of gap were measured, FVA (2004) sets a limit for smaller trees in the bigger circles (ref. to Chapter 3.2.2). Each triangle area was calculated by fitting its sides and interior angle between the 2 sides. The total **expanded gap** area was then obtained by summing the area of all triangles used to fit the polygon (**Fig. 4.2**).

The **canopy gap** was the land surface area directly under the canopy opening (RUNKLE 1992), in this study the **canopy gap** was calculated with hemispherical photographs by the software Winphot 5.0 as „**canopy openness**"(**Fig. 4.4**).

4.2.6 Statistical analysis

For not normally distributed parameters, the analysis of differences between the solar radiation transmittance and the density of regeneration in the 4 different gap compartments were tested by applying the **nonparametric tests** Kruskal-Wallis (H-Test) to compare more than two groups followed by Mann-Whitney-U test as a pairwise post-hoc test.

Correlation analysis based on Spearman's rho was used to find significant correlation between the regeneration of oak and the solar radiation transmittance.

Those statistical tests were performed at a 0.05 significance level. Statistical computations were carried out using the software SPSS 20 (SPSS Inc., Chicago, IL, USA).

4.3 Results

4.3.1 Expanded gap, canopy gap, and solar radiation

The **expanded gap** size of the 11 gaps ranges between 72.8 to 193.3 m^2 (**Annex 4.1**), the mean expanded gap size was 124 m^2. All gaps were small (no gap was more than 200 m^2 in area size). The **canopy gaps** showed no identical trend with the expanded gap size, e.g. gap No. 1 (plot 801#) has a small expanded gap site, but a larger canopy gap than gap No. 1 (plot 805#).

There were significant differences of the **canopy openness**, and the **below canopy diffuse solar radiation** (transmitted diffuse solar radiation during the growing season, %) between the 4 gap compartments, inside gap, gap border, gap-forest transition, closed forest, towards each other (**Fig. 4.5**, **Fig. 4.7**). The gradient of the **canopy openness** (**Fig. 4.5**) and the **below canopy diffuse solar radiation** (**Fig. 4.7**) went down from 18 % and 7 % in the inside gaps to 9 % and 3 % in the closed forests (**Table 4.2**).

The **below canopy direct solar radiation** (transmitted direct solar radiation during the growing season, %) in the inside gaps was the highest difference in comparison with the 3 other gap compartments, but there were no significant differences between the gap borders, the gap-forest transitions, and the closed forests (**Fig. 4.6**).

4.3.2 Regeneration of Quercus aliena var. acutiserrata

There was a strong persistent regeneration capability of *Q. aliena* var. *acutiserrata*. The mean density of *Q. aliena* var. *acutiserrata* seedlings (height <50cm) ranges between 3216 and 5660 individuals per ha in the 4 gap compartments; the mean density of saplings (height 50-130 cm) was lower and ranges between 129 and 1544 individuals per ha, and the mean density of saplings (height ≥130 cm and dbh <5 cm) ranges between 289 and 941 individuals per ha (**Table 4.2**).

The density of seedlings and saplings (dbh <5cm) of *Q. aliena* var. *acutiserrata* reached a high percentage within all the tree species: 11 % in closed forests to 27 % in the inside gaps (**Table 4.2**).

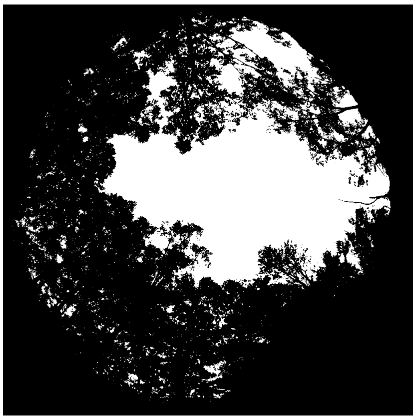
There were no significant differences of the density of juveniles of *Q. aliena* var. *acutiserrata* (height <50 cm, height <130 cm, and height >130 cm) between the 4 gap compartments (inside gap, gap border, gap-forest transition, closed forest), therefore also no significant differences of density in the totality of *Q. aliena* var. *acutiserrata* seedlings and saplings (dbh <5 cm) between the 4 gap compartments (**Table 4.2**).

To find the influence factor, excluding light factor because of the canopy, e.g. human or animal disturbances, the density of juveniles of all the species in the 4 gap compartments were analyzed. There were no significant differences of density in the regeneration of all the species of the 3 height classes (height <50 cm, 50-130 cm, height ≥130 cm) and of the total regeneration (seedlings and saplings with dbh <5 cm) between the 4 gap compartments (**Table 4.2**).

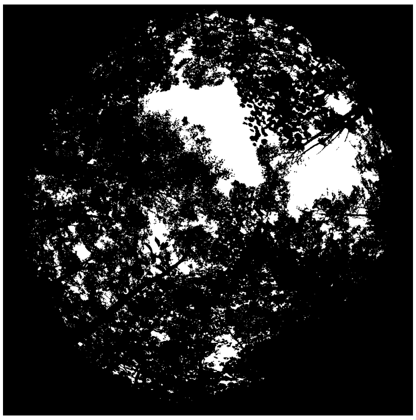
There are, however, significant differences of density in the regeneration of *Q. aliena* var. *acutiserrata* (height 50-130 cm) between inside gap and the other 3 gap compartments (gap border, gap-forest transition, closed forest) (**Fig. 4.8**), but the standard deviations in the 3 gap compartments were very high, i.e. the data was not suitable for the analyses to find any differences.

4.3.3 Relationship between solar radiation and the oak regeneration

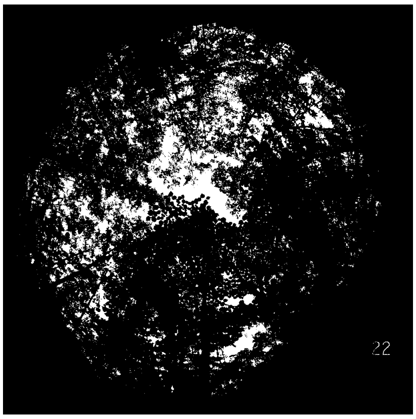
The density (trees ha^{-1}) of oak (*Q. aliena* var. *acutiserrata*, height 50-130 cm) was correlated to openness, to below canopy direct solar radiation, and to below canopy diffuse solar radiation (nonparametric correlations, Spearman's rho) and with significant Spearman's correlations 0.383*, 0.363*, 0.405** (**Annex 4.2**).



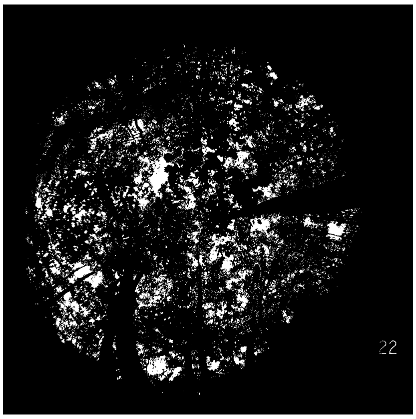
1. Inside gap (openness 35 %)



2. Gap border (openness 20 %)



3. Gap-forest transition (openness 14 %)



4. Closed forest (openness 10 %)

Fig. 4.4: An example of hemispherical photos in the 4 gap compartments (1. inside gap, 2. gap border, 3. gap-forest transition, 4. closed forest, see **Fig. 4.1**) and their openness.

Table 4.2: Mean parameter of light and density of regeneration (dbh <5cm) of oak (*Q. aliena* var. *acutiserrata*) and all tree species in the 4 gap compartments. **%:** Oak / all species; **PACL:** Percentage **above canopy light; PBCL: Percentage below canopy light. Values reported are mean and range, and** in brackets their standard deviation. The differences were tested with KW H-test, ***:** p <0.05, ****:** p <0.01, **¯:** no different. Values with different letters in superscript were significantly different based on pairwise comparisons with MWU-test.

		GAP COMPARTMENTS			
		Inside gap	**Gap border**	**Gap-forest transition**	**Closed forest**
		11	11	11	11
Parameter of light (%)					
Openness **		**18** [a] (8) 11-35	**13** [b] (3) 10-20	**11** [c] (3) 7-18	**9** [d] (3) 5-18
PACL direct ¯		**41** (<0.5) 40-41	**41** (<0.5) 40-41	**41** (<0.5) 40 -41	**41** (<0.5) 40-41
PACL diffuse ¯		**20** (<0.5) 20-21	**20** (<0.5) 20-21	**20** (<0.5) 20-21	**20** (<0.5) 20-21
PBCL direct **		**12** [a] (7) 5-23	**6** [b] (3) 2-12	**6** [b] (1) 4-9	**5** [b] (3) 2-11
PBCL diffuse **		**7** [a] (3) 5-12	**5** [b] (1) 4-6	**4** [c] (1) 3-6	**3** [d] (1) 2-5
Density of regeneration (trees ha^{-1})					
Height cm					
<50	Oak ¯	**4245** (2758) 0-8490	**5660** (7270) 0-25470	**3730** (4114) 0-11320	**3216** (1562) 1415-5660
	%	***27 %***	***29 %***	***24 %***	***14 %***
	All species ¯	**15565** (16489) 0-58015	**19681** (16336) 0-56600	**15694** (12424) 1415-42450	**23026** (17215) 4245-46695
50-130	Oak **	**1544** [a] (1946) 0-5660	**129** [b] (427) 0-1415	**772** [ab] (2560) 0-8490	**129** [b] (427) 0-1415
	%	***31 %***	***4 %***	***19 %***	***2 %***
	All species ¯	**5017** (7197) 0-25470	**3345** (5267) 0-18395	**3988** (3570) 0-11320	**5917** (5546) 0-16980

		Gap compartments			
		Inside gap 11	**Gap border** 11	**Gap-forest transition** 11	**Closed forest** 11
≥130	Oak ¯	**434** (653) 0-1592	**289** (402) 0-796	**941** (1275) 0-3980	**362** (547) 0-1592
	%	***17 %***	***8 %***	***15 %***	***6 %***
	All species ¯	**2605** (2168) 0-6368	**3473** (2084) 0-5572	**6296** (4128) 0-14328	**5789** 5196) 796-19104
Total (<50 & 50-130 & ≥130)	Oak ¯	**6223** (3518) 2830-13531	**6078** (7231) 0-25470	**5443** (5978) 0-18130	**3706** (1924) 1415-6456
	%	***27 %***	***23 %***	***21 %***	***11 %***
	All species ¯	**23187** (22582) 4245-85077	**26499** (18080) 4776-65002	**25977** (16631) 5395-59608	**34732** (19511) 10082-57927
<130	Oak ¯	**5789** (3367) 1415-12735	**5789** (7365) 0-25470	**4502** (5173) 0-14150	**3345** (1701) 1415-5660
	%	***28 %***	***25 %***	***23 %***	***12 %***
	All species ¯	**20582** (22661) 2830-83485	**23026** (18067) 0-59430	**19681** (13726) 1415-45280	**28943** (17415) 7075-52355
≥50	Oak ¯	**1978** (2131) 0-6456	**418** (511) 0-1415	**1713** (3652) 0-12470	**490** (777) 0-2211
	%	***26 %***	***6 %***	***17 %***	***4 %***
	All species¯	**7622** (7185) 0-27062	**6818** (4886) 2211-19191	**10283** (6456) 1415-21668	**11706** (9966) 796-34669

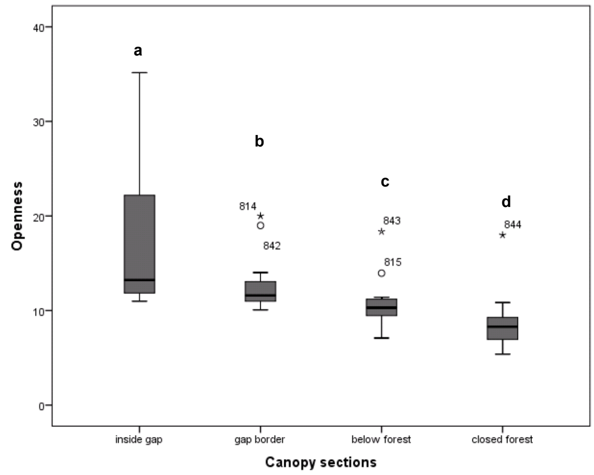


Fig. 4.5: Canopy openness (%) in the different gap compartments: inside gap, gap border, gap-forest transition, closed forest. The differences were tested with Kruskal-Wallis H-test. Significant differences between individual variables by the letters a-d were also tested with Mann-Whitney-U-test.

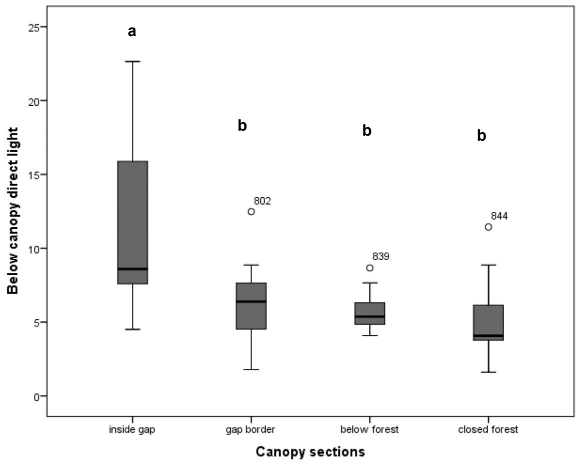


Fig. 4.6: Below canopy direct solar radiation in the different gap compartments: inside gap, gap border, gap-forest transition, closed forest. The differences were tested with Kruskal-Wallis H-test. Significant differences between individual variables by the letters a-b were also tested with Mann-Whitney-U-test.

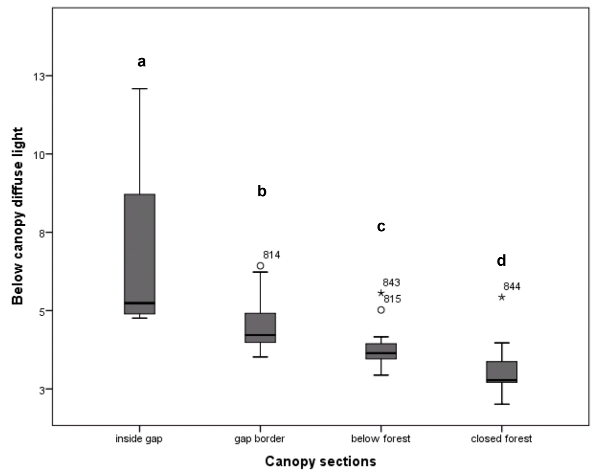


Fig. 4.7: Below canopy diffuse solar radiation in the different gap compartments: inside gap, gap border, gap-forest transition, closed forest. The differences were tested with Kruskal-Wallis H-test. Significant differences between individual variables by the letters a-d were also tested with Mann-Whitney-U-test.

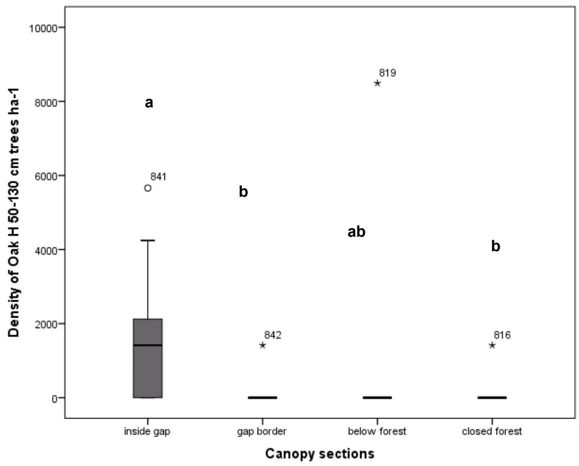


Fig. 4.8: Density (trees ha^{-1}) of Oak height from 50 – 130 cm in the different gap compartments: inside gap, gap border, gap-forest transition, closed forest. The differences were tested with Kruskal-Wallis H-test. Significant differences between individual variables by the letters a-b were also tested with Mann-Whitney-U-test.

4.4 Discussion

4.4.1 What are the differences in solar radiation between gaps and areas below the canopy?

The solar radiations between gaps and below canopy were significantly different. The solar radiation transmittance decreased significantly with the decreased openness of the gaps, of the gap borders, of the gap-forest transitions and of the closed forests. Thus, the openness and the below canopy diffuse solar radiation in the gaps were the highest, followed by the gap borders, by the gap-forest transitions and by the closed forests. Similar phenomenons are found in smaller gap size (21 to 92 m^2) in the old-growth *Nothofagus betuloides* forest in Tierra del Fuego, Chile (PROMIS et al. 2010) and in big range (83 to 1235 m^2) in the montane Guayanan forest, Sierra de Lema, Venezuela (DURÁN RANGEL 2011). There, the studied regions were in different climate zones and their gap sizes were smaller or bigger compared to the Western Qinling Mts. in China, but the gradients of solar radiation transmittance are also along the gradients of canopy closure.

4.4.2 How does the regeneration of *Q. aliena* var. *acutiserrata* differ in gaps and below canopies?

In the research area, this oak species is a native one and dominant in altitudes between 1500 to 1800 m, and it should continue to reside in the forest stands. KANG et al. (2012) found in their study in the central parts of Qinling Mountains that *Q. aliena* var. *acutiserrata* has a strong regeneration capability, too.

In gaps, and also below canopy, *Q. aliena* var. *acutiserrata* had a strong regeneration capability according to the Chinese evaluation criteria of natural regeneration of national forest inventory (SFA 2003) (see **Annex 4.3**), the mean density of saplings (height ≥50 cm) ranges between 490 and 1978 trees ha^{-1}.

Light is one of several factors that influence the regeneration of oak species (KOLB et al. 1990, BUCKLEY et al. 1998). But in this study, there was no difference as to the density of seedlings (height <50cm) and saplings (height ≥50 cm and dbh <5 cm) in gaps and below canopies. This result did not show the influence of variant solar radiation on the regeneration of this oak species. Does this mean that *Q. aliena* var. *acutiserrata* is shade-tolerant in the seedling phase?

The study of WANG & GAO (2005), about the regeneration of this oak species in mixed forests with *Q. aliena* var. *acutiserrata* and *Q. serrata*, in the sub-tropical climate zone showed that oak seedlings and saplings (height <100 cm) are able to grow under the closed canopy of oak forest, waiting for several years to grow up. The results indicate that the seedling pool is able to persist a long time under oak forest canopies. Therefore, *Quercus aliena* var. *acutiserrata* is relatively shade-tolerant in the establishment phase. It can be concluded that oak has evolved a kind of "sit and wait" strategy for regeneration.

It was interesting to notice the big competition for oak seedlings with other species before becoming oak saplings (ref. to **4.3.2**). The number of seedling was enormous, but they had fewer chances to become saplings. Does this mean that *Q. aliena* var. *acutiserrata* in the seedling phase suffers big competition of other species? KANG et al. (2012) found out that this oak seedlings and saplings suffer big competition with seedling and saplings of other shrub and tree species in Qinling Mts., e.g. *Rubus corchorifolius, Euonymus phellomanus*, *Acer grosseri*, *Litsea pungens*, *Spiraea cantoniensis*, *Lonicera ferdinandi*, *Lindera obtusiloba*.

A successful natural regeneration depends upon seedling density and also herbivorous (GILL 1992). Another negative impact is grazing and browsing of animals (PALMER et al. 2004). Grazing in the study area should be taken in consideration. So far, there is no official comment on the local farmers' "habit" to graze their animals in the protected area of NFPP. Further research is needed to find out possible damages to regeneration and how to prevent those. To find out if herbivorous are the real reason for the reduction of saplings from seedling, there should be further study about research damage of seedlings and saplings in forest stand in comparing with e.g. fence-protected areas.

Density of *Q. aliena* var. *acutiserrata* (height 50-130 cm) differed significantly between gaps and the 3 other gap compartments (gap border, gap-forest transition, closed forest), but the variations of density of *Q. aliena* var. *acutiserrata* (height 50-130 cm) in the 3 gap compartments were very high. The data were not suitable for a statistical analysis to find differences, since the number of plots was rather small. But more research is needed with many more plots to get a descriptive answer to the question: Are there really more oak saplings of the height between 50 to 130 cm in gaps than below canopy?

4.4.3 Is there a relationship between solar radiation and the regeneration of *Q. aliena* var. *acutiserrata*?

There was a significant correlation between solar radiation and density of oak saplings (height 50-130 cm), i.e. the correlation between the density (trees ha^{-1}) of oak (height 50130 cm) to openness, and to below canopy direct solar radiation, and to below canopy diffuse solar radiation (ref. to **4.3.3**). Here, too, more research is needed with many more plots to get a descriptive answer to the question: Is there really a relationship between solar radiation and the regeneration of *Q. aliena* var. *acutiserrata*?

4.5 Conclusions

Q. aliena var. *acutiserrata* reached a high percentage in the regeneration of all the tree species (see **4.3.2**), i.e. this species has a high potential in succession in this forest community. It has a strong regeneration capability, especially in the establishment phase of seedlings (<50 cm height): there was a big number of seedlings in the gaps and also below the closed forests. And there were also adequate survivors of saplings (height ≥130 cm and dbh <5 cm). This regeneration potential should be conserved by a further management in this NFPP area.

A study should follow to learn more about the different effects on the regeneration which are caused by the origin of gaps, by the age of gaps and by the dimension of gaps, to see whether these are decisive factors. Grazing effects there should also be taken in consideration.

Furthermore, a sampling design could be used, concerning the shape of gaps, and a research should be made about the regeneration inside and outside the gap border, e.g. arc-shaped in a form of plots along the gap border (VARGAS et al. 2013).

5 Abschließende Diskussion

Im Zentrum der vorliegenden Untersuchung steht die Fragestellung, wie Artenzusammensetzung, Waldtypen und Verjüngung in Relation zu den Standorten in naturnahen Wirtschaftswäldern gesetzt werden können. Die waldbaulichen Maßnahmen sollten auf standörtlichen Grundlagen beruhen und Elemente der natürlichen Dynamik integrieren.

Drei Fragestellungen lassen sich den entsprechenden Themenbereichen zuordnen:

1. „Vegetation und Standort“

Welche Waldgesellschaften der naturnahen Wirtschaftswälder lassen sich abgrenzen, welche Standortfaktoren sind für sie jeweils charakteristisch?

2. „Bestandesstruktur“

Welche Bestandesstrukturen und Naturverjüngung, welche Bestandesdynamiken kommen vor?

3. „Naturverjüngung“

Wie beeinflussen Lichtverhältnisse die Naturverjüngung von Eichen?

Die Ergebnisse dieser Fallstudie sollen zeigen, inwieweit standortangepasste Baumartenwahl möglich ist und eine Grundlage für eine naturnahe Waldbewirtschaftung im westlichen Qinling Gebirge bilden kann.

5.1 Vegetation und Standort

5.1.1 Vegetationsklassifizierung

Verglichen mit den intensiven pflanzensoziologischen Untersuchungen in Europa gibt es wenige Studien in China, besonders unter dem Aspekt seiner außerordentlichen Größe und seiner enormen Vielfalt der Vegetation in unterschiedlichen Klimazonen und geografischen Bedingungen. Es ist sehr wichtig, dass intensive Studien, vergleichbar der hier vorliegenden über das westliche Qinling Gebirge, in ganz China durchgeführt werden.

Die vorliegende Arbeit benutzt das BRAUN-BLANQUET-Verfahren für die pflanzensoziologische Vegetationsaufnahme. In dieser Region (Qinling Gebirge) fand dieses bisher keine Anwendung. Die Baumarten *Quercus mongolica, Quercus aliena* var. *acutiserrata* und *Quercus dentata* sind weitverbreitet und oft in der gemäßigten Zone und in der Bergzone des Qinling Gebirges dominant, jedoch in unterschiedlichen Höhenlagen (WU 1980). Bis jetzt wurden Untersuchungen zur Vegetation in sehr großen Gebieten gemacht, und diese bezogen sich nur auf dominante Arten, z. B. auf *Quercus aliena* var. *acutiserrata* Wälder (WU 1980, ZHU 1983, WANG 1989, YING 1994, ZHAO et al. 2003a, ZHANG et al. 2010), und auch auf *Quercus mongolica* (syn. *Q. liaotungensis*) Wälder (WU 1980, THE COMPILED COMMISSION OF FORESTS OF GANSU 1998).

TANG et al. (2009) arbeiteten mit dem BRAUN-BLANQUET-Verfahren in der warm-gemäßigten Klimazone in China im Bereich sommergrüner *Quercus* Waldgesellschaften in einem sehr großen Gebiet (von 32°30'-42°30'N, 103°30'-124°10'E) mit 80 Aufnahmen, jedoch ohne das Qinling Gebirge. Im westlichen Qinling Gebirge aber kommen viele einheimische Arten vor, die in der Studie von TANG et al. (2009) nicht erwähnt sind, z.B. fehlen die meisten diagnostischen Arten von allen 3 Waldgesellschaftsgruppen: *Quercus dentata-Quercus aliena* var. *acutiserrata*-Waldgesellschaftsgruppe, *Sorbus alnifolia-Quercus mongolica*-Waldgesellschaftsgruppe, *Juglans mandshurica-Corylus chinensis*-Waldgesellschaftsgruppe, die in der vorliegenden Arbeit identifiziert wurden.

Weiterhin führte die Differenzierung der Arten in der Krautschicht zu einer ausführlicheren Informationsgrundlage und zu einer Fundierung der Waldgesellschaften in der vorliegende Arbeit, verglichen mit der bisherigen Klassifizierung durch dominante Baumarten vor Ort. Die untersuchte Waldvegetation wurde in 7 Waldgesellschaften der o.a. 3 Waldgesellschaftengruppen unterteilt.

Die *Sorbus alnifolia-Quercus mongolica*-Waldgesellschaftsgruppe hat Ähnlichkeit mit den von KRESTOV et al. (2006) untersuchten Wäldern, die von *Quercus mongolica* dominiert sind. Diese Waldgesellschaftsgruppe könnte in der Klasse „*Quercetea mongolica* Song ex Krestov et al. 2006“ zugeordnet werden. Es erfordert weitere pflanzensoziologische Forschungen in größeren Gebieten des Qinling Gebirges, um den syntaxonomischen Status der Waldgesellschaften zu bestätigen. Der syntaxonomische Status der *Quercus dentata-Quercus aliena* var. *acutiserrata*-Waldgesellschaftsgruppe und der *Juglans mandshurica-Corylus chinensis*-Waldgesellschaftsgruppe ist noch offen.

Derzeit wird eine Enzyklopädie der Vegetation Chinas zusammengestellt, und man sucht nach Beiträgen, um das Vegetationsklassifizierungssystem zu verbessern. SONG (2011) empfahl, “diagnostic species” bei Klassifizierungen der Assoziationsgruppen und der Assoziationen zu nutzen. Dabei handelt es sich um eine für China neue Definition von Assoziationen. Die vorliegende Arbeit mit ihrem pflanzensoziologischen Ansatz trägt einer Weiterentwicklung des chinesischen Vegetationsklassifizierungssystems bei und wird weitere Untersuchungen in China anregen, ein hierarchisches System der Vegetationseinheiten zu vergleichen und umzusetzen.

5.1.2 Beziehung zwischen Vegetation und Standort

Die Kenntnisse über die Beziehung zwischen Waldvegetation und Standort ist eine wichtige ökologische Grundlage für standortangepasste Forstwirtschaft. In China fehlten die forstlichen Standortsinformationen, die alle für das Waldwachsturm relevanten natürlichen Standortbedingungen erfassen sollten, z.B. die Waldstandortkartierungen bzw. Vegetationskartierung auf Bestandesebene, die es in Ländern wie Deutschland flächendeckend gibt. Die Standortsklassifizierung und -kartierung im Xiaolongshan-Forstamt im westlichen Qinling Gebirge befand sich auf Betriebsebene der Forsteinrichtungen und berücksichtigte eher allgemeine regionale Standortsmerkmale, wie Klima, Höhenlagen, Landschaftsformen und dominante Baumarten. Die Vegetation war als Standortzeiger nicht herangezogen werden.

Das Standortmosaik des Qinling Gebirges ist durch eine geologische und topographische Vielfalt und deren kleinräumigen Wechsel gekennzeichnet (LIU 2001, FANG et al. 2004, LIU et al. 2004). Es ist geprägt von dem entsprechenden Wechsel von Exposition und Hangneigung, und dem entsprechenden Wechsel von Kleinklima, Bodeneigenschaften wie Bodentiefe und –körnung, Humusform und -mächtigkeit, pH-Wert, etc. Wie in anderen zahlreichen Gebirgslandschaften gibt es deshalb im Qinling Gebirge Flächen mit ähnlich bodenbedingtem Grundcharakter: viel zu klein, um als forstliche Planungseinheit verwendbar zu sein. Wegen der steilen Geländemorphologie und der oft schweren Zugänglichkeit waren ausgewiesene Flächen oft nur ungenau in Kartenwerke eingetragen und im Gelände oft schwer wiederzufinden.

Besonders im Gebirge, wo die Bodensituation auf engstem Raum wechselt, ist die Vegetation ein integrierender Indikator, ein Spiegel der Umweltvariablen für den baumrelevanten Größenmaßstab (FISCHER 2003).

In der vorliegenden Arbeit wurden das kombinierte Vegetations-Standortverfahren benutzt, in dem sowohl die Parameter des Reliefs (und somit des Mesoklimas), des Bodens, und auch die Vegetation als wesentliche Standortzeiger erfasst wurden. Die Vegetation- und Standortinformation wurden berücksichtigt und klassifiziert, um standörtlich einheitliche Waldteile als „ökologische Einheiten“ zu identifizieren.

Die 3 Waldgesellschaftsgruppen und die 7 Waldgesellschaften unterscheiden sich zuerst durch die Bodenvegetation, abhängig vor allem vom Gradient der Wasserbedingungen und der Temperaturen, d.h. von klimatischen und bodenbedingten Faktoren:

- Die *Quercus dentata-Quercus aliena* var. *acutiserrata*-Waldgesellschaftsgruppe (CG QQ) waren die *Quercus aliena* Wälder auf trockenen, sonnigen, warmen Submontan-Standorten. Sie wurden in zwei Waldgesellschaften unterteilt: *Q. aliena*-Wald (C1, VuQa) und *Q. aliena*-Mischwald (C2, VcQa);
- Die *Sorbus alnifolia-Quercus mongolica*-Waldgesellschaftsgruppe (CG SQ) waren die *Quercus mongolica* Wälder auf mäßig frischen, sonnigen, kühlen Montan-

Standorten. Sie wurden in zwei Waldgesellschaften unterteilt: *Q. mongolica-Beluta*-Mischwald (C3, AcQm) und *Q. mongolica-Sorbus*-Mischwald (C4, VpQm);

- Die *Juglans mandshurica-Corylus chinensis*-Waldgesellschaftsgruppe (CG JC) waren die *Juglans-Corylus*-Laubmischwälder auf feuchten, schattigen, warmen Submontan-Standorten. Sie wurden in drei Waldgesellschaften unterteilt: *Q. aliena-Corylus*-Mischwald in warmen, schattigen Tälern (C5, CrQa), *Juglans-Fraxinus*-Mischwald in schattigen frischen Tälern (C6, OgJm) und *Corylus-Acer*-Mischwald auf schattigem Hangfuß (C7, LbCc).

Die standortbedingenden Unterschiede der 3 Waldgesellschaftsgruppen hängen offensichtlich stärker ab von der Höhenlagen bzw. Temperatur und der direkten Sonneneinstrahlung, jedoch weniger von nutzbaren Wasserkapazitäten des Bodens, wie das non-Metrik multidimensionale Skalierung (nMDS) Diagramm (**Fig. 2.5)** zeigt. Die Gründe dafür könnten folgende sein:

- Die Vegetationsperiode von April bis Oktober ist warm und feucht (LIU et al. 2003). Alle 3 Waldgesellschaftsgruppen hatten einen hohen Anteil von Phanerophyten, davon meistens Mesophanerophyten und Mikro-phanerophyten, gefolgt von Hemicryptophyten und Geophyten. Es gab nur wenige Chamaephyten und Therophyten. Das bestätigt, dass Wärme- und Wasserbedingungen im Allgemeinen hier günstig sind für Bäume und Sträucher.
- Die nutzbaren Wasserkapazitäten des Bodens von 75 % der Relevés waren mittel bis hoch (90-180 mm).
- Die (55 %) jährlichen Niederschläge fallen von Juli bis September, manchmal verbunden mit sehr heftigem Regen (LIU 1997).

Das in der vorliegenden Arbeit benutzte, kombinierte Vegetations-Standortverfahren, in dem sowohl die Parameter des Reliefs des Bodens, und auch die Vegetation als Standortzeiger erfasst wurden, hat wesentliche Vorteile, wie bereits von (FISCHER 2003, EWALD & BINNER 2007) erwähnt.

Die vorliegende Arbeit kann als Methodik Beispiel für Standortsklassifizierung und -

Kartierung im gesamten Qinling Gebirge dienen. Diese Arbeit stellt auch einen guten Ansatz für weitere Untersuchungen der Indikatorenarten und Indikatorenartengruppen und eine ökologische Grundlage für den Schutz und eine nachhaltige Waldwirtschaft in diesem Gebiet dar.

Die Beschreibung der gegenwärtigen Situation von Vegetation und Standorten in der vorliegenden Arbeit könnte als Grundlage dienen:

- für die Vegetationskartierung der Untersuchungsfläche und
- für Walddynamikuntersuchungen mit dem dauerhaften Versuchsflächen-netzwerk des nationalen Monitoringsystems.

5.2 Bestandesstruktur

Die Bestandesstruktur der Waldgesellschaften wurde im zweiten Teil der vorliegenden Arbeit mit Aspekten von Standort, Standortqualität und Bestandesdynamik beschrieben.

Durch die Ergebnisse wurden zuerst die Unterschiede zwischen den **3 Waldgesellschaftsgruppen** in der Bestandesstruktur, in der Verjüngung von Baumarten (<5 cm), in den Lebensformen, sowie in der Diversität der Vegetationsschichten gezeigt. Diese Ergebnisse in der Vegetations- und Standortsklassifizierung wurde im ersten Teil der vorliegende Arbeit erwartet. Sie weisen besonders auf die Wirkung der unterschiedlichen Standorte hin.

Weitere Ergebnisse für die Oberhöhen bewerteten die **Bonitierung** der 3 unterschiedlichen Standorte für die **3 Waldgesellschaftsgruppen**:

- Der Standort der *Sorbus alnifolia-Quercus mongolica*-Waldgesellschaftsgruppe (auf mäßig frischen sonnigen, kühlen montanen Standorten) wies eine bessere Bonität für die Eiche auf als die Standorte der *Quercus dentata-Quercus aliena* var. *acutiserrata*-Waldgesellschaftsgruppe (auf trocken, sonnigen, warmen submontanen Standorten) und der *Juglans mandshurica-Corylus chinensis*-Waldgesellschaftsgruppe (auf feuchten, schattigen, warmen submontanen Standorten).

- Der Standort der *Juglans mandshurica*-*Corylus chinensis*-Waldgesellschaftsgruppe (auf feuchten, schattigen, warmen submontan Standorten) ist günstiger, nicht nur für Eiche, sondern auch für andere Laubbaumarten wie *Juglans mandshurica*, *Corylus chinensis*, *Cornus macrophylla* var. *macrophylla*, *Cornus controversa*, *Ulmus davidiana* var. *japonica*.

Die allgemeine Standortsqualität liegt im mittlerer Bereich. Doch die Vorräte sind allgemein höher als der durchschnittlichen Vorrat von Altbeständen bezogen auf das Xiaolongshan-Forstamts (vgl. Kapitel 1.6), also die Bergmischwälder auf der Untersuchungsfläche stehen vielleicht auf besserem Standort oder wurden weniger intensiv genutzt als andere Altbestände des Forstamts. Jedoch sind die Vorräte immer noch zu klein, verglichen mit Vorräten von 200 oder 300 m^3/ha in mittleren Standortsqualitäten des Forstamts in den 80er Jahren (THE COMPILED COMMISSION OF FORESTS OF GANSU 1998). Die Störung durch den Menschen, durch Nutzung in der Vergangenheit könnte die Ursache sein.

Weiterhin zeigten die Ergebnisse die Unterschiede zwischen den **7 Waldgesellschaften** in der Baumartenzusammensetzung, der BHD-Klassenverteilung (>5 cm), in der Verjüngungen von Baumarten und auch in den Lebensformen, sowie in der Diversität der Vegetationsschichten. Wie erwartet, entsprachen diese Unterschiede den Ergebnissen der Vegetationsklassifizierung im ersten Teil der vorliegende Arbeit.

Diese Unterschiede der 7 Waldgesellschaften können so zusammengefasst diskutiert werden:

- Die Bergmischwälder auf der Untersuchungsfläche sind vielfältig strukturiert gemischt.
- In den Beständen der 7 Waldgesellschaften kommen Pionierbaumarten wie *Betula platyphylla* in den dominanten Schichten und als Verjüngungen nur in einer Waldgesellschaft vor.
- Allgemein herrscht viel Jungwuchs und wenig Starkholz der Späte-Sukzession-Arten z.B. *Quercus aliena* var. *acutiserrata*, *Quercus mongolica* vor.

- Es gibt eine große Artenvielfalt.
- Die Diversität der vier Vegetationsschichten zeigt, dass die dominante Baumschicht eine viel kleinere Artenvielfalt als die drei anderen Unterschichten aufweist.

Die 7 Waldgesellschaften waren vielfältig strukturiert gemischt und in unterschiedlichem Bestandesdynamikzustand. Sie scheinen allgemein in einem Übergangsstadium zwischen Pionier- und Späte-Sukzession-Stadium zu sein.

Die Störung durch den Menschen, durch Nutzung in der Vergangenheit könnte die Ursache für diesen unterschiedlichen Bestandesdynamikzustand sein. Nach Angabe des Xiaolongshan-Forstamts (FOREST BUREAU OF XIAOLONGSHAN 2006) gab es keinen Kahlschlag, auch keinen kleinflächigen Kahlschlag (5-10 ha) in den Bergmischwäldern auf dem Untersuchungsgebiet (vgl. Kapitel 1.6). Es wurden offensichtlich zuerst dicke starke Stämme (mehr als 20 cm) als Einzelwesen abgeholzt, z.B. der Pionierbaumarten: *Betula platyphylla* für Papierholz und *Betula albosinensis* für Bauholz, oder auch der Spät-Sukzessions-Arten: *Quercus aliena* var. *acutiserrata*, *Quercus mongolica* für Bauholz. Durch solche Einzelbaumnutzung wurden nur die dicken starken Stämme der Spät-Sukzessions-Arten gefällt, die dünneren Stämme blieben für die Spät-Sukzessionsphase erhalten, somit wurde das Späte-Sukzession-Stadium nicht total verhindert.

Die Bergmischwälder auf der Untersuchungsfläche zeigen auch eine große Artenvielfalt. Es wurden 448 Arten von Gefäßpflanzen in 120 Plots im Wald auf einer 300 ha großen Fläche aufgenommen. *Cornus hemsleyi* und *Sorbus hupehensis* sind beispielsweise endemische Arten, die nur im Bergwald der Qinling Gebirge wachsen; die selten Arten in der nationalen Artenschutzlisten (CAI et al. 2003) wie *Paeonia suffruticosa* var. *papaveracea* in der Waldgesellschaften VuQa und VcQa; or *Euptelea pleiosperma* in der Waldgesellschaft VpQm; or *Corylus chinensis, Juglans mandshurica* in der Waldgesellschaften CrQa, OgJm, und LbCc; or *Cephalotaxus sinensis* in der Waldgesellschaften OgJm. Diese Ergebnisse derer Untersuchungen lassen erwarten, dass eine solche Vielfalt an Vegetation und Arten im Westlichen Qinling Gebirge unbedingt schützenswert ist. Das Qinling Gebirge hat eine besondere Bedeutung für den Artenschutz (FANG 2004, H. YUAN et al. 2009) im Vergleich zu anderen Gebieten in gemäßigten Klimazonen von China (WU et al. 2004).

In dem untersuchten Gebiet ist die Hangneigung steil (30 %-60 %, in Grad:16,7°-31°) bis sehr steil (≥60 %). Die Böden sind dort von Erosion gefährdet, vor allem nach Kahlschlag. Die Waldvegetation würde dadurch definitiv zerstört und ihre Wiederherstellung wäre fast unmöglich, falls die Wälder nicht sorgfältig geschützt würden. Die Wälder sind auch für den Wasserschutz im gesamten Wassereinzugsgebiet des Yangtze- und des Gelben Flusses verantwortlich. Dies ist ein zwingender Grund für weitere Anstrengungen für Schutzmaßnahmen, auch nach dem nationalen Waldschutz-programm NFPP, und weitere Anstrengungen in der Erforschung der natürlichen Vegetation, des Standorts und des Ökosystems-Monitorings sind erforderlich.

Allerdings haben die Bergwälder mit ihrer Arten- und Struckturvielfalt eine Anpassungsfähigkeit gegen Klimawandel und große Potenziale zur Erfüllung des zukünftigen Bedarfs an Holz- und Nicht-Holzprodukten. Dies zu bestätigen, bedarf es weiterer Untersuchungen der Walddynamik unter Schutz und mit Hilfe von kontrollierten Nutzungen, dabei sollten waldbaulichen Maßnahmen auf standörtlicher Grundlage und Sukzession-Phase differenziert und optimiert werden. So könnte die Artenvielfalt und die Artenzusammensetzung besser erhalten werden.

5.3 Lichtverhältnisse und Naturverjüngung der Eiche *Quercus aliena* var. *acutiserrata*

In der vorliegenden Arbeit konnte mit Hilfe von Daten zur Inventur der Baumverjüngung und einer Aufnahme der Lichtschätzung mit Hilfe von hemisphärischen Fotos die Beziehung zwischen Lichtverhältnissen und Naturverjüngungen der Eiche *Quercus aliena* var. *acutiserrata* gezeigt werden.

Die Gradienten der Sonneneinstrahlungsintensität am Waldboden in 1,3 m Höhe wiesen folgendes auf: In Bestandeslücken trat die stärkste Einstrahlungsintensität auf, Lückenränder zeigten die nächsthöhere Intensität, dann folgten der Trauf, und den Schluss bildeten geschlossene Bestände.

Es gab keine großen Lücken innerhalb der Untersuchungsfläche, d.h. diese kleinflächigen Lücken wären nicht durch großflächige Nutzung in der Vergangenheit entstanden, sondern eher durch Einzelbaumnutzung.

Die Baumart *Quercus aliena* var. *acutiserrata* zeigte eine gute Naturverjüngung. Es konnte kein Unterschied in der Jungwuchsdichte (Bäume/ha) der Eiche in der Höheklasse unterhalb oder oberhalb von 1,3 m mit einem BHD kleiner als fünf Zentimeter bei 4 unterschiedlichen Aufnahmepunkten innerhalb eines Transekts (Bestandeslücke, Lückenrand, Trauf, geschlossener Bestand) (N=44) nachgewiesen werden. Dies bestätigte die Ergebnisse von WANG & GAO (2005), dass die Eiche *Quercus aliena* var. *acutiserrata* schattentolerant in ihrer frühen Jungwuchsphase ist.

Waldbauliche Maßnahmen sollten die Verjüngung fördern. Nach diesen Ergebnissen besteht für die frühe Jungwuchsphase von Eichennaturverjüngung kein Bedarf, größere Lichtungshiebe durchzuführen.

Allerdings gab es in den Lücken signifikant mehr Eichenverjüngung in der Höhenklasse 50-130 cm. Jedoch sind weitere Untersuchungen mit einer größeren Aufnahmezahl nötig, um eine korrekte Aussage zu treffen.

Fazit: Die Eichenverjüngung kam jedoch allgemein (auch in der Höhenklasse 50-130 cm) auch gut in den kleinflächigen Bestandeslücken vor. Einzelbaumnutzung könnte durchgeführt werden, wenn das Xiaolongshan-Forstamt dort die „Stragie des Schutzs durch Nutzung“ anwenden würde: die Verjüngung der Eiche könnte positiv reagieren.

6 Zusammenfassung

Seit 1998 wurde das nationale Naturwaldschutzprogramm in 17 Provinzen der VR China durchgeführt und der Holzeinschlag in Naturwäldern und in semi-natürlichen Wäldern gestoppt. Es ist eine große Herausforderung, Konzepte für den Schutz und das nachhaltige Management der naturnahen Wirtschaftswälder zu entwickeln. Eine nachhaltige Entwicklung einer naturnahen Forstwirtschaft unter Berücksichtigung von Naturschutz erfordert Kenntnisse über die Ökologie der Standorte und ihrer Artenzusammensetzung, Waldgesellschaften, und Verjüngung der Baumarten. Diese Kenntnisse sind in China nur unzureichend vorhanden.

Die Doktorarbeit untersucht die Zusammenhänge zwischen Waldvegetation und Standort in einem arten- und strukturreichen naturnahen Wirtschaftswald im westlichen Qingling-Gebirge, Gansu Provinz, welche in dem Gebiet des nationalen Naturwaldschutzprogramms NFPP liegt. Die Dissertation verfolgte drei Ziele:

1. Analyse der Beziehung zwischen Waldvegetation und Standort.
2. Beschreibung der Bestandesstrukturen, der Naturverjüngung und deren Bestandesdynamiken.
3. Analyse der Zusammenhänge zwischen Naturverjüngung und Lichtversorgung in den Eichenbeständen.

Die im Rahmen der Dissertation gewonnenen Erkenntnisse geben Hinweise auf eine standortangepasste Baumartenwahl und auf eine Verbesserung der waldbaulichen Maßnahmen zur Steuerung der Naturverjüngung im Hinblick auf den Erhalt artenreicher Eichenmischwälder als Wirtschaftswald.

6.1 Vegetation und Standort im sommergrünen Eichenmischwald in der montanen Zone im westlichen Qinling Gebirge, China

Das Qinling Gebirge ist ein Gebiet von hoher Biodiversität in China. Die vorliegende Dissertation über die montane Zone im westlichen Qinling Gebirge, mit semi-natürlichen Beständen, beruft sich auf 120 Vegetationsaufnahmen von je 400 m^2 in Höhenlagen zwischen 1500 und 2200 m, und klassifiziert die Waldvegetation der sommergrünen Eichenwälder in der warm-gemäßigten Klimazone.

Methode: Die pflanzensoziologischen Aufnahmen wurden mit dem BRAUN-BLANQUET-Verfahren in einem systematischen Gitternetz (100 m×200 m, N=120) erhoben. Vegetationsparameter von 4 definierten Schichten wurden aufgenommen. Gemessen und ausgerichtet für jede Aufnahme wurden die Standortdaten, wie direkte Sonneneinstrahlung, Temperatur und verfügbare Wasser-Speicherkapazität (nutzbare Wasserkapazität, nWK) des Bodens.

Die Vegetationsdaten der Krautschicht wurden mit multivarianten Klassifikations- und Ordinations-Methoden analysiert, um Waldgesellschaften zu definieren und nach ihren diagnostischen Arten zu identifizieren. Die diagnostischen Arten in der Strauchschicht und den zwei Baumschichten wurden mithilfe „indicator species analysis“ für diese Waldgesellschaften identifiziert. Eine indirekte Gradienten-Analyse unter Verwendung von „non-metric multidimensional scaling (nMDS)” ermittelte die floristischen Beziehungen zwischen den Aufnahmen und den Waldgesellschaften. Ihre Vegetations-Standort-Beziehungen wurden in einem nMDS-Diagramm dargestellt (Ordination Overlays).

Ergebnisse: 448 Arten von Gefäßpflanzen aus 91 Familien und 267 Gattungen wurden aufgelistet. Die Eichenwälder wurden in 3 Waldgesellschaftsgruppen und 7 Waldgesellschaften unterteilt, und nach Artenzusammensetzung aller Gefäßpflanzen (diagnostische, konstante und dominante Arten), nach Artenvielfalt (Artendiversität), Lebensform und Typen der Standorte klassifiziert. Folgende Syntaxa wurden beschrieben:

1. *Quercus dentata-Quercus aliena* var. *acutiserrata*-Waldgesellschaftsgruppe (QQ):

1a. *Vicia unijuga-Quercus aliena* var. *acutiserrata*-Waldgesellschaft (VuQa);

1b. *Viola collina-Quercus aliena* var. *acutiserrata*-Waldgesellschaft (VcQa);

2. *Sorbus alnifolia-Quercus mongolica*-Waldgesellschaftsgruppe (SQ):

2a. *Agrostis clavata-Quercus mongolica*-Waldgesellschaft (AcQm);

2b. *Viola phalacrocarpa-Quercus mongolica*-Waldgesellschaft (VpQm);

3. *Juglans mandshurica-Corylus chinensis*-Waldgesellschaftsgruppe (JC):

3a. *Laportea bulbifera-Corylus chinensis*-Waldgesellschaft (LbCc);

3b. *Carex rubrobrunnea* var. *taliensis-Quercus aliena* var. *acutiserrata*-Waldgesellschaft (CrQa);

3c. *Oxalis griffithii-Juglans mandshurica*-Waldgesellschaft (OgJm).

Die zwei Waldgesellschaften (VuQa und VcQa) der *Quercus dentata-Quercus aliena* var. *acutiserrata*-Waldgesellschaftsgruppe (QQ) bevorzugen trockene Standorte, mit hoher Sonneneinstrahlung in geringerer Höhelage also warme Standorte. Die zwei *Quercus mongolica*-Waldgesellschaften (AcQm und VpQm) der *Sorbus alnifolia-Quercus mongolica*-Waldgesellschaftsgruppe (SQ) wachsen auf mäßig frischen, ebenfalls mit hoher Sonneneinstrahlung, aber in höherer Lage und daher kühleren Standorten. Die drei Waldgesellschaften (LbCc, CrQa und OgJm) der *Juglans mandshurica-Corylus chinensis* Waldgesellschaftsgruppe (JC) wachsen auf feuchten, schattigen und wärmeren Standorten in geringerer Höhelage. Die topographische Lage erschien viel wichtiger Wirkung als die Wasserspeicherkapazität des Bodens zu haben.

Die Arbeit ist vornehmlich eine pflanzensoziologische Studie, die eine floristische Vielfalt auf vielseitigen Standorten registrierte und so einen Referenzbeitrag für weitere Vegetationsforschungen in anderen Teilen der Qinling Mountains und anderen Gebieten Chinas biete.

Stichworte: Quercus, Waldvegetation, Standort, pflanzensoziologische Studie, Qinling Mts, China.

6.2 Bestandestruktur, Verjüngung und Standortsqualität im sommergrünen Eichenmischwald in der montanen Zone im westlichen Qinling Gebirge, China – Schutz und Waldbewirtschaftung auf ökologischer Grundlage

Die **Ziele** des zweiten Teils der Dissertation waren:

1. Analyse der Bestandestrukturen der 7 Waldgesellschaften und ihrer 3 oberen Waldgesellschaftsgruppen, und Erklärung über die Unterschiede und die Ähnlichkeiten der Bestandestrukturen zwischen Waldgesellschaftsgruppen und zwischen Waldgesellschaften, basierend auf ihrem Standort, und deren Entwicklung.
2. Einschätzung der Entwicklung der Waldbestände in den seit 1998 geschützten Eichenwäldern des westlichen Qinling Gebirges, China.
3. Anregungen für Naturschutz und standortangepasste Baumartenwahl für eine nachhaltige Waldbewirtschaftung.

Folgende **Fragen** wurden untersucht:

1. **Bestandestruktur** in den 3 Waldgesellschaftsgruppen und den 7 Waldgesellschaften:
   - Wie unterscheidet sich die Baumzahl pro Hektar, die Grundfläche und das Volumen zwischen den 3 Gruppen und den 7 Gesellschaften?
   - Wie verändert sich die Baumzahl pro Hektar Naturverjüngung in den 3 verschiedenen Gruppen und den 7 verschiedenen Gesellschaften?
   - Was sagen die Oberhöhen über die Bonität der 3 Waldgesellschaftsgruppen aus?
2. **Walddynamik** in den 7 Waldgesellschaften:
   - Wie variiert die Durchmesserverteilung der wichtigen Baumarten zwischen den 7 Waldgesellschaften?
   - Wie verändern sich die Höhen- und Durchmesserverteilungen der Naturverjüngung der wichtigen Baumarten in den 7 Waldgesellschaften?
3. **Artenvielfalt** und **Lebensform** in den vertikalen Abschnitten der Kronen (Vegetationsschichten im Bestand):
   - Wie variiert die Artenvielfalt in den 4 unterschiedlichen Vegetationsschichten

zwischen den 3 Waldgesellschaftsgruppen und den 7 Waldgesellschaften?

- Wie verändern sich die Lebensformspektren in der Krautschicht zwischen den 3 Waldgesellschaftsgruppen und den 7 Waldgesellschaften?

Methode: Für die Inventur von Bestandesstruktur und Naturverjüngung wurde ein systematisches Gitternetz neben den Vegetationsaufnahmen erstellt. Für die 120 Probeflächen wurden konzentrische Kreise nach der FORSTLICHEN VERSUCHS- UND FORSCHUNGSANSTALT BADEN-WÜRTTEMBERG (FVA 2004) eingerichtet. Die Verjüngung der Baumarten wurden in der 3 Höhenklassen (0-20 cm and 20-50 cm and 50-130 cm), und der 4 DBH-Klassen (1-2 cm, 2-3 cm, 3-4 cm, 4-5 cm, Jungwuchs mit einer Höhe über 130 cm) aufgenommen.

Die Oberhöhe der dominanten Bäume der 3 Baumartengruppen (*Quercus*-Arten, Laubbaum-Arten und *Betula/Populus*-Arten) wurde als Indikator für die Produktivität der Standorte (Bonität) der 3 Waldgesellschaftsgruppen herangezogen. Das Alter der dominanten Bäume wurde nicht durch ihre Jahrringe bestimmt, sondern erfolgte durch Fortschreibung aus dem alten Revierbuch, Stockzählung in der Umgebung (Jahrringzählung), Astquirlzählung bei Nadelbäumer in der Umgebung, oder durch Schätzung unter Berücksichtigung der standörtlichen Wuchsdynamik. Es sollte das jeweils sicherste Alter notiert werden. Einzelbaumalter innerhalb des Altersrahmens im Revierbuch wurden als Fortschreibung deklariert werden (FVA 2004). Die 3 Baumartengruppen standen bereits in der Bonitätszuordnungstabelle des FOREST BUREAU OF XIAOLONGSHAN (1982b). Die absoluten Höhenbonitäten entsprechen bei Eichen- oder Laubbaum-Beständen im Alter von 40, bei Pappel- oder Birken-Waldbeständen im Alter von 30 dieser Tabelle.

Die Lebensformenspektren aller Arten (Daten ihres Deckungsgrades) der Krautschicht in den 7 Waldgesellschaften und in den 3 Waldgesellschaftsgruppen wurden verglichen. Die Diversitäts-Indices – Artenreichturm (α-Diversität), Evenness, Shannon-Index, Simpson-Index – in den vier Vegetationsschichten der 7 Waldgesellschaften und der 3 Waldgesellschaftsgruppen wurden deckungsgradgewichtet.

Die Interpretation der Bestandesdynamik erfolgte durch die Verteilung der BHD-Klassen (BHD ≥5 cm) und auch durch die Verteilung der Verjüngung der Höhen- und BHD-Klassen (BHD <5 cm) der Baumarten in den 7 Waldgesellschaften.

Die statistischen Tests (Kruskal-Wallis H-Test bzw. Mann-Whitney-U-Test) wurden verwendet, um die Unterschiede in den 7 Waldgesellschaften und in den 3 Waldgesellschaftsgruppen zu vergleichen.

Ergebnisse: Der Bestandesstruktur wurde durch die Baumzahl pro Hektar, Naturverjüngung, Grundfläche und Volumen auf der Wald-Ebene und innerhalb der 7 Waldgesellschaften und der 3 Waldgesellschaftsgruppen beschrieben. Es gab nur wenige Bäume mit BHD >20 cm.

Die Unterschiede zwischen den 3 Waldgesellschaftsgruppen und den 7 Waldgesellschaften wurden in der Bestandesstruktur und der Verjüngung von Baumarten, der Lebensformenformenspektren alle Arten in der Krautschicht, sowie der Diversität der vier Vegetationsschichten gezeigt.

Insgesamt 56 Baumarten (BHD ≥5 cm) wurden identifiziert in 120 Aufnahme. Die mittlere Baumzahl, mittlere Grundfläche und das mittlere Volumen waren 1199 Bäume /ha, 24 m^2/ha und 156 m^3/ha. Es gab allgemein eine gute Naturverjüngung (BHD <5 cm). Die Baumzahl pro Hektar der Naturverjüngung war abnehmend, von Sämling mit einer Höhe <20 cm bis Jungwuchs mit einer Höhe über 130 cm und einer BHD 4-5 cm: Mittlere Baumzahl der Verjüngung waren 7.500 Bäume/ha (Höhe <20 cm) und 1.200 Bäume/ha (BHD 4-5 cm). *Quercus aliena* var. *acutiserrata*, *Quercus mongolica*, *Betula platyphylla*, *Sorbus alnifolia*, *Corylus chinensis*, *Ulmus davidiana* var. *japonica* waren die häufigsten Baumarten in der Frequenz (62 %-23 %). *Quercus aliena* var. *acutiserrata* zeigte mit 20 % der gesamten Bäume pro Hektar und 24 % des Gesamtvolumens die höchste Baumzahl und das höchste Volumen.

Es zeigten sich signifikante Unterschiede der Baumzahl (BHD ≥5 cm), der Grundflächen und des Volumens pro Hektar zwischen den **3 Waldgesellschafts-gruppen**. Die Waldgesellschaftsgruppe QQ (*Quercus aliena*-Wälder auf trockenen, sonnigen, warmen submontanen-Standorten) hatte eine deutlich höhere Baumzahl als die Waldgesellschaftsgruppe JC (*Juglans*-Laubbaummischwälder auf feuchten, schattigen, warmen submontanen-Standorten). Es gab keinen signifikanten Unterschied der Baumzahl zwischen der Waldgesellschaftsgruppe SQ (*Quercus mongolica*-Wälder auf mäßig frischen, sonnigen, kühlen montanen-Standorten) und den zwei Waldgesellschaftsgruppen QQ und JC. Aber die Grundfläche und das Volumen in der Waldgesellschaftsgruppe SQ waren signifikant höher als in den Waldgesellschafts-gruppen QQ und JC. Die Waldgesellschaftsgruppe QQ hatte eine signifikant höhere Baumzahl von *Quercus aliena* var. *acutiserrata* und *Quercus dentata* (BHD ≥5 cm) als die zwei Waldgesellschaftsgruppen SQ und JC. Die Waldgesellschaftsgruppe SQ hatte eine signifikant höhere Baumzahl von *Quercus mongolica*, *Betula albosinensis* und *Sorbus alnifolia* als die zwei Waldgesellschaftsgruppen QQ und JC. Die Waldgesellschaftsgruppe JC hatte eine signifikant höhere Baumzahl von *Ulmus davidiana* var. *japonica, Juglans mandshurica* als die zwei Waldgesellschaftsgruppen QQ und SQ.

Die Baumzahl der Verjüngung (BHD <5 cm) war allgemein in allen 3 Waldgesellschaftsgruppen hoch. Es gab deutlich mehr Verjüngung in den Waldgesellschaftsgruppe QQ und JC (mittlere Baumzahl 13.000 und 14.000 Bäume/ha) als in der Waldgesellschaftsgruppe SQ (8.500 Bäume/ha). Nur zwei Baumarten *Quercus aliena* var. *acutiserrata* und *Ulmus davidiana* var. *japonica* zeigten Unterschiede in der Baumzahl der Verjüngung zwischen den 3 Waldgesellschaftsgruppen. Es gab deutlich mehr Verjüngung von *Q. aliena* var. *acutiserrata* in der Waldgesellschaftsgruppe QQ als in den zwei Waldgesellschaftsgruppen JC und SQ. Es gab aber mehr Verjüngung von *Ulmus davidiana* var. *japonica* in der Waldgesellschaftsgruppe JC als in den zwei Waldgesellschaftsgruppen QQ und SQ.

Es zeigten sich signifikante Unterschiede in dem Volumen und der Grundfläche pro Hektar (BHD ≥5 cm) zwischen den **7 Waldgesellschaften**, aber kein Unterschied in der gesamten Baumzahl (Bäume/ha). Es zeigten sich signifikante Unterschiede zwischen den 7 Waldgesellschaften in der Baumzahl der Baumarten *Quercus aliena* var. *acutiserrata*, *Quercus mongolica*, *Betula platyphylla*, *Sorbus alnifolia*, *Corylus chinensis*, *Ulmus davidiana* var. *japonica*, *Juglans mandshurica*, *Quercus dentata*, *Betula albosinensis* und der anderen 46 Arten kombiniert (BHD ≥5 cm).

Die Waldgesellschaft VuQa hatte signifikant niedrigere Grundfläche und Volumen (BHD ≥5 cm) als die Waldgesellschaft VcQa. Aber die Baumzahl (BHD ≥ 5cm) pro Hektar von *Quercus aliena* var. *acutiserrata*, *Quercus dentata* war signifikant höher als in der Waldgesellschaft VcQa auf ähnlichen Standorten (in der gleichen Waldgesellschafts-gruppe QQ). *Quercus mongolica*, *Betula platyphylla* und *Corylus chinensis* (BHD ≥5 cm) zeigten signifikant höhere Baumzahl in der Waldgesellschaft VcQa als in der Waldgesellschaft VuQa. Die gesamte Verjüngung (BHD <5 cm), die Verjüngung von *Quercus aliena* var. *acutiserrata* in der Waldgesellschaft VuQa waren signifikant höher als in der Waldgesellschaft VcQa.

Es gab keine signifikanten Unterschiede in der Grundfläche und dem Volumen (BHD ≥5 cm), in der Baumzahl pro Hektar der gesamten Verjüngung (BHD <5 cm) zwischen den 2 Waldgesellschaften AcQm und VpQm der Waldgesellschaftsgruppe SQ (*Quercus mongolica*-Wälder auf mäßig frischen, sonnigen, kühlen montanen-Standorten). Die Waldgesellschaft AcQm hatte aber signifikant höhere Baumzahl (BHD ≥5 cm) von *Betula platyphylla*, *Betula albosinensis*, aber niedrigere Baumzahl von *Quercus aliena* var. *acutiserrata*, *Sorbus alnifolia* als die Waldgesellschaft VpQm.

In der Waldgesellschaftsgruppe JC (*Juglans*-Laubbaummischwälder auf feuchten, schattigen, warmen submontanen-Standorten) gab es signifikante Unterschiede im gesamten Volumen (BHD ≥5 cm), nur zwischen der Waldgesellschaft CrQa und der Waldgesellschaft OgJm. Die Waldgesellschaft CrQa hatte auch signifikant höhere Baumzahl (BHD ≥5 cm) von *Betula platyphylla*, *Quercus aliena* var. *acutiserrata*, aber niedrigere Baumzahl von *Juglans mandshurica* als die Waldgesellschaften OgJm und LbCc. Die Waldgesellschaft CrQa hatte signifikant höhere Baumzahl von Verjüngung (BHD <5 cm) von *Sorbus alnifolia* und von den gesamte Baumarten.

In der Waldgesellschaftsgruppe SQ (*Quercus mongolica*-Wälder auf mäßig frischen, sonnigen, kühlen montanen-Standorten) war die **Oberhöhe** am höchsten von allen 3 Waldgesellschaftsgruppen. Die Waldgesellschaftsgruppe QQ (*Quercus aliena*-Wälder auf trockenen, sonnigen, warmen Submontan-Standorten) und die Waldgesellschaftsgruppe JC (*Juglans*-Laubbaummischwälder auf feuchten, schattigen, warmen submontanen-Standorten) waren von ähnlicher Standortsqualität und wurden als mittlere Standortsqualität für *Quercus*-Arten betrachtet. Günstiger für *Quercus*-Artengruppe war der Standort der Waldgesellschaftsgruppe SQ. Für die Laubbaum-Artengruppe wurden die Standorte der allen 3 Waldgesellschaftsgruppen QQ, SQ und JC als durchschnittliche Standortsqualität betrachtet.

Die Waldgesellschaftsgruppe QQ (*Quercus aliena*-Wälder auf, trockenen, sonnigen, warmen submontanen-Standorten) und die Waldgesellschaftsgruppe SQ (*Quercus mongolica*-Wälder auf mäßig frischen, sonnigen, kühlen montanen-Standorten) hatten die höchste Deckung von Phanerophyten. Die Waldgesellschaftsgruppe JC (*Juglans*-Laubbaummischwälder auf feuchten, schattigen, warmen submontanen-Standorten) hatte die höchste Deckung von Hemikryptophyten und Therophyten. Es gab eine deutliche Artenvielfalt in der Waldgesellschafsgruppe SQ. Die Vielfalt der vier Vegetationsschichten zeigte jedoch, daß die Artenvielfalt in den dominanten und subdominanten Baumschichten kleiner ist als in den Strauch- und Krautschichten, besonders in den Waldgesellschaftsgruppe QQ. Die seltenen Arten der nationalen Artenschutzlisten (CAI et al. 2003) kammen vor: wie *Paeonia suffruticosa* var. *papaveracea* in den Waldgesellschaften VuQa und VcQa; oder *Euptelea pleiosperma* in der Waldgesellschaft VpQm; oder *Corylus chinensis, Juglans mandshurica* in den Waldgesellschaften CrQa, OgJm, und LbCc; oder *Cephalotaxus sinensis* in der Waldgesellschaft OgJm.

Unterschiede im Standort und menschliche Störungen könnten ein Grund für unterschiedliche Bestandesdynamik der Waldgesellschaften sein. Die Beschreibung über den Zustand der Bestandesdynamik der 7 Waldgesellschaften erlaubt, Vermutungen über eine dynamische Entwicklung der Bestände unter gleichen Standortbedingungen zu äußern. Die Bergwälder mit ihrer Arten- und Struckturvielfalt hätten eine Anpassungsfähigkeit gegen Klimawandel und große Potenziale zur Erfüllung des zukünftigen Bedarfs an Holz- und Nicht-Holzprodukten. Dies zu bestätigen, bedarf es weiterer Untersuchungen der Walddynamik unter Schutz und mit Hilfe von kontrollierten Nutzungen, dabei sollten waldbauliche Maßnahmen auf standörtlicher Grundlage und Sukzession-Phase differenziert und optimiert werden. So könnte die Artenvielfalt und die Artenzusammensetzung besser erhalten werden.

Stichworte: Bestandestruktur, Verjüngung, Diversität, Lebensform, Waldgesellschaft, Standort, Qinling Gebirge, China.

6.3 Einfluss der Struktur von Kronendachlücken und Licht auf die natürliche Verjüngung von *Quercus aliena* var. *acutiserrata* in den naturnahen Eichenwälder im westlichen Qinling Gebirge, China

Bei der Untersuchung über Einflüsse von Kronendachlücken und transmittierten Sonneneinstrahlungen auf die Regeneration von *Quercus aliena* var. *acutiserrata* in diesen Gebieten stellten sich die folgenden **Fragen**:

1. Welches sind die Unterschiede der transmittierten Sonneneinstrahlung in den Bestandeslücken und unter dem Kronendach (dem Schirm der Baumkronen)?
2. Wie unterscheidet sich die natürliche Verjüngung von *Q. aliena* var. *acutiserrata* in den Bestandeslücken und unter dem Kronendach?
3. Gibt es eine Beziehung zwischen Sonneneinstrahlung und der Naturverjüngung von *Q. aliena* var. *acutiserrata*?

Methode: Die Verjüngung aller Baumarten wurden auf 44 Plots mit je zwei konzentrischen Kreisen im Radius von 1,5 m und 2 m (Größe 7,1 m^2 und 12,6 m^2) in 4 unterschiedlichen Aufnahmefläche innerhalb von Transekten (11 Bestandeslücken, 11 Lückenränder, 11 Traufläche, 11 geschlossenen Bestände) gemessen. In ca. 1,3 m Höhe wurden jeweils hemisphärische Fotos (Fischaugenfotos) aufgenommen, um die transmittierte Sonneneinstrahlung in den vier Aufnahmefläche von Transekten (N=44) zu berechnen.

Die Baumzahl der Naturverjüngung von der Baumarten *Q. aliena* var. *acutiserrata* und von allen Baumarten (summarisch) wurde berechnet für die 44 Plots der 4 verschiedenen Aufnahmeflächen. Kruskal-Wallis H-Test sowie Mann-Whitney-U-Test wurden verwendet, um signifikante Unterschiede der Verjüngungen und der transmittierten Sonnenstrahlung in den vier Aufnahmefläche von Transekten zu testen. Auf Spearman-rho-Basis wurde die non-parametrische Korrespondenzanalyse durchgeführt, um signifikante Zusammenhänge zwischen Eichen-Verjüngung und transmittierter Sonneneinstrahlung zu erkennen.

Ergebnisse: Die transmittierte Sonneneinstrahlung war signifikant abnehmend, am höchsten in den Bestandeslücken, weniger am Lückenrand, noch weniger im Lücken-Bestand-Trauf, am geringsten im geschlossenem Bestand.

Quercus aliena var. *acutiserrata* hatte ein starkes Naturverjüngungsvermögen in den naturnahen Eichenwäldern.

Es gab keine signifikanten Unterschiede in der Baumzahl (Bäume/ha) von *Q. aliena* var. *acutiserrata* als Sämling mit einer Höhe <50 cm, als Jungwuchs mit einer Höhe <130 cm, als Jungwuchs mit einer Höhe >130 cm zwischen den vier Bereichen (Bestandeslücke, Lückenrand, Lücken-Bestand-Trauf und geschlossener Bestand).

Allerdings zeigten sich signifikante Unterschiede in der Baumzahl (Bäume/ha) von *Q. aliena* var. *acutiserrata* als Jungwuchs (Höhe 50-130 cm) zwischen den Bestandeslücken und den anderen 3 Bereichen (Lückenrand, Lücken-Bestand-Trauf und geschlossener Bestand). Die Baumzahl (Bäume/ha) von *Q. aliena* var. *acutiserrata* als Jungwuchs (Höhe 50-130 cm) zeigte signifikante Korrelationen zwischen Lichtschacht (openness), und direkter Sonneneinstrahlung oder diffuser Sonneneinstrahlung unterm Kronendach (non-parametrische Korrelationen, Speaman rho).

Es gab keine großen (>200 m^2) Bestandeslücken innerhalb des Untersuchungs-gebietes. Die untersuchten kleinflächigen Bestandeslücken waren nicht durch großflächige Waldnutzung entstanden, sondern durch Einzelbaumnutzung. Die Naturverjüngung von Eiche *Quercus aliena* var. *acutiserrata* war allgemein (auch in der

Höhenklasse 50-130 cm) gut, auch in den kleinflächen Bestandeslücken. Die Verjüngung der Eiche scheint auf Einzelbaumnutzung positiv zu reagieren.

Stichworte: Bestandeslücke, licht, *Quercus aliena* var. *acutiserrata*, Naturverjüngung, Qinling Gebirge, China.

7 Summary

The Qinling Mts. are the major watershed of the upper Yangtze River and the upper- and mid-part of the Yellow River. Therefore, the forests of that region are protected by China's Natural Forest Protection Programme (NFPP) since 1998. The knowledge about the ecology of tree species, site conditions and forest vegetation, including natural regeneration of tree species is essential for a sustainable forest management, e.g. in the form of close-to-nature forestry. In China, this knowledge is still insufficient for most forest types.

This thesis studied the relationship between site conditions and forest vegetation in a forest area of the Western Qingling Mountains, Gansu Province, China, which is in the area of the national protection program NFPP.

The thesis follows three aims. First, an analysis of the relationship between site conditions and forest vegetation. Second, a description of stand structure, natural regeneration, and succession. Third, a discussion of the relation between the regeneration of tree species and solar radiation in the oak forest. The achieved results of this study might offer indications concerning site-adapted tree species, in order to optimize the silvicultural measures for natural regeneration, aiming at conservation of the diversity in the managed mixed oak forests.

7.1 Vegetation and sites of the deciduous mixed oak forest in the montane zone of the Western Qinling Mountains, China

The Qinling Mountains are one of the biodiversity hotspots in China. This phytosociological study of semi-natural stands was the first one in the montane zone of the Western Qinling Mts. to classify the forest vegetation of the temperate deciduous oak

forests on the basis of 120 relevés within a size of 400 m^2 each, on altitudes between 1500 and 2200 m.

Methods: A BRAUN-BLANQUET-plot-approach was used in a systematic sampling design (grid 100 m×200 m, N=120). Site and vegetation parameters of 4 defined layers were recorded. For each plot, the site data were recorded and modelled for direct solar radiation, temperature and available water storage capacity (available water content, AWC) of soil.

The vegetation data of the herb layer were analyzed using multivariate classification and ordination methods to define communities and identify their diagnostic species. The species occurring in the shrub layer and the two tree layers were attributed to these relevé groups by using the Indicator Species Analysis, resulting in the diagnostic species of these 3 layers. An indirect gradient analysis using non-metric multidimensional scaling (nMDS) detected the floristic relationships between the plots and the forest communities, and was used to explore and visualize vegetation-environment relationships (ordination overlays).

Results: The listed 448 species of vascular plants belong to 91 families, 267 genera. The oak forests were classified into 3 community groups and 7 communities, including species composition of all vascular plant species (diagnostic, constant and dominant species), diversity, life-form, and site condition patterns. The following syntaxa were described:

1. *Quercus dentata*–*Quercus aliena* var. *acutiserrata*-community group (QQ):
   1a. *Vicia unijuga*–*Quercus aliena* var. *acutiserrata*-community (VuQa);
   1b. *Viola collina*–*Quercus aliena* var. *acutiserrata*-community (VcQa);
2. *Sorbus alnifolia*–*Quercus mongolica* (*syn.Q. liaotungensis*)-community group (SQ):
   2a. *Agrostis clavata*-*Quercus mongolica*-community (AcQm);
   2b. *Viola phalacrocarpa*-*Quercus mongolica*-community (VpQm);
3. *Juglans mandshurica*–*Corylus chinensis*-community group (JC):
   3a. *Laportea bulbifera*-*Corylus chinensis*-community (LbCc);

3b. *Carex rubrobrunnea* var. *taliensis-Quercus aliena* var. *acutiserrata*-community (CrQa);

3c. *Oxalis griffithii–Juglans mandshurica*-community (OgJm).

The two *Quercus aliena* var. *acutiserrata*-communities (VuQa and VcQa) preferred higher solar radiation and warmer, therefore drier sites; the two *Quercus mongolica*-communities (AcQm and VpQm) occurred also under relatively high direct solar radiation conditions, but on cooler sites of higher elevation; the communities of the *Juglans mandshurica-Corylus chinensis*-community group (LbCc, CrQa, and OgJm) occurred on less sun-exposed plots and lower elevation, and were found on the most humid, but warmer sites. Soil water storage capacity was more variable and played a less important role.

Therefore this study was a syntaxonomic one which recorded a floristic abundance on diverse forest sites and which might be a reference for further comparative studies of vegetations in other areas of the Qinling Mountains, and elsewhere in China.

Keywords: *Quercus*, forest, vegetation, site, phytosociological study, Qinling Mts., China

7.2 Stand structure, regeneration and site quality of the deciduous mixed oak forest in the montane zone of the Western Qinling Mts. -Protection and silviculture on an ecological basis

The objectives of the second study were: 1) Analysing the stand structures of the 7 communities and their 3 upper unit community groups in order to understand current and future forest succession processes, i.e. to find and to explain differences and similarities of stand structures between the different site types (forest vegetation types), based on their sites and their successions. 2) Proposing the choice of site adapted tree species for sustainable forest management. 3) Anticipating forest stand developments in the oak forests, protected since 1998, in the Western Qinling Mountains, China.

The **questions** of this study referred to:

1. Stand structure in the 3 community groups and the 7 communities:

- How do the number of trees per hectare, the basal area and the volume differ between the 3 community groups and the 7 communities?
- How does the number of regrowth per hectare change between the 3 community groups and the 7 communities?
- How do top heights reflect the site quality of the 3 community groups?

2. Successional patterns or trends in the 7 communities:

- How does the number of trees per hectare vary in different dbh-classes for individual important tree species in the 7 communities?
- How does the number of regrowth per hectare vary in different height- and dbh-classes for individual important tree species between the 7 communities?

3. Diversity and life form spectra in 3 community groups and 7 communities:

- How does the diversity of vascular plants vary in the 4 different vegetation layers between the 3 community groups and the 7 communities?
- How do the life form spectra in the herb layer differ between the 3 community groups and the 7 communities?

Methods: The inventory of stand structure and natural regeneration used a systematic sampling-design and concentric circles after the FVA BW (2004) for the position of 120 sample plots in relation to the vegetation relevés.

The height distribution of dominant trees in 3 tree species groups (*Quercus* species, broad-leaves tree species, and *Populus-/ Betula* species) was calculated as indicator of site productivity (Bonität). The site quality index with absolute top height and age referd in particular to the *Quercus* and broad-leaved tree species in the stand-age of 40 years and to the *Populus*-/*Betula* species in the stand-age of 30 years (Forest Bureau of Xiaolongshan 1982b).

The interpretation of the succession range was based on the distribution of dbh-classes (dbh >5 cm) and regeneration (dbh <5 cm) of height classes and dbh classes of all species in the 7 communities.

The life-form spectra of herb layer in the 7 communities and in their 3 upper unit community groups were analyzed by their cover of vegetation.

The diversity indices (richness, evenness, Shannon index, Simpson index) in the 4 vegetation layers of the 7 communities and their 3 upper unit community groups were analyzed by their cover of vegetation.

The statistic tests (Kruskal-Wallis H-test, as well as Mann-Whitney-U-test) were used to compare the differences in the 7 communities and their 3 upper unit community groups.

Results: The stand structure was described by density, basal area and volume at stand level and among the forest communities (3 upper unit tree community groups and 7 communities). There were only few trees with dbh >20 cm.

A total of 56 tree species (**dbh ≥5 cm**) were identified and measured in **120 plots**. The mean density, mean basal area, and volume were 1199 trees/ha, 24 m^2/ha and 156 m^3/ha. In general, there was a good natural regeneration: There was more **regrowth** (dbh <5 cm) with a height <130 cm, less regrowth with height over 130 cm, mean density ranging between 7,500 trees/ha (height <20 cm) and 1,200 trees/ha (dbh 4-5 cm). *Quercus aliena* var. *acutiserrata, Quercus mongolica, Betula platyphylla, Sorbus alnifolia, Corylus chinensis, Ulmus davidiana* var. *japonica* were most common tree species in frequency (62 %-23 % in 120 plots). *Quercus aliena* var. *acutiserrata* with 20 % of the total trees per hectare and 24 % of the total volume showed the highest density and the highest volume.

There were significant differences between the **3 community groups** in density, in basal area, and in volume of all tree species combined (**dbh ≥5 cm**). The community groups **QQ** on dry sunny warm sub-montane-sites had a significantly higher density of all tree species combined than the community group **JC** on moist shady warm submontane-sites. There was no significant difference in density of the community **SQ** on fresh sonny cold montane-sites to the other community groups (QQ and JC). But the basal area and the volume in the community group SQ were significantly higher than in the community groups QQ and JC. The community group QQ had a significantly higher density (dbh ≥5 cm) of *Quercus aliena* var. *acutiserrata,* and *Quercus dentata* than the 2 other community groups (SQ and JC). The community group SQ had a significantly higher density of *Quercus mongolica, Betula albosinensis,* and *Sorbus alnifolia* than the other community groups (QQ and JC). The community group JC had a significantly higher density of *Ulmus davidiana* var. *japonica, Juglans mandshurica* than the other community groups (QQ and SQ).

The density of **regrowth** (dbh <5 cm) of all species combined was remarkably high in all the **3 community groups**. There was significantly more regrowth (mean density 13,000 and 14,000 trees/ha) in the 2 community groups on sub-montane-sites (**QQ** and **JC)** than in the community group **SQ** on montane-sites (8,500 trees/ha). Only 2 tree species *Quercus aliena* var. *acutiserrata* and *Ulmus davidiana* var. *japonica* showed differences in density of regrowth in the 3 community groups. There were significantly more regrowth of *Q. aliena* var. *acutiserrata* in the community group **QQ** than in the community group **JC**, significantly less in the community group **SQ**. There was more regrowth of *Ulmus davidiana* var. *japonica* in the community group **JC** on moist shady warm sub-montane-sites than in the other 2 community groups QQ and SQ.

The **top heights** of all 3 tree species groups in the community group SQ were higher than in the other 2 community groups (QQ and JC), where the top heights were similar. The site quality of the community group QQ and the community group JC could be regarded as medium site quality for *Quercus* species. The site quality of SQ seemed to be better for *Quercus* species than the other 2 community groups (QQ and JC). The site quality of the 3 community groups QQ, SQ and JC were similar and could be regarded as medium site quality for broad-leaved tree species.

There were significant differences between the **7 communities**, in volume and basal area of all tree species combined (**dbh ≥5 cm**), but no difference in density (trees/ha) of all tree species combined. There were significant differences between the 7 communities in the density of *Quercus aliena* var. *acutiserrata, Quercus mongolica, Betula platyphylla, Sorbus alnifolia*, *Corylus chinensis, Ulmus davidiana* var. *japonica, Juglans mandshurica, Quercus dentata, Betula albosinensis* and the other 46 species combined (dbh ≥5 cm).

The community VuQa had significantly lower basal area and volume of all tree species combined (dbh ≥5 cm), but higher density of *Quercus aliena* var. *acutiserrata, Quercus dentata* than the community VcQa on similar sites (in the same community group QQ). There were significantly more regrowth (dbh <5 cm) of all species combined, of *Quercus aliena* var. *acutiserrata* in the community VuQa than in the community VcQa. *Quercus mongolica, Betula platyphylla,* and *Corylus chinensis* (dbh ≥5 cm) showed significantly higher density in the community VcQa.

There were no significant differences in basal area and volume of all tree species combined (dbh ≥5 cm), in density of regrowth (dbh <5 cm) between the 2 communities AcQm and VpQm on fresh sonny cold montane-sites (although in the same community group SQ). The community AcQm had significantly higher density of *Betula platyphylla, Betula albosinensis,* but lower density of *Quercus aliena* var. *acutiserrata, Sorbus alnifolia* (dbh ≥5 cm) than the community VpQm.

In the community group JC on moist shady warm sub-montane-sites, there were significant differences in volume of all tree species combined (dbh ≥5 cm) only between the community CrQa and the community OgJm. The community CrQa had significantly higher density of *Betula platyphylla, Quercus aliena* var. *acutiserrata,* but lower density of *Juglans mandshurica* than the community OgJm and the community LbCc. The community CrQa had significantly higher density of regrowth (dbh <5 cm) of all tree species combined, and also of *Sorbus alnifolia.*

The both community groups QQ and SQ had the higher cover of the phanerophytes. The community group JC had the highest cover of hemicryptophytes and of therophytes. There was an evident richness of species in the community group SQ. However, the diversity of the four vegetation layers showed that in the dominant tree layer the species richness was smaller than in the other three layers, especially in the community group QQ. The rare species of the List of Wild Plants Under State Protection (CAI et al. 2003) were there too: *Paeonia suffruticosa* var. *papaveracea* in the communities VuQa und VcQa; or *Euptelea pleiosperma* in the community VpQm; or *Corylus chinensis, Juglans mandshurica* in the communities CrQa, OgJm, and LbCc; or *Cephalotaxus sinensis* in the community OgJm.

The reason for different succession would be the difference in site condition and human disturbance. The description in this study also allowed the presumption (conjecture) of a stand dynamic development under the same site conditions. The mixed mountain forests in the research area were rich in structure and species. They might be adaptable to a climate change and have a great potential to meet the future demands for wood and non-wood products. To confirm this, further studies of forest dynamics will be needed under protection and with the help of controlled forest use, by differentiating and optimizing silvicultural activities with the knowledge of site and succession. So biodiversity and composition of species might be better preserved.

Keywords: stand structure, natural regeneration, diversity, life form, forest community, site, Qinling Mts., China.

7.3 Effects of the variability of solar radiation transmittance in gaps and below canopies on the regeneration of *Quercus aliena* var. *acutiserrata* in the uneven-aged deciduous oak forest in the Western Qinling Mountains, China

The influence of solar radiation transmittance in forest canopy gaps and below canopy on the regeneration of the oak species *Quercus aliena* var. *acutiserrata* was analyzed. Main objectives were three questions:

1. Which are the differences in solar radiation between gaps and areas below the canopy?

2. How does the regeneration of *Q. aliena* var. *acutiserrata* differ in gaps and below canopies?

3. Is there a relationship between solar radiation and the regeneration of *Q. aliena* var. *acutiserrata*?

Method: The samplings were taken on transects along the gradients of canopy closure for the inventory of regeneration and for the hemispherical photographs. The regeneration of tree species was recorded on 44 plots each in two concentric circles with a radius of 1.5 m and 2 m (area size 7.1 m^2 and 12.6 m^2). The plots were taken in 4 different gap compartments on transects (11 inside-gap, 11 gap-border, 11 gap-forest transition, 11 closed-forest). Hemispherical photographs were taken at 1.3 m above the ground for each plot; and used to calculate the solar radiation transmittance of the 4 different gap compartments on transects.

Density (trees/ha) of juveniles of oak and of all tree species were calculated for the plots in the different gap compartments (sections). Kruskal-Wallis H-test and Mann-Whitney-U-test were used to find significant differences in regeneration and solar radiation transmittance between gap compartments (inside-gap, gap-border, gap-forest transition, closed-forest). Non-parametrical correspondence analysis based on Spearman's rho was used to find significant correlations between the regeneration of oak and the solar radiation transmittance.

Results: The solar radiation transmittance decreased significantly, highest in the inside-gaps, lower in the gap-borders, and lower in the gap-forest transitions and lowest in the closed-forests.

Quercus aliena var. *acutiserrata* was with a strong persistent regeneration capability. Between the 4 gap compartments (inside-gap, gap-border, gap-forest transition, closed-forest), there were no significant differences in the density of seedlings with a height <50 cm, of saplings with a height <130 cm or of saplings a height >130 cm.

There were significant differences in density of juveniles of *Quercus aliena* var. *acutiserrata* (height 50-130 cm) between the inside-gap and the other 3 gap compartments (gap-border, gap-forest transition, and closed-forest). The density of juveniles of oak (height 50-130 cm) showed significantly highest in the inside-gap, but the standard deviation of density in the other 3 gap compartments was very high. The density (trees ha-1) of oak (height 50-130 cm) was correlated to openness, to below canopy direct solar radiation, and to below canopy diffuse solar radiation (nonparametric correlations, Spearman's rho).

Conclusions: **a.)** There were solar radiation differences between the inside-gap, the gap-border, the gap-forest transition and the closed-forest. **b.)** *Quercus aliena* var. *acutiserrata* showed strong persistent regeneration capability. **c.)** There were no significant differences in density of juveniles of *Quercus aliena* var. *acutiserrata* (height <50 cm, height <130 cm, height >130 cm) between the 4 gap compartments. **d.)** In gaps there was significantly more regeneration of juvenile oaks with a height of 50-130 cm. **e.)** There was a significant correlation between the solar radiation and the density of the oak juvenile (only height 50-130 cm).

There were no large (>200 m^2) gaps within the study area. The studied small gaps were obviously not caused by large-scale forest use, but by individual tree use. The natural regeneration of *Quercus aliena* var *acutiserrata* (even in the height-class of 50-130 cm) has happened also in these small gaps. The regeneration of this oak species seems to react positively to individual tree use.

Keywords: gap, solar radiation, *Quercus aliena* var. *acutiserrata*, natural regeneration, Qinling Mts., China.

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9 Abbildungsverzeichnis

10 Tabellenverzeichnis

11 Appendix

11.1 Appendix zu Kapitel 2

Annex 2.1: Vegetation Table

The Vegetation Table is found in the envelope at the back page. (available online)

Annex 2.2: Infrequent species (presence < 5 occurrences, i.e. presence=1-4 in 120 relevés) in the Vegetation Table (Annex 2.1)

In 1st tree layer (24 species): in col. 7: *Kalopanax septemlobus* (刺楸) r; in col. 29: *Tilia oliveri* (鄂椴) +; in col. 31: *Pinus tabuliformis* (油松) r; in col. 34: Cerasus polytricha (多毛樱桃) +; in col. 38: *Pyrus xerophila* (木梨) r; in col. 46: *Salix caprea* (黄花柳) +, *Zelkova serrata* (榉树) a; in col. 55: *Malus baccata* (山荆子) +; in col. 56: *Tilia henryana* var. *henryana* (毛糯米椴(原变种)) a; in col. 57: *Tilia henryana* var. *henryana* (毛糯米椴(原变种)) a, *Carpinus cordata* (千金榆) a; in col. 63: *Salix wallichiana* (皂柳) r; in col. 66: *Acer ginnala* (茶条槭) a; in col. 68: *Acer caudatum* (长尾槭) a; in col. 81: *Euptelea pleiosperma* (领春木) +; in col. 86: *Tilia oliveri* (鄂椴) +; in col. 87: *Tilia henryana* var. *henryana* (毛糯米椴(原变种)) a; in col. 91: *Tilia henryana* var. *henryana* (毛糯米椴(原变种)) a; in col. 94: *Malus hupehensis* (湖北海棠) r; in col. 95: *Staphylea holocarpa* (膀胱果) r; in col. 97: *Quercus spinosa* (刺叶栎) a; in col. 102: *Cladrastis delavayi* (小花香槐) b; in col. 104: *Acer ginnala* (茶条槭) a; in col. 105: *Acer ginnala* (茶条槭) a; in col. 106: *Salix caprea* (黄花柳) a, *Cerasus tomentosa* (毛樱桃) r; in col. 107: *Cerasus polytricha* (多毛樱桃) r; in col. 111: *Celastrus orbiculatus* (南蛇藤) r; in col. 115: *Cerasus polytricha* (多毛樱桃) r; in col. 116: *Acer ceriferum* (杈叶枫) +; in col. 117: *Staphylea holocarpa* (膀胱果) r; in col. 118: *Cerasus tomentosa* (毛樱桃) b; in col. 119: *Celtis bungeana* (黑弹树) r.

In 2nd tree layer (35 species): in col. 1: *Dipelta floribunda* (双盾木) r*, Prunus salicina* (李) +; in col. 3: *Tilia paucicostata* var. *dictyoneura* (红皮椴) a; in col. 4: *Dipelta floribunda* (双盾木) r; in col. 8: *Tilia paucicostata* var. *dictyoneura* (红皮椴) a; in col. 13: *Kalopanax septemlobus* (刺楸) r; in col. 15: *Prunus salicina* (李) r; in col. 21: *Forsythia suspensa* (连翘) +; in col. 24: *Aralia chinensis* (楤木) r; in col. 29: *Prunus salicina* (李) +; in col. 32: *Armeniaca vulgaris* var. *vulgaris* (杏(原变种)) a; in col. 34: *Tilia oliveri* (鄂椴) r; in col. 46: *Picrasma quassioides* (苦树) 1, *Tilia oliveri* (鄂椴) a; in col. 47: *Quercus spinosa* (刺叶栎) a*, Cotoneaster acutifolius* (灰栒子) +; in col. 52: *Aralia chinensis* (楤木) b; in col. 53: *Dipelta floribunda* (双盾木) r; in col. 57: *Carpinus cordata* (千金榆) b; in col. 61: *Betula albosinensis* (红桦) a; in col. 63: *Elaeagnus umbellata* (牛奶子) a, *Populus purdomii* (冬瓜杨) a, *Salix wallichiana* (皂柳) a; in col. 64: *Salix spathulifolia* (匙叶柳) b; in col. 65*: Tilia paucicostata* var. *dictyoneura* (红皮椴) r, *Clematoclethra scandens* subsp. *actinidioides* (猕猴桃藤山柳) +, *Prinsepia utilis* (扁核木) 1; in col. 66: *Quercus spinosa* (刺叶栎) a; in col. 68: *Tilia henryana* var. *henryana* (毛糯米椴(原变种)) +, *Sorbus tsinlingensis* (秦岭花楸) r; in col. 69: *Tilia henryana* var. *henryana* (毛糯米椴(原变种)) a, *Acer davidii* subsp. *grosseri (*葛罗枫) +; in col. 72: *Carpinus cordata* (千金榆) a; in col. 73: *Catalpa fargesii* (灰楸) r; in col. 75: *Hydrangea bretschneideri* (东陵绣球) +; in col. 88: *Picrasma quassioides* (苦树) r; in col. 94: *Kalopanax septemlobus* (刺楸) r; in col. 99: *Sambucus williamsii* (接骨木) r; in col. 101: *Quercus spinosa* (刺叶栎) a; in col. 102: *Padus brachypoda* (短梗稠李) r; in col. 103: *Sambucus williamsii* (接骨木) a; in col. 104: *Celastrus orbiculatus* (南蛇藤) r, *Crataegus kansuensis* (甘肃山楂) r; in col. 106: *Padus brachypoda* (短梗稠李) r; in col. 110: *Kalopanax septemlobus* (刺楸) r, *Morus australis* (鸡桑) +; in col. 111: *Cerasus tomentosa* (毛樱桃) r; in col. 116: *Picrasma quassioides* (苦树) +; in col. 119: *Acer ceriferum* (杈叶枫) r, *Celtis bungeana* (黑弹树) r; in col. 120: *Fraxinus bungeana* (小叶梣) r, *Rhamnus leptophylla* (薄叶鼠李) r, *Sabia campanulata* subsp. *ritchieae* (鄂西清风藤) +.

In shrub layer (56 species): in col. 1: *Rubus pungens* (针刺悬钩子) r, *Ampelopsis glandulosa* var. *brevipedunculata* (东北蛇葡萄) r, *Pinus tabuliformis* (油松) +; in col. 3: *Armeniaca vulgaris* var. *vulgaris* (杏(原变种)) r, *Rhododendron micranthum* (照山白) r; in col. 5: *Ulmus bergmanniana* (兴山

榆) +; in col. 6: *Quercus spinosa* (刺叶栎) r, *Spiraea blumei* (绣球绣线菊) +; in col. 7: *Rubus pungens* (针刺悬钩子) 1; in col. 8: *Smilax scobinicaulis* (短梗菝葜) +; in col. 9: *Piptanthus nepalensis* (黄花木) r; in col. 10: *Ampelopsis glandulosa* var. *brevipedunculata* (东北蛇葡萄) r, *Cotoneaster horizontalis* (平枝栒子) r; in col. 13: *Celastrus angulatus* (苦皮藤) r; in col. 15: *Eupatorium chinense* (多须公) r; in col. 16: *Ampelopsis glandulosa* var. *brevipedunculata* (东北蛇葡萄) r, *Viscum coloratum* (槲寄生) r, *Anemone tomentosa* (大火草) r; in col. 17: *Catalpa fargesii* (灰楸) r; in col. 19: *Viscum coloratum* (槲寄生) r, *Artemisia gmelinii* (细裂叶莲蒿) 1, *Pteridium aquilinum* var. *latiusculum* (蕨) +; in col. 21: *Spiraea blumei* (绣球绣线菊) +, *Euonymus frigidus* (冷地卫矛) 1, *Rhododendron micranthum* (照山白) r; in col. 23: *Picrasma quassioides* (苦树) +, *Armeniaca vulgaris* var. *vulgaris* (杏(原变种)) r; in col. 26: *Celastrus angulatus* (苦皮藤) r; *Vitis piasezkii* (变叶葡萄) r; in col. 31: *Cotoneaster divaricatus* (散生栒子) 1, *Vitis heyneana* subsp. *heyneana* (毛葡萄(原亚种)) +; in col. 32: *Salix caprea* (黄花柳) r; in col. 35: *Salix caprea* (黄花柳) +; *Vitis piasezkii* (变叶葡萄) r, *Salix matsudana* (旱柳) +, *Tilia oliveri* (鄂椴) r; in col. 38: *Salix wallichiana* (皂柳) +; in col. 39: *Sorbus tsinlingensis* (秦岭花楸) r; in col. 42: *Actinidia kolomikta* (狗枣猕猴桃) +; in col. 44: *Spiraea blumei* (绣球绣线菊) +; in col. 45: *Sorbus tsinlingensis* (秦岭花楸) r; in col. 46: *Picrasma quassioides* (苦树) 1, *Zanthoxylum schinifolium* (青花椒) r, *Rubus mesogaeus* (喜阴悬钩子) 1; in col. 48: *Celastrus angulatus* (苦皮藤) +; in col. 49: *Quercus spinosa* (刺叶栎) r; in col. 50: *Rhamnus utilis* (冻绿) r, *Rubus pungens* (针刺悬钩子) r; in col. 51: *Ribes moupinense* (宝兴茶藨子) r, *Cotoneaster horizontalis* (平枝栒子) +; in col. 52: *Salix caprea* (黄花柳) a; in col. 53: *Catalpa fargesii* (灰楸) r, *Acer davidii* subsp. *grosseri* (葛罗枫) r; in col. 56: *Tilia henryana* var. *henryana* (毛糯米椴(原变种)) 1, *Clematoclethra scandens* subsp. *actinidioides* (猕猴桃藤山柳) b, *Actinidia polygama* (葛枣猕猴桃) +; in col. 57: *Clematoclethra scandens* subsp. *actinidioides* (猕猴桃藤山柳) *+, Hydrangea xanthoneura* (挂苦绣球) r; in col. 60: *Tilia henryana* var. *henryana* (毛糯米椴(原变种)) +; in col. 61: *Betula albosinensis* (红桦) +; in col. 65: *Actinidia kolomikta* (狗枣猕猴桃) +, *Euonymus frigidus* (冷地卫矛) 1, *Clematis peterae* (钝萼铁线莲) 1, *Viburnum schensianum* (陕西荚蒾) 1; in col. 66: *Clematoclethra scandens* subsp. *actinidioides* (猕猴桃藤山柳) r; in col. 68: *Philadelphus pekinensis* (太平花) +; in col. 69: *Sorbus tsinlingensis* (秦岭花楸) +; in col. 70: *Tilia henryana* var. *henryana* (毛糯米椴(原变种)) +; in col. 71: *Lonicera hispida* (刚毛忍冬) +; in col. 72: *Philadelphus pekinensis* (太平花) +; in col. 80: *Lonicera fargesii* (粘毛忍冬) +; in col. 84: *Hydrangea robusta* (粗枝绣球) +, *Sinofranchetia chinensis* (串果藤) r; in col. 87: *Hydrangea xanthoneura* (挂苦绣球) a; in col. 88: *Actinidia polygama* (葛枣猕猴桃) +, *Zanthoxylum schinifolium* (青花椒) r; in col. 89: *Cladrastis delavayi* (小花香槐) +; in col. 90: *Clematoclethra scandens* subsp. *actinidioides* (猕猴桃藤山柳) +, *Ribes moupinense* (宝兴茶藨子) a; in col. 92: *Rubus pungens* (针刺悬钩子) +; in col. 93: *Quercus spinosa* (刺叶栎) r; in col. 95: *Catalpa fargesii* (灰楸) r; in col. 96: *Rhamnus utilis* (冻绿) +, *Padus brachypoda* (短梗稠李) r, *Spiraea longigemmis* (长芽绣线菊) a; in col. 97: *Tilia henryana* var. *henryana* (毛糯米椴(原变种)) +; in col. 100: *Celastrus angulatus* (苦皮藤) r, *Rhamnus utilis* (冻绿) +, *Actinidia polygama* (葛枣猕猴桃) +, *Berchemia sinica* (勾儿茶) +; in col. 101: *Acer ceriferum* (杈叶枫) r, *Acer davidii* subsp. *grosseri* (葛罗枫) r; in col. 103: *Lonicera fargesii* (粘毛忍冬) +; in col. 104: *Cotoneaster multiflorus* (水栒子) +, *Euonymus schensianus* (陕西卫矛) r, *Pyrus betulifolia* (杜梨) r; in col. 108: *Fraxinus bungeana* (小叶梣) +, *Cotoneaster multiflorus* (水栒子) +; in col. 110: *Fraxinus bungeana* (小叶梣) r; in col. 112: *Fraxinus bungeana* (小叶梣) +; in col. 114: *Quercus spinosa* (刺叶栎) r; in col. 115: *Fraxinus bungeana* (小叶梣) +, *Cotoneaster multiflorus* (水栒子) +; in col. 116: *Padus brachypoda* (短梗稠李) r, *Picrasma quassioides* (苦树) +, *Ribes moupinense* (宝兴茶藨子) r, *Ulmus bergmanniana* (兴山榆) r, *Acer ceriferum* (杈叶枫) +, *Euonymus schensianus* (陕西卫矛) +; in col. 117: *Padus brachypoda* (短梗稠李) r, *Cephalotaxus sinensis* (粗榧) +; in col. 118:

Rhamnus utilis (冻绿) r; in col. 119: *Padus brachypoda* (短梗稠李) r, *Picrasma quassioides* (苦树) +, *Cephalotaxus sinensis* (粗榧) +, *Ulmus bergmanniana* (兴山榆) +, *Acer ceriferum* (杈叶枫) r; in col. 120: *Cephalotaxus sinensis* (粗榧) r.

In herb layer (211 species): in col. 1: *Lilium pumilum* (山丹) r, *Cotoneaster adpressus* (匍匐栒子) +; in col. 2: *Hypericum perforatum* (贯叶连翘) r, *Lactuca triangulata* (翼柄翅果菊) +, *Lespedeza tomentosa* (绒毛胡枝子) 1, *Patrinia heterophylla* (墓头回) 1, *Potentilla centigrana* (蛇莓委陵菜) 2m, *Elymus pendulinus* subsp. *multiculmis* (多秆缘毛草) 2m, *Ophioglossum reticulatum* (心脏叶瓶尔小草) 1, *Origanum vulgare* (牛至) 1, *Gentiana macrophylla* (秦艽) +; in col. 3: *Dipelta floribunda* (双盾木) 2m, *Drynaria sinica* (华槲蕨) 2a, *Paeonia suffruticosa* var. *papaveracea* (紫斑牡丹) r, *Smilax scobinicaulis* (短梗菝葜) r, *Lespedeza tomentosa* (绒毛胡枝子) 1, *Patrinia heterophylla* (墓头回) r, *Poa nemoralis* (林地早熟禾) 1, *Tilia paucicostata* var. *dictyoneura* (红皮椴) +, *Zabelia dielsii* (南方六道木) +, *Lilium pumilum* (山丹) +, *Rubia alata* (金剑草) r; in col. 4: *Patrinia heterophylla* (墓头回) r, *Artemisia japonica* (牡蒿) +; in col. 6: *Cotoneaster zabelii* (西北栒子) 2m, *Drynaria sinica* (华槲蕨) +, *Lespedeza tomentosa* (绒毛胡枝子) 2m, *Tilia paucicostata* var. *dictyoneura* (红皮椴) +, *Elymus nutans* (三颖披碱草) +, *Vicia sinogigantea* (大野豌豆) +, *Silene fortunei* (鹤草) +; in col. 7: *Lilium brownii* (野百合) r, *Paederia foetida* (鸡矢藤) +; in col. 8: *Bolbostemma paniculatum* (假贝母) r; in col. 9: *Paeonia suffruticosa* var. *papaveracea* (紫斑牡丹) +; in col. 10: *Lilium leucanthum* (宜昌百合) +; in col. 11: *Vicia sinogigantea* (大野豌豆) +, *Epipactis mairei* (大叶火烧兰) r, *Libanotis buchtormensis* (岩风) +, *Scutellaria baicalensis* (黄芩) 1; in col. 12: *Cotoneaster zabelii* (西北栒子) +; in col. 13: *Dipelta floribunda* (双盾木) +; in col. 14: *Drynaria sinica* (华槲蕨) r; in col. 15: *Eupatorium chinense* (多须公) +, *Fallopia convolvulus* (蔓首乌) r; in col. 16: *Bolbostemma paniculatum* (假贝母) +, *Elymus pendulinus* subsp. *multiculmis* (多秆缘毛草) +, *Euonymus phellomanus* (栓翅卫矛); in col. 18: *Dipelta floribunda* (双盾木) r, *Lilium brownii* (野百合) r, *Euonymus phellomanus* (栓翅卫矛) +; in col. 19: *Lithospermum zollingeri* (梓木草) r, *Rubia alata* (金剑草) r; in col. 20: *Cotinus coggygria* (黄栌) +; in col. 21: *Spiraea trilobata* (三裂绣线菊) 1; in col. 22: *Smilax scobinicaulis* (短梗菝葜) +, *Ligularia fischeri* (蹄叶橐吾); in col. 23: *Aralia chinensis* (楤木) +, *Smilax scobinicaulis* (短梗菝葜) +, *Lactuca triangulata* (翼柄翅果菊) +, *Parasenecio pilgerianus* (太白蟹甲草) +, *Pilea japonica* (山冷水花) 2a, *Polygonum hydropiper* (辣蓼) 2m, *Asplenium sarelii* (华中铁角蕨) r, *Anthriscus sylvestris* (峨参) r, *Epilobium hirsutum* (柳叶菜) r, *Mimulus szechuanensis* (四川沟酸浆) 2m; in col. 24: *Aralia chinensis* (楤木) +, *Parasenecio pilgerianus* (太白蟹甲草) +; in col. 25: *Vitis piasezkii* (变叶葡萄) +; in col. 26: *Cotoneaster zabelii* (西北栒子) +, *Elymus nutans* (三颖披碱草) 1, *Rosa brunonii* (复伞房蔷薇) +; in col. 27: *Poa acroleuca* (白顶早熟禾) *+, Angelica decursiva* (紫花前胡) +, *Cornopteris crenulatoserrulata* (细齿角蕨) r; in col. 28: *Cotoneaster zabelii* (西北栒子) 2m, *Astragalus mongholicus* (蒙古黄耆) +; in col. 30: *Paeonia suffruticosa* var. *papaveracea* (紫斑牡丹) +, *Vitis piasezkii* (变叶葡萄) +, *Bromus remotiflorus* (疏花雀麦) +; in col. 31: *Cotoneaster divaricatus* (散生栒子) +; in col. 32: *Lactuca sibirica* (山莴苣) +, *Artemisia japonica* (牡蒿) +, *Lespedeza cuneata* (截叶铁扫帚) 1; in col. 33: *Clinopodium urticifolium* (麻叶风轮菜) +, *Ligularia hodgsonii* (鹿蹄橐吾) 2a; in col. 35: *Paeonia suffruticosa* var. *papaveracea* (紫斑牡丹) +, *Tilia paucicostata* var. *dictyoneura* (红皮椴) +, *Galium bungei* (四叶律) r, *Lactuca raddeana* (毛脉翅果菊) +, *Ampelopsis humulifolia* (葎叶蛇葡萄) r, *Iris tectorum* (鸢尾) r; in col. 36: *Pyrola rotundifolia* (圆叶鹿蹄草) r; in col. 37: *Aralia chinensis* (楤木) +; in col. 38: *Betula platyphylla* (白桦) 1, *Cornus macrophylla* var. *macrophylla* (梾木(原变种)) 2m, *Lathyrus pratensis* (牧地山黧豆) +; in col. 41: *Origanum vulgare* (牛至) r; in col. 42: *Actinidia kolomikta* (狗枣猕猴桃) 1; in col. 43: *Codonopsis pilosula* (党参) +, *Armeniaca vulgaris* var. *vulgaris*

(杏(原变种)) r; in col. 45: *Lonicera chrysantha* (金花忍冬) +; in col. 46: *Berchemia flavescens* (黄背勾儿茶) +, *Bolbostemma paniculatum* (假贝母) r, Myosoton aquaticum (鹅肠菜) 2m, Pilea japonica (山冷水花) 2m, *Cardamine impatiens* (弹裂碎米荠) 1, *Chenopodium glaucum* (灰绿藜) 1, *Salvia umbratica* (荫生鼠尾草) r, *Saussurea populifolia* (杨叶风毛菊) +, *Viburnum schensianum* (陕西荚蒾) *+, Zanthoxylum schinifolium* (青花椒) +; in col. 47: *Actinidia polygama* (葛枣猕猴桃) +, *Lilium brownii* (野百合) r; in col. 48: *Sinosenecio oldhamianus* (蒲儿根) r; in col. 49: *Padus brachypoda* (短梗稠李) r; in col. 52: *Aralia chinensis* (楤木) 1, *Hypericum perforatum* (贯叶连翘) +, *Lathyrus pratensis* (牧地山黧豆) r, *Medicago minima* (小苜蓿) 1, *Plantago depressa* (平车前) 2a, *Codonopsis pilosula* (党参) +, *Halenia elliptica* (椭圆叶花锚) 2m, *Ophioglossum reticulatum* (心脏叶瓶尔小草) +, *Pedicularis resupinata* (返顾马先蒿) +, *Achillea alpina* (高山蓍) r, *Farfugium japonicum* (大吴风草) +, *Melilotus officinalis* (草木犀) r, *Prunella vulgaris* (夏枯草) +, *Sedum planifolium* (平叶景天) r, *Veronicastrum sibiricum* (草本威灵仙) +; in col. 53: *Vitis piasezkii* (变叶葡萄) r, *Veratrum nigrum* (藜芦) r; in col. 54: *Padus brachypoda* (短梗稠李) r; in col. 55: *Clinopodium urticifolium* (麻叶风轮菜) r, *Lonicera chrysantha* (金花忍冬) +, *Parasenecio pilgerianus* (太白蟹甲草) 1, *Sanicula giraldii* (首阳变豆菜) +, *Heracleum moellendorffii* (短毛独活) r, *Lilium leucanthum* (宜昌百合) +, *Stellaria* sp. (繁缕属) 1; in col. 56: *Hypericum perforatum* (贯叶连翘) +, *Ribes moupinense* (宝兴茶藨子) r, *Caryopteris divaricata* (莸) +; in col. 57: *Parthenocissus tricuspidata* (地锦) 2a, *Zabelia dielsii* (南方六道木) +, *Actinidia kolomikta* (狗枣猕猴桃) +, *Asarum himalaicum* (苕叶细辛) 1, *Stipa przewalskyi* (甘青针茅) +, *Asplenium pekinense* (北京铁角蕨) r, *Chloranthus japonicus* (银线草) 2b, *Cynoglossum amabile* (倒提壶) r, *Isodon japonicus var. glaucocalyx* (蓝萼变种) 1, *Lindernia nummulariifolia* (宽叶母草) r, *Pternopetalum asplenioides* (线叶囊瓣芹) +, *Pternopetalum vulgare* (五匹青) +, *Rodgersia aesculifolia* (七叶鬼灯檠) r; in col. 58: *Euptelea pleiosperma* (领春木) +, *Pyrrosia petiolosa* (有柄石韦) +; in col. 59: *Rosa helenae* (卵果蔷薇) +; in col. 60: *Neottia acuminata* (尖唇鸟巢兰) r; in col. 61: *Betula platyphylla* (白桦) +, *Poa annua* (早熟禾) 2a, *Stachyurus chinensis* (中国旌节花) r, *Anemone rivularis* (草玉梅) r, *Lactuca triangulata* (翼柄翅果菊) 1; in col. 62: *Betula platyphylla* (白桦) +, *Hypericum perforatum* (贯叶连翘) 1; in col. 63: *Poa annua* (早熟禾) 2b, *Anemone rivularis* (草玉梅) 2a, *Lathyrus pratensis* (牧地山黧豆) +, *Medicago minima* (小苜蓿) 1, *Plantago depressa* (平车前) 2a, *Potentilla centigrana* (蛇莓委陵菜) 2a, *Anemone flaccida* (鹅掌草) r, *Crepidiastrum sonchifolium* subsp. *sonchifolium* (尖裂假还阳参(原亚种)) r, *Lithospermum zollingeri* (梓木草) +, *Pedicularis resupinata* (返顾马先蒿) r, *Polygonum nepalense* (尼泊尔蓼) +, *Taraxacum mongolicum* (蒙古蒲公英) 2b, *Capsella bursa-pastoris* (荠) r, *Echinochloa crusgalli* (稗) r, *Potentilla chinensis* (委陵菜) r; in col. 64: *Poa annua* (早熟禾) 2a, *Stellaria vestita* var. *vestita* (箐姑草(原变种)) +, *Anemone rivularis* (草玉梅) 2a, *Medicago minima* (小苜蓿) 1, *Potentilla centigrana* (蛇莓委陵菜) 2m, *Artemisia argyi* (艾) r, *Polygonum nepalense* (尼泊尔蓼) 1, *Taraxacum mongolicum* (蒙古蒲公英) 1, *Elsholtzia ciliata* (香薷) +, *Gentianopsis paludosa* (湿生扁蕾) +, *Geum aleppicum* (路边青) +, *Salix spathulifolia* (匙叶柳) r*, Stachys sieboldii* (甘露子) +; in col. 65: *Disporum cantoniense* (万寿竹) r, *Rorippa indica* (焯菜) +; in col. 67: *Betula platyphylla* (白桦) +; in col. 68: *Poa annua* (早熟禾) 2b, *Ribes moupinense* (宝兴茶藨子) r, *Cornus macrophylla* var. *macrophylla* (梾木(原变种)) +, *Geranium dahuricum* (粗根老鹳草) +, *Carpesium triste* (暗花金挖耳) r, *Geranium platyanthum* (毛蕊老鹳草) 2a, *Silene tatarinowii* (石生蝇子草) r, *Viola chaerophylloides* (南山堇菜) +; in col. 69: *Maianthemum henryi* (管花鹿药) +, *Lonicera acuminata* (淡红忍冬) r; in col. 70: *Sinosenecio oldhamianus* (蒲儿根) r; in col. 71: *Stachyurus chinensis* (中国旌节花) +; in col. 72: *Cornus macrophylla* var. *macrophylla* (梾木(原变种)) +, *Carpinus cordata* (千金榆) 1, *Eleutherococcus wilsonii var. wilsonii* (狭叶五加(原变种)) +, *Euonymus frigidus* (冷地卫矛) r; in col. 73: *Lonicera chrysantha* (金花忍冬) r, *Euonymus maackii* (白

杜) +, *Hedera nepalensis* var. *sinensis* (常春藤) +; in col. 74: *Clinopodium urticifolium* (麻叶风轮菜) +, *Myosoton aquaticum* (鹅肠菜) +, *Poa acroleuca* (白顶早熟禾) +, *Galium bungei* (四叶律) +; *Hydrangea bretschneideri* (东陵绣球) +, *Lactuca raddeana* (毛脉翅果菊) r; in col. 76: *Berchemia flavescens* (黄背勾儿茶) r, *Berchemia flavescens* (首阳变豆菜) r, *Ligularia sagitta* (箭叶橐吾) r; in col. 77: *Actinidia polygama* (葛枣猕猴桃) r; in col. 82: *Berchemia flavescens* (黄背勾儿茶) +, *Ligularia fischeri* (蹄叶橐吾) r; in col. 83: *Erigeron annuus* (一年蓬) +, *Halenia elliptica* (椭圆叶花锚) r, *Saussurea japonica* (风毛菊) r; in col. 84: *Parthenocissus tricuspidata* (地锦) 1, *Euptelea pleiosperma* (领春木) r, *Hydrangea robusta* (粗枝绣球) 2a; in col. 85: *Sinosenecio oldhamianus* (蒲儿根) +, *Saussurea japonica* (风毛菊) r, *Ribes mandshuricum* (东北茶藨子) +, *Saxifraga stolonifera* (虎耳草) r; in col. 86: *Hydrangea bretschneideri* (东陵绣球) +, *Zabelia dielsii* (南方六道木) r; in col. 87: *Lonicera maackii* (金银忍冬) +, *Parthenocissus tricuspidata* (地锦) r, *Polystichum neolobatum* (新裂耳蕨) 2a; in col. 88: *Actinidia polygama* (葛枣猕猴桃) +, *Coniogramme sinensis* (紫柄凤丫蕨) 1, *Hydrangea bretschneideri* (东陵绣球) +, *Pilea mongolica* (透茎冷水花) +, *Asplenium sarelii* (华中铁角蕨) +, *Impatiens stenosepala* (窄萼凤仙花) r, *Aconitum scaposum* var. *hupehanum* (等叶花葶乌头) r; in col. 89: *Cephalotaxus sinensis* (粗榧) +, *Allium paepalanthoides* (天蒜) r, *Cladrastis delavayi* (小花香槐) 1; in col. 90: *Carex lehmannii* (膨囊薹草) 2a, *Neottia acuminata* (尖唇鸟巢兰) +, *Pyrola rotundifolia* (圆叶鹿蹄草) r; in col. 91: *Tricyrtis pilosa* (黄花油点草) r; in col. 92: *Lactuca sibirica* (山莴苣) r, *Actinidia arguta* (软枣猕猴桃) r, *Tilia henryana* var. *henryana* (毛糯米椴(原变种)) +; in col. 93: *Berberis* dasystachya (直穗小檗) r; in col. 94: *Hydrangea bretschneideri* (东陵绣球) 2b, *Ligularia przewalskii* (掌叶橐吾) 1, *Lonicera maackii* (金银忍冬) r, *Stachyurus chinensis* (中国旌节花) +, *Stellaria vestita* var. *vestita* (箐姑草(原变种)) +, *Osmorhiza aristata* (香根芹) 2m, *Forsythia giraldiana* (秦连翘) 2a; in col. 95: *Cardiocrinum giganteum* var. *yunnanense* (云南大百合) r, *Viburnum erubescens* (红荚蒾) +, *Glechoma biondiana* var. *glabrescens* (白透骨消(无毛变种)) +, *Maianthemum henryi* (管花鹿药) +, *Boehmeria spicata* (小赤麻) 2a, *Catalpa fargesii* (灰楸) +; in col. 96: *Carex lehmannii* (膨囊薹草) 2a, *Coniogramme sinensis* (紫柄凤丫蕨) r, *Leonurus pseudomacranthus* (錾菜) 2m, *Pilea japonica* (山冷水花) 2a, Cirsium leo (魁蓟) r, *Glechoma biondiana* var. *glabrescens* (白透骨消(无毛变种)) 2b, *Prinsepia utilis* (扁核木) +, *Smilax riparia* (牛尾菜) +, *Cayratia japonica* (乌蔹莓) r, *Clinopodium polycephalum* (灯笼草) 2m, *Loxocalyx urticifolius* (斜萼草) r; in col. 97: *Impatiens noli-tangere* (水金凤) +, *Impatiens stenosepala* (窄萼凤仙花) 2a, *Ampelopsis delavayana* var. *glabra* (掌裂蛇葡萄) +; in col. 98: *Polygonum hydropiper* (辣蓼) r, *Sanicula giraldii* (首阳变豆菜) r, *Aralia cordata* (食用土当归) r, *Cirsium leo* (魁蓟) +, *Geranium dahuricum* (粗根老鹳草) 2m, *Heracleum moellendorffii* (短毛独活) r, *Cheilanthes kuhnii* (华北粉背蕨) 1; in col. 99: *Carex lehmannii* (膨囊薹草) 2m, P*ilea mongolica* (透茎冷水花) +, *Stachyurus chinensis* (中国旌节花) r, *Polygonum hydropiper* (辣蓼) 1, *Anemone flaccida* (鹅掌草) 2m, *Veronica szechuanica* (四川婆婆纳) r; in col. 100: *Actinidia polygama* (葛枣猕猴桃) +, *Carex lehmannii* (膨囊薹草) 2b, *Sinosenecio oldhamianus* (蒲儿根) 1, *Leonurus pseudomacranthus* (錾菜) 1, *Plantago depressa* (平车前) 2m, *Poa acroleuca* (白顶早熟禾) 2a, *Adenocaulon himalaicum* (和尚菜) 1, *Crepidiastrum sonchifolium* subsp. *sonchifolium* (尖裂假还阳参(原亚种)) +, *Erigeron annuus* (一年蓬) +, *Dichocarpum fargesii* (纵肋人字果) +; in col. 101: *Drynaria sinica* (华槲蕨) +, *Lilium brownii* (野百合) r, *Leonurus pseudomacranthus* (錾菜) r, *Stipa przewalskyi* (甘青针茅) +, *Acer ceriferum* (杈叶枫) r, *Salvia tricuspis* (黄鼠狼花) r; in col. 102: *Viburnum erubescens* (红荚蒾) +; in col. 103: *Viburnum erubescens* (红荚蒾) r, *Disporum cantoniense* (万寿竹) +, *Sambucus williamsii* (接骨木) +; in col. 104: *Dipelta floribunda* (双盾木) r, *Ligularia przewalskii* (掌叶橐吾) +, *Osmorhiza aristata* (香根芹) 1; in col. 105: *Ligularia przewalskii* (掌叶橐吾) +, *Ribes moupinense* (宝兴茶藨子) 1, *Viburnum mongolicum* (蒙古荚蒾) +; in col. 106: *Berchemia sinica* (勾儿茶) r, *Galium hoffmeisteri* (六叶律) +, *Lactuca sibirica* (山莴苣) +, *Nasturtium officinale* (豆瓣菜) 2a, *Lysimachia barystachys* (虎尾草) +, *Veronica laxa* (疏花婆婆纳) +; in col. 107: *Lonicera maackii* (金银忍冬) r, *Impatiens noli-tangere* (水金凤) +, *Silene baccifera* (狗筋蔓) 2m, *Veratrum nigrum* (藜芦) r; in col. 108: *Viburnum mongolicum* (蒙古荚蒾) r, *Galium hoffmeisteri* (六叶律) +, *Rubus biflorus* (粉枝莓) +, *Fraxinus bungeana* (小叶梣) +; in col. 109: *Panax japonicus* var. *japonicus* (竹节参(原变种)) +; in col. 110: *Agrostis alba* (小糠草) r, *Berchemia sinica* (勾儿茶) r, *Nasturtium officinale* (豆瓣菜) 1, *Poa nemoralis* (林地早熟禾) +, *Rubus biflorus* (粉枝莓) 2a, *Silene baccifera* (狗筋蔓) 1, *Aralia cordata* (食用土当归) r, *Rhamnus leptophylla* (薄叶鼠李) r, *Viburnum farreri* (香荚蒾) +; in col. 111: *Cardiocrinum giganteum* var. *yunnanense* (云南大百合) r, *Pilea mongolica* (透茎冷水花) r, *Impatiens noli-tangere* (水金凤) +, *Adenocaulon himalaicum* (和尚菜) +, *Tricyrtis pilosa* (黄花油点草) 1; in col. 112: *Agrostis alba* (小糠草) +; in col. 113: *Agrostis alba* (小糠草) 1, *Galium hoffmeisteri* (六叶律) r, *Myosoton aquaticum* (鹅肠菜) +, *Nasturtium officinale* (豆瓣菜) 2b, *Osmorhiza aristata* (香根芹) +, *Poa nemoralis* (林地早熟禾) 1, *Smilax riparia* (牛尾菜) r, *Carpesium minus* (小花金挖耳) r, *Senecio argunensis* (额河千里光) 1; in col. 114: *Lonicera maackii* (金银忍冬) 1, *Stellaria vestita* var. *vestita* (箐姑草(原变种)) +, *Viburnum mongolicum* (蒙古荚蒾) r, *Panax japonicus* var. *japonicus* (竹节参(原变种)) +, *Fraxinus bungeana* (小叶梣) +, *Habenaria glaucifolia* (粉叶玉凤花) r, *Quercus spinosa* (刺叶栎) r; in col. 115: *Ligularia przewalskii* (掌叶橐吾) 2a, *Ribes moupinense* (宝兴茶藨子) +, *Viburnum mongolicum* (蒙古荚蒾) r, *Berchemia sinica* (勾儿茶) r, *Rubus biflorus* (粉枝莓) +, *Silene baccifera* (狗筋蔓) r, *Hylodesmum podocarpum* subsp. *oxyphyllum* (尖叶长柄山蚂蝗) +, *Liparis japonica* (羊耳蒜) r; in col. 116: *Agrostis alba* (小糠草) 1, *Cardiocrinum giganteum* var. *yunnanense* (云南大百合) r, *Coniogramme sinensis* (紫柄凤丫蕨) +, *Pilea mongolica* (透茎冷水花) 2a, *Cephalotaxus sinensis* (粗榧) r, *Asarum himalaicum* (苕叶细辛) 1, *Alangium chinense* (八角枫) r; in col. 117: *Cardiocrinum giganteum* var. *yunnanense* (云南大百合) r, *Cephalotaxus sinensis* (粗榧) +, *Panax japonicus* var. *japonicus* (竹节参(原变种)) r, *Prinsepia utilis* (扁核木) +; in col. 118: *Stellaria vestita* var. *vestita* (箐姑草(原变种)) 2b; in col. 119: *Coniogramme sinensis* (紫柄凤丫蕨) +, *Delphinium giraldii* (秦岭翠雀花) r; in col. 120: *Artemisia argyi* (艾) r, *Cimicifuga acerina* (小升麻) +.

Annex 2.3: List of Synonyms

For complette names (including authors) and Chinese names see “International Plant Name Index” (IPNI; www.ipni.org), “W3TROPICOS” of Missouri Botanical Garden (www.tropicos.org), “Flora of China” (www.efloras.org), and “Chinese Virtual Herbarium” (CVH; www.cvh.org.cn) as references.

Adopted mames	Nanes used in bibliographic sources	Adopted Chinese mames	Chinese Names used in bibliographic sources
Acer ceriferum	*Acer robustum*	**杈叶枫 cha ye feng**	杈叶槭 cha ye qi
Acer ginnala	*Acer tataricum subsp. ginnala*	**茶条槭 cha tiao qi**	茶条枫 cha tiao feng
Acer pictum subsp. mono	*Acer mono*	**五角枫 wu jiao feng**	色木槭 se mu qi
Acer stachyophyllum subsp. betulifolium	*Acer tetramerum var. betulifolium*	**四蕊枫 si rui feng**	桦叶四蕊槭 hua ye si rui qi
Adenophora paniculata	*Adenophora capillaria subsp. paniculata*	**细叶沙参 xi ye sha sen**	紫沙参 zi sha sen
Adonis davidii	*Adonis brevistyla*	**短柱侧金盏花 duan zhu ce jin zhan hua**	狭瓣侧金盏花 xia ban ce jin zhan hua, 宝兴侧金盏花 bao xing ce jin zhan hua
Ampelopsis glandulosa var. brevipedunculata	*Ampelopsis heterophylla var. brevipedunculata*	**东北蛇葡萄 dong bei she pu tao**	蛇葡萄 she pu tao
Amphicarpaea edgeworthii	*Amphicarpaea trisperma*	**两型豆 liang xing dou**	野扁豆 ye bian dou, 银豆 yin dou
Arisaema erubescens	*Arisaema consanguineum*	**一把伞南星 yi ba san nan xing**	天南星 tia nan xing
Artemisia gmelinii	*Artemisia sacrorum*	**细裂叶莲蒿 xi lie ye lian hao**	铁杆蒿 tie gan hao,白莲蒿 bai lian hao
Astragalus mongholicus	*Astragalus membranaceus*	**蒙古黄耆 meng gu huang qi**	黄耆 huang qi, 膜荚黄芪 mo jia huang qi
Athyrium brevisorum	*Athyrium niponicum*	**日本蹄盖蕨 ri ben ti gai jue**	华东蹄盖蕨 hua dong ti gai jue
Berberis dasystachya	*Berberis dolichobotrys*	**直穗小檗 zhi sui xiao bo**	长穗小檗 chang shi xiao bo
Berberis salicaria	*Berberis giraldii*	**柳叶小檗 liu ye xiao bo**	毛脉小檗 mao mai xiao bo
Berchemia flavescens	*Berchemia hypochrysa*	**黄背勾儿茶 huang bei gou er cha**	
Berchemia floribunda	*Berchemia giraldiana*	**多花勾儿茶 duo hua gou er cha**	纪氏勾儿茶 ji shi gou er cha
Betula albosinensis	*Betula albo-sinensis*	**红桦 hong hua**	
Buckleya henryi	*Buckleya lanceolate*	**米面蓊 mi mian weng**	
Cacalia ambigua	*Parasenecio ambiguus*	**两似蟹甲草 liang si xie jia cao**	两假蟹甲草 liang jia xie jia cao
Cacalia hastata	*Parasenecio hastatus*	**山尖子 shan jian zi**	
Cacalia tangutica	*Senecio tanguticus*	**羽裂蟹甲草 yu lie xie jia cao**	华蟹甲 hua xie jia
Carex lehmannii	*Carex lehmanii*	**膨囊薹草 peng nang tai cao**	膨囊苔草 peng nang tai cao
Carex rubrobrunnea var. taliensis	*Carex taliensis*	**大理薹草 da li tai cao**	大理苔草 da li tai cao
Carpinus turczaninowii	*Carpinus turczaninovii*	**鹅耳枥 e er li**	
Celastrus angulatus	*Celastrus angulata*	**苦皮藤 ku pi teng**	棱枝南蛇藤 ling zhi nan she teng

Adopted mames	Nanes used in bibliographic sources	Adopted Chinese mames	Chinese Names used in bibliographic sources
Chrysanthemum indicum	*Dendranthema indicum*	**野菊 ye ju**	野菊花 ye ju hua
Circaea canadensis subsp. quadrisulcata	*Circaea lutetiana subsp. quadrisulcata*	**水珠草 shui zhu cao**	露珠草 lu zhu cao
Cladrastis delavayi	*Cladrastis sinensis*	**小花香槐 xiao hua xiang huai**	黄山槐 huang shan huai
Clematoclethra scandens subsp. Actinidioides	*Clematoclethra lasioclada*	**猕猴桃藤山柳 mi hou tao teng shan liu**	藤山柳 teng shan liu, 铁线藤山柳 tie xian teng shan liu
Cornus controversa	*Bothrocaryum controversum*	**灯台树 deng tai shu**	
Cornus hemsleyi	*Swida hemsleyi*	**红椋子 hong liang zi**	
Cornus macrophylla	*Swida macrophylla*	**梾木 lai mu**	大叶梾木 da ye lai mu
Corydalis turtschaninovii	*Corydalis remota*	**齿瓣延胡索 chi ban yan hu suo**	山延胡索 shan yan hu suo
Dryopteris bissetiana	*Dryopteris setosa*	**两色鳞毛蕨 liang se lin mao jue**	
Dryopteris goeringiana	*Dryopteris laeta*	**华北鳞毛蕨 hua bei lin mao jue**	
Duchesnea indica	*Fragaria indica*	**蛇莓 she mei**	
Eleutherococcus giraldii	*Acanthopanax giraldii*	**红毛五加 hong mao wu jia**	纪氏五加 ji shi wu jia
Eleutherococcus leucorrhizus var. setchuenensis	*Acanthopanax setchuenensis*	**蜀五加 shu wu jia**	
Elymus dahuricus	*Clinelymus dahuricus*	**披碱草 pi jian cao**	
Elymus kamoji var. kamoji	*Roegneria kamoji*	**柯孟披碱草 ke meng pi jian cao**	鹅观草 e guan cao
Elymus nutans	*Clinelymus nutans*	**三颖披碱草 san ying pi jian cao**	垂穗披碱草 chui sui pi jian cao
Euonymus frigidus	*Euonymus porphyreus*	**冷地卫矛 leng di wei mao**	紫花卫矛 zi hua wei mao
Euonymus hamiltonianus	*Euonymus hamiltonianus var. yedoensis*	**西南卫矛 xi nan wei mao**	桃叶卫矛 tao ye wei mao
Euptelea pleiosperma	*Euptelea pleiospermum*	**领春木 ling chun mu**	
Fargesia nitida	*Sinarundinaria nitida*	**华西箭竹 hua xi jian zhu**	箭竹 jian zhu
Fragaria orientalis	*Fragaria corymbosa*	**东方草莓 dong fang cao mei**	伞房草莓 san fang cao mei
Galium aparine	*Galium aparine var. echinospermum*	**拉拉藤 la la teng**	猪殃殃 zhu yang yang
Glechoma longituba	*Glechoma brevituba*	**活血丹 huo xue dan**	佛耳草 fo er xao,连钱草 lian xian cao
Juglans mandshurica	*Juglans cathayensis*	**胡桃楸 hu tao qiu**	野核桃 ye he tao, 山核桃 shan he tao
Laportea bulbifera	*Laportea terminalis*	**珠芽艾麻 zhu ya ai ma**	珠芽螫麻 zhu ya ao ma, 顶花螫麻 ding hua ao ma
Lindera obtusiloba	*Lindera cercidifolia*	**三桠乌药 san ya wu yao**	
Lindernia nummulariifolia	*Lindernia nummularifolia*	**宽叶母草 kuan ye mu cao**	
Lonicera fragrantissima var. fragrantissima	*Lonicera fragrantissima subsp. fragrantissima*	**郁香忍冬 yu xiang ren dong**	羊奶子 yang nai zi

Adopted mames	Nanes used in bibliographic sources	Adopted Chinese mames	Chinese Names used in bibliographic sources
Maianthemum henryi	*Smilacina henryi*	**管花鹿药 guan hua lu yao**	
Maianthemum japonicum	*Smilacina japonica*	**鹿药 lu yao**	
Notopterygium franchetii	*Notopterygium forbesii*	**宽叶羌活 kuan ye qiang huo**	
Ostryopsis davidiana	*Corylus davidiana*	**虎榛子 hu zhen zi**	
Oxalis griffithii	*Oxalis acetosella subsp. griffithii*	**山酢浆草 shan cu jiang cao**	
Paederia foetida	*Paederia scandens, Paederia chinensis*	**鸡矢藤 ji shi teng**	
Paeonia suffruticosa var. papaveracea	*Paeonia papaveracea*	**紫斑牡丹 zi ban mu dan**	
Phryma leptostachya subsp. asiatica	*Phryma leptostachya*	**透骨草 tou gu cao**	
Pilea japonica	*Achudemia japonica*	**山冷水花 shan leng shui hua**	
Pilea mongolica	*Achudemia mongolica*	**透茎冷水花 tou jing leng shui hua**	蒙古冷水花 meng gu leng shui hua
Pinus tabuliformis	*Pinus tabulaeformis*	**油松 you song**	
Quercus mongolica*	*Quercus liaotungensis, Quercus wutaishanica*	**蒙古栎 meng gu li**	辽东栎 lao dong li
Ranunculus grandis	*Ranunculus japonicus*	**毛茛 mao gen**	
Rubia alata	*Rubia lanceolata*	**金剑草 jin jian cao**	披针叶茜草 pi zhen ye qian cao, 锯锯藤 ju ju teng
Sabia campanulata subsp. ritchieae	*Sabia ritchieae*	**鄂西清风藤 e xi qing feng teng**	清风藤 qing feng teng
Sinosenecio oldhamianus	*Senecio oldhamianus*	**蒲儿根 pu er gen**	
Stellaria vestita var. vestita	*Stellaria saxatilis*	**箐姑草 qing gu cao**	石生繁缕 shi sheng fan lü
Tetradium daniellii	*Euodia daniellii*	**臭檀吴萸 chou tan wu yu**	辣子树 la zi shu,白山槐 bai shan huai
Tilia paucicostata var. dictyoneura	*Tilia dictyoneura*	**红皮椴 hong pi duan**	网脉椴 wang mai duan
Ulmus davidiana var. japonica	*Ulmus propinqua*	**春榆 chun yu**	山榆 shan yu
Viburnum betulifolium	*Viburnum lobophyllum*	**桦叶荚蒾 hua ye jia mi**	阔叶荚蒾 kuo ye jia mi
Viburnum erubescens	*Viburnum erubescens var. gracilipes*	**红荚蒾 hong jia mi**	细梗红荚蒾 xi geng hong jia mi
Viola philippica var. philippica	*Viola yedoensis*	**紫花地丁 zi hua di ding**	
Vitis heyneana subsp. heyneana	*Vitis quinquangularis*	**毛葡萄 mao pu tao**	野生毛葡萄 ye shen mao pu tao
Vitis piasezkii	*Vitis piasezkii var. pagnuccii*	**变叶葡萄 bian ye pu tao**	少毛变叶葡萄 shao mao bian ye pu tao, 少毛复叶葡萄 shao mao fu ye pu tap

***** Often in literaturs ***Quercus liaotungensis*** (syn. *Quercus wutaishanica*) and ***Quercus mongolica*** are two different species, e.g. in Chinese Virtual Herbarium (http://www.cvh.org.cn). Moreover in the book Chinese vegetation (1980), there are ***Quercus liaotungensis*** **formation** and ***Quercus mongolica*** **formation**, and in each formation both species can be found, one was the dominant species, the other one companion species.

Annex 2.4: The statistics of number of genera and species (and subspecies) of different families in the flora (120relevés)

Family	Family Chinese	Genus	Genus Chinese	No. of speciesin genus	No. of species in family	No. of genera in family
91	**91**	**267**	**267**	**448**	**448**	**267**
Rosaceae	**蔷薇科**	Cotoneaster	栒子属	6	**42**	**22**
		Rubus	悬钩子属	4		
		Spiraea	绣线菊属	4		
		Rosa	蔷薇属	3		
		Sorbus	花楸属	3		
		Cerasus	樱属	2		
		Crataegus	山楂属	2		
		Malus	苹果属	2		
		Potentilla	委陵菜属	2		
		Pyrus	梨属	2		
		Agrimonia	龙芽草属	1		
		Amelanchier	唐棣属	1		
		Armeniaca	杏属	1		
		Duchesnea	蛇莓属	1		
		Fragaria	草莓属	1		
		Geum	路边青属	1		
		Kerria	棣棠花属	1		
		Neillia	绣线梅属	1		
		Padus	稠李属	1		
		Prinsepia	扁核木属	1		
		Prunus	李属	1		
		Sorbaria	珍珠梅属	1		
Asteraceae	**菊科**	Artemisia	蒿属	5	**40**	**22**
		Carpesium	天名精属	5		
		Ligularia	橐吾属	4		
		Parasenecio	蟹甲草属	4		
		Lactuca	莴苣属	3		
		Saussurea	风毛菊属	3		
		Achillea	蓍属	1		
		Adenocaulon	和尚菜属	1		
		Anaphalis	香青属	1		
		Aster	紫菀属	1		
		Chrysanthemum	菊属	1		
		Cirsium	蓟属	1		
		Crepidiastrum	假还阳参属	1		
		Erigeron	飞蓬属	1		
		Eupatorium	泽兰属	1		
		Farfugium	大吴风草属	1		
		Kalimeris	马兰属	1		
		Prenanthes	福王草属	1		
		Senecio	千里光属	1		
		Sinacalia	华蟹甲属	1		
		Sinosenecio	蒲儿根属	1		

		Taraxacum	蒲公英属	1		
		Polygonatum	黄精属	4		
		Smilax	菝葜属	4		
		Lilium	百合属	3		
		Allium	葱属	2		
		Disporum	万寿竹属	2		
Liliaceae	**百合科**	Maianthemum	舞鹤草属	2	**22**	**11**
		Asparagus	天门冬属	1		
		Cardiocrinum	大百合属	1		
		Paris	重楼属	1		
		Tricyrtis	油点草属	1		
		Veratrum	藜芦属	1		
		Anemone	银莲花属	4		
		Aconitum	乌头属	3		
		Cimicifuga	升麻属	2		
		Ranunculus	毛茛属	2		
		Actaea	类叶升麻属	1		
		Adonis	侧金盏花属	1		
Ranunculaceae	**毛茛科**	Clematis	铁线莲属	1	**19**	**12**
		Delphinium	翠雀属	1		
		Dichocarpum	人字果属	1		
		Helleborus	铁筷子属	1		
		Thalictrum	唐松草属	1		
		Trollius	金莲花属	1		
		Clinopodium	风轮菜属	3		
		Glechoma	活血丹属	2		
		Salvia	鼠尾草属	2		
		Ajuga	筋骨草属	1		
		Elsholtzia	香薷属	1		
		Isodon	香茶菜属	1		
		Lamium	野芝麻属	1		
Lamiaceae	**唇形科**	Leonurus	益母草属	1	18	**14**
		Loxocalyx	斜萼草属	1		
		Origanum	牛至属	1		
		Phlomis	糙苏属	1		
		Prunella	夏枯草属	1		
		Scutellaria	黄芩属	1		
		Stachys	水苏属	1		
		Pimpinella	茴芹属	2		
		Pternopetalum	囊瓣芹属	2		
		Sanicula	变豆菜属	2		
		Angelica	当归属	1		
		Anthriscus	峨参属	1		
Apiaceae	**伞形科**	Bupleurum	柴胡属	1	**16**	**13**
		Cryptotaenia	鸭儿芹属	1		
		Heracleum	独活属	1		
		Libanotis	岩风属	1		
		Notopterygium	羌活属	1		
		Osmorhiza	香根芹属	1		

		Peucedanum	前胡属	1		
		Torilis	窃衣属	1		
		Lespedeza	胡枝子属	3		
		Vicia	野豌豆属	3		
		Lathyrus	山黧豆属	2		
		Amphicarpaea	两型豆属	1		
		Astragalus	黄耆属	1		
Fabaceae	**豆科**	Cladrastis	香槐属	1	**16**	**11**
		Hylodesmum	长柄山蚂蝗属	1		
		Indigofera	木蓝属	1		
		Medicago	苜蓿属	1		
		Melilotus	草木犀属	1		
		Piptanthus	黄花木属	1		
		Elymus	披碱草属	4		
		Poa	早熟禾属	3		
		Agrostis	剪股颖属	2		
		Bromus	雀麦属	1		
Poaceae	**禾本科**	Echinochloa	稗属	1	**15**	**9**
		Fargesia	箭竹属	1		
		Melica	臭草属	1		
		Miscanthus	芒属	1		
		Stipa	针茅属	1		
		Lonicera	忍冬属	10		
		Dipelta	双盾木属	1		
Caprifoliaceae	**忍冬科**	Dipsacus	川续断属	1	**14**	**5**
		Patrinia	败酱属	1		
		Triosteum	莛子藨属	1		
		Stellaria	繁缕属	6		
Caryophyllaceae	**石竹科**	Silene	蝇子草属	3	**10**	**3**
		Myosoton	鹅肠菜属	1		
Celastraceae	**卫矛科**	Euonymus	卫矛属	7	**9**	**2**
		Celastrus	南蛇藤属	2		
		Eleutherococcus	五加属	3		
		Aralia	楤木属	2		
Araliaceae	**五加科**	Hedera	常春藤属	1	**8**	**5**
		Kalopanax	刺楸属	1		
		Panax	人参属	1		
Adoxaceae	**五福花科**	Viburnum	荚蒾属	7	**8**	**2**
		Sambucus	接骨木属	1		
		Betula	桦木属	2		
Betulaceae	**桦木科**	Carpinus	鹅耳枥属	2	**7**	**4**
		Corylus	榛属	2		
		Ostrya	铁木属	1		
		Ampelopsis	蛇葡萄属	3		
Vitaceae	葡萄科	Vitis	葡萄属	2	**7**	**4**
		Cayratia	乌蔹莓属	1		
		Parthenocissus	地锦属	1		
Rubiaceae	**茜草科**	Galium	拉拉藤属	3	**7**	**3**
		Rubia	茜草属	3		

		Paederia	鸡矢藤属	1		
Sapindaceae	**无患子科**	Acer	槭属	7	**7**	**1**
Orchidaceae	**兰科**	Epipactis	火烧兰属	2	**6**	**5**
		Habenaria	玉凤花属	1		
		Liparis	羊耳蒜属	1		
		Neottia	鸟巢兰属	1		
		Platanthera	舌唇兰属	1		
Rhamnaceae	**鼠李科**	Berchemia	勾儿茶属	3	**6**	**2**
		Rhamnus	鼠李属	3		
Salicaceae	**杨柳科**	Salix	柳属	4	**6**	**2**
		Populus	杨属	2		
Violaceae	**堇菜科**	Viola	堇菜属	6	**6**	**1**
Saxifragaceae	**虎耳草科**	Astilbe	落新妇属	1	**5**	**5**
		Chrysosplenium	金腰属	1		
		Rodgersia	鬼灯檠属	1		
		Saxifraga	虎耳草属	1		
		Tiarella	黄水枝属	1		
Brassicaceae	**十字花科**	Cardamine	碎米荠属	2	**5**	**4**
		Capsella	荠属	1		
		Nasturtium	豆瓣菜属	1		
		Rorippa	蔊菜属	1		
Cyperaceae	**莎草科**	Carex	薹草属	5	**5**	**1**
Hydrangeaceae	**绣球科**	Hydrangea	绣球属	3	**5**	**2**
		Philadelphus	山梅花属	2		
Oleaceae	**木犀科**	Fraxinus	梣属	3	**5**	**2**
		Forsythia	连翘属	2		
Urticaceae	**荨麻科**	Pilea	冷水花属	2	**5**	**4**
		Boehmeria	苎麻属	1		
		Laportea	艾麻属	1		
		Urtica	荨麻属	1		
Gentianaceae	**龙胆科**	Gentiana	龙胆属	1	**4**	**4**
		Gentianopsis	扁蕾属	1		
		Halenia	花锚属	1		
		Pterygocalyx	翼萼蔓属	1		
Actinidiaceae	**猕猴桃科**	Actinidia	猕猴桃属	3	**4**	**2**
		Clematoclethra	藤山柳属	1		
Berberidaceae	**小檗科**	Berberis	小檗属	2	**4**	**3**
		Caulophyllum	红毛七属	1		
		Epimedium	淫羊藿属	1		
Campanulaceae	**桔梗科**	Adenophora	沙参属	2	**4**	**3**
		Campanula	风铃草属	1		
		Codonopsis	党参属	1		
Cornaceae	**山茱萸科**	Cornus	山茱萸属	3	**4**	**2**
		Alangium	八角枫属	1		
Fagaceae	**壳斗科**	Quercus	栎属	4	**4**	**1**
Malvaceae	**锦葵科**	Tilia	椴树属	4	**4**	**1**
Plantaginaceae	**车前科**	Veronica	婆婆纳属	2	**4**	**3**
		Plantago	车前属	1		
		Veronicastrum	腹水草属	1		

Polygonaceae	**蓼科**	Polygonum	蓼属	3	**4**	**2**
		Fallopia	何首乌属	1		
Anacardiaceae	**漆树科**	Cotinus	黄栌属	1	**3**	**3**
		Rhus	盐肤木属	1		
		Toxicodendron	漆属	1		
Ericaceae	**杜鹃花科**	Chimaphila	喜冬草属	1	**3**	**3**
		Pyrola	鹿蹄草属	1		
		Rhododendron	杜鹃属	1		
Woodsiaceae	**岩蕨科**	Athyrium	蹄盖蕨属	1	**3**	**3**
		Cornopteris	角蕨属	1		
		Cystopteris	冷蕨属	1		
Onagraceae	**柳叶菜科**	Circaea	露珠草属	2	**3**	**2**
		Epilobium	柳叶菜属	1		
Papaveraceae	**罂粟科**	Corydalis	紫堇属	2	**3**	**2**
		Hylomecon	荷青花属	1		
Ulmaceae	**榆科**	Ulmus	榆属	2	**3**	**2**
		Zelkova	榉属	1		
Geraniaceae	**牻牛儿苗科**	Geranium	老鹳草属	3	**3**	**1**
Grossulariaceae	**茶藨子科**	Ribes	茶藨子属	3	**3**	**1**
Dryopteridaceae	**鳞毛蕨科**	Dryopteris	鳞毛蕨属	2	**3**	**2**
		Polystichum	耳蕨属	1		
Boraginaceae	**紫草科**	Cynoglossum	琉璃草属	1	**2**	**2**
		Lithospermum	紫草属	1		
Cucurbitaceae	**葫芦科**	Bolbostemma	假贝母属	1	**2**	**2**
		Thladiantha	赤瓟属	1		
Lardizabalaceae	**木通科**	Akebia	木通属	1	**2**	**2**
		Sinofranchetia	串果藤属	1		
Ophioglossaceae	**瓶尔小草科**	Botrychium	阴地蕨属	1	**2**	**2**
		Ophioglossum	瓶尔小草属	1		
Phrymaceae	**透骨草科**	Mimulus	沟酸浆属	1	**2**	**2**
		Phryma	透骨草属	1		
Polypodiaceae	**水龙骨科**	Drynaria	槲蕨属	1	**2**	**2**
		Pyrrosia	石韦属	1		
Pteridaceae	**凤尾蕨科**	Cheilanthes	碎米蕨属	1	**2**	**2**
		Coniogramme	凤丫蕨属	1		
Rutaceae	**芸香科**	Tetradium	四数花属	1	**2**	**2**
		Zanthoxylum	花椒属	1		
Sabiaceae	**清风藤科**	Meliosma	泡花树属	1	**2**	**2**
		Sabia	清风藤属	1		
Santalaceae	**檀香科**	Buckleya	米面蓊属	1	**2**	**2**
		Viscum	槲寄生属	1		
Apocynaceae	**夹竹桃科**	Cynanchum	鹅绒藤属	2	**2**	**1**
Araceae	**天南星科**	Arisaema	天南星属	2	**2**	**1**
Aspleniaceae	**铁角蕨科**	Asplenium	铁角蕨属	2	**2**	**1**
Balsaminaceae	**凤仙花科**	Impatiens	凤仙花属	2	**2**	**1**
Crassulaceae	**景天科**	Sedum	景天属	2	**2**	**1**
Lauraceae	**樟科**	Lindera	山胡椒属	2	**2**	**1**
Paeoniaceae	**芍药科**	Paeonia	芍药属	2	**2**	**1**
Pinaceae	**松科**	Pinus	松属	2	**2**	**1**

Primulaceae	**报春花科**	Lysimachia	珍珠菜属	2	**2**	**1**
Schisandraceae	**五味子科**	Schisandra	五味子属	2	**2**	**1**

The families were represented by only 1 genus and 1 species of shrubs: Amaranthaceae (苋科): Chenopodium (藜属); Aristolochiaceae (马兜铃科): Asarum (细辛属); Bignoniaceae (紫葳科) Catalpa (梓属); Cannabaceae (大麻科): Celtis (朴属); Cephalotaxaceae (三尖杉科): Cephalotaxus (三尖杉属); Chloranthaceae (金粟兰科): Chloranthus (金粟兰属); Dennstaedtiaceae (碗蕨科): Pteridium (蕨属); Dioscoreaceae (薯蓣科): Dioscorea (薯蓣属); Elaeagnaceae (胡颓子科): Elaeagnus (胡颓子属); Equisetaceae (木贼科): Equisetum (木贼属); Eupteleaceae (领春木科): Euptelea (领春木属); Helwingiaceae (青荚叶科): Helwingia (青荚叶属); Hypericaceae (金丝桃科): Hypericum (金丝桃属); Iridaceae (鸢尾科): Iris (鸢尾属); Juglandaceae (胡桃科): Juglans (胡桃属); Linderniaceae (母草科): Lindernia (母草属); Linnaeaceae (北极花科): Zabelia (六道木属); Moraceae (桑科): Morus (桑属); Onocleaceae (球子蕨科): Matteuccia (荚果蕨属); Orobanchaceae (列当科): Pedicularis (马先蒿属); Oxalidaceae (酢浆草科): Oxalis (酢浆草属); Simaroubaceae (苦木科): Picrasma (苦树属); Stachyuraceae (旌节花科): Stachyurus (旌节花属); Staphyleaceae (省沽油科): Staphylea (省沽油属); Thymelaeaceae (瑞香科): Daphne (瑞香属); Verbenaceae (马鞭草科): Caryopteris (莸属).

Annex 2.5: Life form and species richness

Life form variables (mean percentage) and mean of species richness (number of species per relevé) of 4 vegetation layers in relation to 7 communities (VuQa, VcQa, AcQm, VpQm, CrQa, OgJm, LbCc, abbrev. see Table 3.1 and Annex 2.1) of 120 relevés (Data of species ware present/absence). **P**: phanerophyte, **C**: chamaephyte, **H**: hemicryptophyte, **G**: geophyte, **T**: therophyte; **Ms**: Mesophanerophyte, **Mc**: Microphanerophyte, **N**: nanophanerophyte, **Ep**: epiphytic phanerophyte.

	Community Number of relevés	**VuQa** 19	**VcQa** 36	**AcQm** 15	**VpQm** 24	**CrQa** 12	**OgJm** 5	**LbCc** 9	**Total** **120**
Phanerophyte	**Ms** (%)	37.9	37.6	39.3	39.7	41.1	**52.4**	43.3	**36.4**
	Mc (%)	45.3	46.6	46.7	48.4	44.4	45.2	46.7	**47.7**
	N (%)	14.7	15.0	14.0	11.1	13.3	2.4	10.0	**14.8**
	Ep (%)	2.1	0.8	0.0	0.8	1.1	0.0	0.0	**1.1**
	No. of species	**95**	**133**	**107**	**126**	**90**	**42**	**90**	**176**
Life form	**P** (%)	**53.1**	48.5	46.9	52.7	48.1	48.8	45.0	**39.3**
	C (%)	5.0	2.2	1.3	0.8	2.1	0.0	1.5	**2.9**
	H (%)	26.8	**27.7**	25.4	21.8	22.5	17.4	25.0	**29.0**
	G (%)	14.0	16.8	21.5	20.9	22.5	**30.2**	22.5	**22.5**
	T (%)	1.1	4.7	4.8	3.8	4.8	3.5	6.0	**6.3**
	Total number of species	**179**	**274**	**228**	**239**	**187**	**86**	**200**	**448**
species richness	1st tree layer	2.4	4.1	4.5	6.0	5.7	4.2	4.7	4.5
	2nd tree layer	4.9	5.9	7.2	6.5	8.0	4.6	5.7	6.2
	Shrub layer	21.1	23.5	18.0	22.3	17.4	11.6	16.1	20.5
	Herb layer	32.8	38.2	34.9	37.0	44.7	22.8	35.1	36.5

Annex 2. 6: The Chi-Square test with SPSS

The Chi-Square test with SPSS showed, there were correlations between the 7 communities (VuQa, VcQa, AcQm, VpQm, CrQa, OgJm, LbCc, abbrev. see Table 3.1 and Annex 2.1, the number of relevés are in brackets) and the 5 relief classes. This was a dissimilarity matrix.

	Chi-square between Sets of Frequencies	
	Slope position Classes	Communities
Slope position Classes	0.000	7.343
Communities	7.343	0.000

7 Communities and 5 Slope Position Classes (number of relevés)

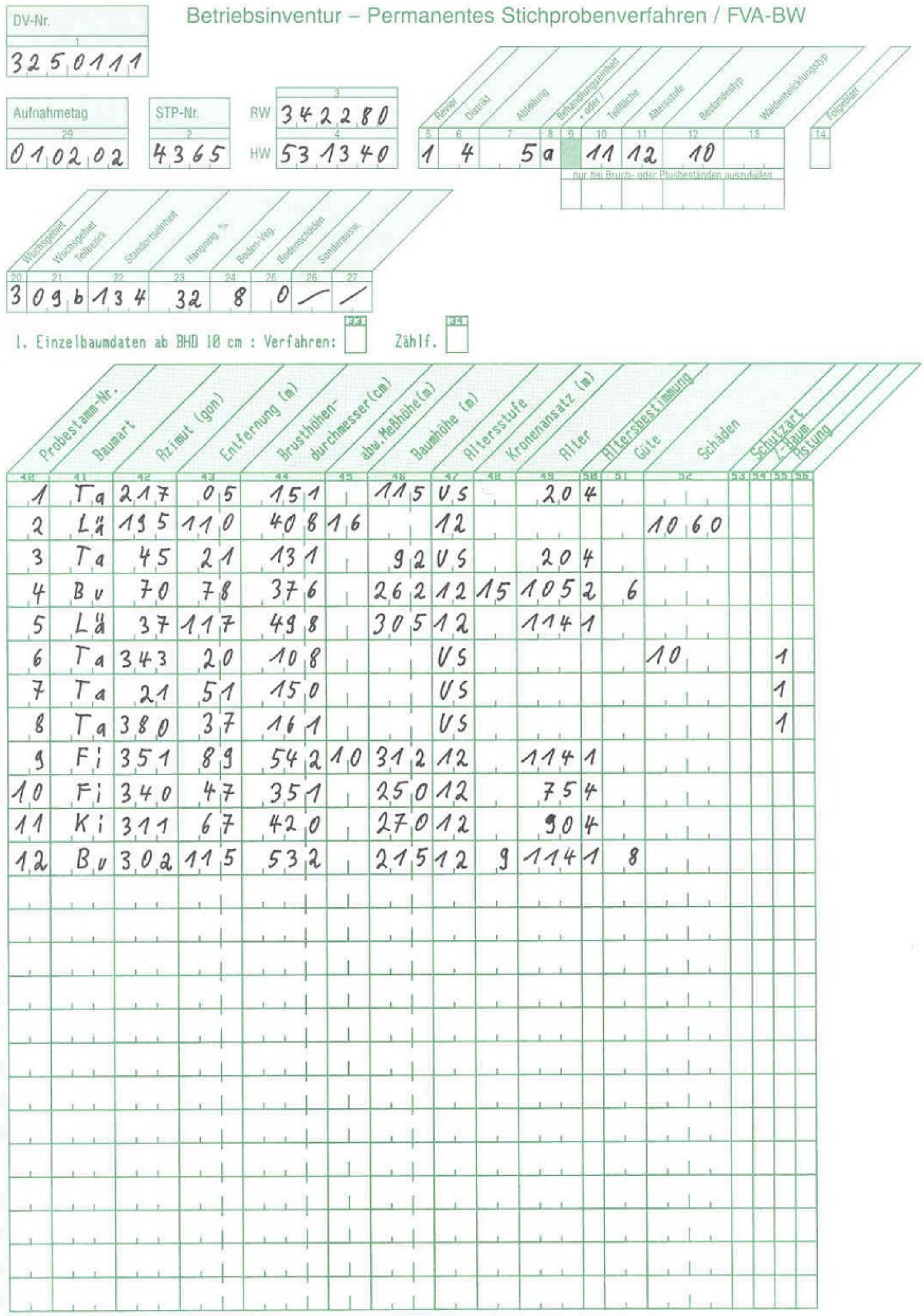
Community	Ridge	Upper slope	Mid Slope	Lower slope	Vallay	Tatal
VuQa (19)	4	4	5	6	0	19
VcQa (36)	5	15	7	6	3	36
AcQm (15)	7	5	2	1	0	15
VpQm (24)	2	7	7	6	2	24
CrQa (12)	0	0	0	1	11	12
OgJm (5)	0	0	0	0	5	5
LbCc (9)	0	1	1	3	4	9
Total (120)	18	32	22	23	25	120

7 Communities and 5 Slope Position Classes (frequency)

Community	Ridge	Upper slope	Mid Slope	Lower slope	Vallay	Tatal
VuQa (19)	21%	21%	26%	32%	0%	100%
VcQa (36)	14%	42%	19%	17%	8%	100%
AcQm (15)	47%	33%	13%	7%	0%	100%
VpQm (24	8%	29%	29%	25%	8%	100%
CrQa (12)	0%	0%	0%	8%	92%	100%
OgJm (5)	0%	0%	0%	0%	100%	100%
LbCc (9)	0%	11%	11%	33%	44%	100%

11.2 Appendix zu Kapitel 3

Annex 3.1. Field form for permanent forest inventory (English translation: MATTHIAS SEEBAUER)



Betriebsinventur – Permanentes Stichprobenverfahren / FVA-BW

DV-Nr. (1)	Aufnahmetag (29)	STP-Nr. (2)	RW (3)	HW (4)
3250111	010202	4365	342280	531340

Revier (5)	Distrikt (6)	Abteilung (7)	Behandlungseinheit (8)	+ oder / (9)	Teilfläche (10)	Altersstufe (11)	Bestandestyp (12)	Waldentwicklungstyp (13)	Folgeblatt (14)
1	4	5	a		11	12	10		

nur bei Bruch- oder Plusbeständen ausfüllen

Wuchsgebiet (20)	Wuchsgebiet Teilbezirk (21)	Standortseinheit (22)	Hangneig. % (23)	Boden-Veg. (24)	Bodenschäden (25)	Sonderausw. (26)	(27)
3	09b	134	32	8	0	/	/

1. Einzelbaumdaten ab BHD 10 cm : Verfahren: (33) Zählf. (34)

	Probestamm-Nr. (40)	Baumart (41)	Azimut (gon) (42)	Entfernung (m) (43)	Brusthöhendurchmesser (cm) (44)	abw. Meßhöhe (m) (45)	Baumhöhe (m) (46)	Altersstufe (47)	Kronenansatz (m) (48)	Alter (49)	Altersbestimmung (50)	Güte (51)	Schäden (52)	Schutzart (53)	Z-Baum (54)	Astung (55)	(56)
1	1	Ta	217	05	151		115	VS		20	4						
2	2	Lä	195	110	408	16		12					1060				
3	3	Ta	45	21	131		92	VS		20	4						
4	4	Bu	70	78	376		262	12	15	105	2	6					
5	5	Lä	37	117	498		305	12		114	1						
6	6	Ta	343	20	108			VS					10			1	
7	7	Ta	21	51	150			VS								1	
8	8	Ta	380	37	161			VS								1	
9	9	Fi	351	89	542	10	312	12		114	1						
10	10	Fi	340	47	351		250	12		75	4						
11	11	Ki	311	67	420		270	12		90	4						
12	12	Bu	302	115	532		215	12	9	114	1	8					
13																	
14																	
15																	
16																	
17																	
18																	
19																	
20																	
21																	
22																	
23																	
24																	
25																	

General information

Name: Name of the person responsible for plot measurement

1. **ID forest farm:** Index code for the forest bureau (3 digits) and the forest farm (4 digits)
2. **ID sample plot:** Index code for the sample plot
3. **Latitude:** Latitude measured with GPS
4. **Longitude:** Longitude measured with GPS
5. **Forest farm**: Name of the forest farm
6. **District:** Name of the forest bureau
7. **Management block**: Name of the management block
8. **Forest stand**: Chinese name of the forest stand
9. **not relevant**
10. **to be defined**
11. **Age-class:** In case of homogeneous age structure (plantations) age class, in case of natural forests, estimated time since last harvest
12. **Forest type:** Forest type as per the traditional Chinese classification
13. **Target forest management type:** Name of the particular TFMT, where applicable.
14. **Sheet number:** Number of the sheet in the event that more than one is necessary

Site description and infrastructure

15. **Altitude:** Metres above sea level (taken from geo-referenced map or measured using GPS or altimeter)
16. **Exposition:** Exposition of the slope according to compass (N, NE, E, SE, S, SW, W, NW)
17. **Terrain:** 1=lowland, 2=plateau, 3=valley, 4=terrace, 5=floodplain, 6=slope
18. **to be defined**
19. **to be defined**
20. **Macro-region:** Name of the geo-morphological region
21. **Sub-region**: Subdivision of the macro-region
22. **Site unit:** Index of site unit taking into consideration altitude, exposition, terrain and soil type
23. **Slope:** Slope in degrees of the area within the 12 m circle
24. **Ground vegetation:** 0 = no relevant ground cover, 1 = needles, 2 = leaves, 3 = mosses, 4 = ferns, 5 = grasses, 6 = dicotyledonous herbs, 7 = shrubs, 8 = natural regeneration, 9 = other vegetation or ground cover types
25. **Soil damage:** 0 = no visible damage to the ground, 20 = soil compaction by machines, 30 = machine path, 40 = soil compaction by animals
26. **Humus layer:** Depth of the humus layer in cm

27. **Rooting depth:** Rooting depth in cm

28. **Soil skeleton:** Estimated percentage of stones bigger than 6.3 mm

Indicator	Volume %
Very little stone, grit, or gravel content	< 2
Little stone, grit or gravel content	2-10
Moderate stone, grit or gravel content	10-25
High stone, grit or gravel content	25-50
Very high stone, grit or gravel content	50-75
Solely stones, grit or gravel	>75

29. **Date:** Date of measurement

30. **Non-timber forest products (NTFP):** Names of the relevant NTFP

31. **to be defined**

32. **Rare species:** Names of any rare species present

33. **Method:** Permanent or temporary

34. **Repetition:** Number of repetitions

35. **Special biotope:** Names of special biotopes

36. **Dead wood:** Estimated length and diameter (mid stem) of standing and lying dead wood >10 cm in the 12 m circle

37. **Human influence:** Signs of human influence such as grazing, litter utilisation, lopping, etc.

38. **Soil type:** Soil type

39. **Distance to road:** Distance to next skidder trail or road in metres

Regeneration

40. **Regeneration:** Number of trees per species in the height classes <20 cm, 20-50 cm and 51-130 cm (measured in the 1.5 m circle) and species of trees >1.3 m and <7 cm dbh (measured in the 2 m circle)

Trees

41. **Tree number:** All trees ≥5 cm dbh receive a number. Numbering starts with the tree closest to centre and continues in a clockwise direction. The number is written on the bark with crayon. The following trees are considered: in the 3 m circle: dbh ≥5 cm and <10 cm; in the 6 m circle: dbh ≥10 cm and < 20 cm; in the 12 m circle trees ≥20 cm dbh

42. **Azimuth:** Azimuth in degrees from the position of the tree to the plot centre

43. **Distance:** Horizontal distance in metres from the tree centre to the centre of the plot

44. **Species:** Index of the tree species

45. **dbh:** Diameter at 1.3 m, measured to 1 mm accuracy with a diameter tape

46. **Diameter measuring height:** height of diameter measurement if not taken at 1.3 m due to stem irregularities

47. **Height:** Height of trees >15 cm dbh
47. **to be defined**
48. **Stem height:** The stem height is defined as the height up to that point of the stem at which the last sawn timber can be cut. Above this point there is only fire wood. The stem height is measured in the same way as the total height.
49. **Age:** Estimated age
50. **Age estimation method**: The method of age determination employed: 1=taken from secondary sources, 2=determined from trunks, 3=count of whorls on branches, 4=increment core, 5=estimate, 6=extrapolation, 7=same age as stand
51. **Stem quality:** 1=straight without deformations and a minimum length of 3 m; 2=slightly curved, 3=crooked
52. **Damage**: Economically relevant biological or mechanical damage: 0=undamaged, 1=skidding damage, 3=damage caused by animals, 5 = felling damage, 6 = broken crown, 9=other
53. **Protection:** 0=unprotected, 1=fence, 2=individual protection
54. **Future crop tree**: tag if marked as future crop tree
55. **Pruning**: 0=no pruning, 1=pruned to 2.5 m, 2=pruned to 5 m, 3=pruned to 10 m, 4=pruned to 15 m

Annex 3.2. Probeflächengröße

Das Verfahren mit konzentrischen Kreisen erfasst die Bäume in Abhängigkeit von ihrem Brusthöhendurchmesser (BHD) bzw. ihrer Höhe auf unterschiedlich großen Flächen. Die Probekreisgrößen sind folgendermaßen festgelegt (Orginal FVA Anwenderhandbuch Betriebsinventur Version 1.1) (FVA 2004):

BHD	Höhe	Radius	Kreisgröße	1 Probebaum = Bäume/ha
≥ 30 cm	über 1,3 m	12,0 m	452,4 m^2	22
15 bis <30 cm	über 1,3 m	6,0 m	113,1 m^2	88
10 bis <15 cm	über 1,3 m	3,0 m	28,3 m^2	354
<10 cm	über 1,3 m	2,0 m	12,6 m^2	796
<10 cm	bis 1,3 m	1,5 m	7,1 m^2	1.415

Die Probekreisradien bezeichnen bei Bäumen >1,3 m Höhe die horizontale Distanz vom Stichprobenmittelpunkt zum Mittelpunkt des Brusthöhenquerschnitts, bei Bäumen < 1,3 m Höhe die horizontale Distanz vom Stichprobenmittelpunkt zum Wurzelhals. Am Hang ist eine Korrektur erforderlich.

Annex 3.3. Variables of stand structure for the 7 different communities

Ranges of mean density (trees/ha), mean basal area (m^2/ha), and mean volume (m^3/ha) of the 7 communities (VuQa, VcQa, AcQm, VpQm, CrQa, OgJm, LbCc, abbrev. see Table 3.1) (dbh ≥5cm), and their std. deviation in brackets, from minimum to maxium. The differences were tested with Kruskal-Wallis H-test, *: p<0.05, **: p<0.01. For each variable, values with different letters in superscript were significantly different with Mann-Whitney U test.

Community	**VuQa**	**VcQa**	**AcQm**	**VpQm**	**CrQa**	**OgJm**	**LbCc**
Number of relevés	19	36	15	24	12	5	9
Total							
Density	1301.12	1458.11	1024.13	1138.25	997.17	971.20	804.00
	(702.23)	(932.40)	(513.42)	(679.58)	(645.08)	(513.32)	(501.77)
	486-3294	88-4152	176-1828	242-3068	308-2366	418-1656	330-1724
Basal area*	18.38 ^{b}	23.73 ^{a}	26.57 ^{a}	30 ^{a}	18.61 ^{b}	25.12 ^{ab}	21.00 ^{ab}
	(7.41)	(10.22)	(9.93)	(14.97)	(2.79)	(8.19)	(8.62)
	3.85-29.96	1.00-54.09	5.10-46.46	5.81-55.30	13.09-23.86	17.22-36.97	12.28-39.12
Volume**	97.38 ^{b}	157.84 ^{a}	190.15 ^{a}	210.77 ^{a}	105.29 ^{b}	154.24 ^{ab}	137.85 ^{ab}
	(48.04)	(76.87)	(85.32)	(117.88)	(17.55)	(56.44)	(77.43)
	17.20-168.17	3.64-363.37	23.96-358.17	26.52-412.46	74.42-133.45	103.42-240.34	60.81-293.29
Quercus aliena* var. *acutiserrata							
Density**	818.67	360.39		73.50	226.17	4.40	29.33
.	(770.09)	(682.29)	0	(127.05)	(300.84)	(9.84)	(33)
	66-2940	0-3514		0-486	0-906	0-22	0-88
Basal area**	12.21	6.90		2.64	5.80	0.30	2.11
	(7.59)	(9.12)	0	(3.82)	(3.99)	(0.67)	(2.69)
	1.47-24.57	0-37.94		0-13.48	0-13.62	0-1.50	0-6.40
Volume**	66.37	45.72		18.90	35.03	1.83	14.32
	(46.03)	(64.14)	0	(27.87)	(25.95)	(4.08)	(18.28)
	7.34-141.67	0-266.38		0-102.05	0-84.83	0-9.13	0-42.12

Community	VuQa	VcQa	AcQm	VpQm	CrQa	OgJm	LbCc
Number of relevés	19	36	15	24	12	5	9
Quercus mongolica							
Density**	20.95 (81.28) 0-354	173.72 (290.14) 0-1146	195.20 (268.41) 0-948	195.25 (245.95) 0-748	0	0	56.22 (91.45) 0-264
Basal area**	0.38 (1.33) 0-5.68	5.33 (7.39) 0-24.11	8.82 (11.06) 0-38.02	13.59 (15.67) 0-47.81	0	0	4.87 (8.93) 0-27.04
Volume**	1.63 (6.19) 0-26.89	38.82 (53.36) 0-168.90	64.85 (85.78) 0-306.02	106.40 (123.73) 0-383.58	0	0	36.34 (69.09) 0-209.59
Betula platyphylla							
Density**	20.84 (90.85) 0-396	155.94 (295.61) 0-1210	202.40 (279.05) 0-748	6.42 (19.97) 0-88	31.17 (33.11) 0-88	0	0
Basal area**	0.44 (1.90) 0-8.30	4.03 (6.81) 0-28.01	6.72 (8.04) 0-23.22	0.41 (1.44) 0-6.84	2.59 (3.19) 0-9.59	0	0
Volume**	2.27 (9.89) 0-43.10	29.83 (52.52) 0-215.05	52.20 (63.29) 0-180.72	3.26 (12.17) 0-58.73	16.28 (20.45) 0-62.99	0	0

Community Number of relevés	VuQa 19	VcQa 36	AcQm 15	VpQm 24	CrQa 12	OgJm 5	LbCc 9
Sorbus alnifolia							
Density**	9.26 (40.38) 0-176	120.33 (376.05) 0-1922	26.40 (75.39) 0-286	258.50 (437.57) 0-1768	14.67 (21.66) 0-66	0	39.33 (118) 0 -354
Basal area**	0.09 (0.38) 0-1.66	0.78 (2.64) 0-15.17	0.47 (1.19) 0-4.40	2.26 (3.31) 0-11.61	0.69 (1.07) 0-3.32	0	0.24 (0.73) 0-2.20
Volume**	0.60 (2.62) 0-11.40	4.46 (15.91) 0-92.32	2.93 (7.38) 0-27.41	12.20 (18.09) 0-61.68	3.91 (6.42) 0-20.32	0	1.39 (4.16) 0-12.47
Corylus chinensis							
Density**	0	49.11 (187.23) 0-884	35.33 (98.81) 0-376	44.00 (69.87) 0-286	71.67 (176.1) 0-618	30.80 (42.89) 0-88	14.67 (36.48) 0-110
Basal area**	0	0.23 (0.82) 0-4.15	0.59 (1.24) 0-3.39	1.54 (1.88) 0-5.67	1.12 (1.71) 0-4.53	2.36 (3.26) 0-6.54	0.56 (1.44) 0-4.35
Volume**	0	1.17 (4.31) 0-22.37	3.85 (8.17) 0-22.62	10.85 (13.49) 0-44.71	6.33 (9.42) 0-26.30	15.63 (21.59) 0-43.13	4.45 (11.39) 0-34.42

Community	VuQa	VcQa	AcQm	VpQm	CrQa	OgJm	LbCc
Number of relevés	19	36	15	24	12	5	9
Ulmus davidiana* var. *japonica							
Density**	59.72 (182.76) 0-737	19.61 (69.22) 0-376	1.47 (5.68) 0-22	1.83 (6.21) 0-22	68.00 (108.92) 0-398	4.40 (9.84) 0-22	137.56 (245.07) 0-708
Basal area**	0.26 (0.60) 0-2.38	0.24 (0.58) 0-2.35	0.21 (0.83) 0-3.19	0.18 (0.71) 0-3.42	2.33 (2.83) 0-10.74	0.25 (0.56) 0-1.26	0.99 (1.51) 0-4.49
Volume**	1.22 (2.70) 0-9.85	1.21 (2.84) 0-9.86	1.37 (5.23) 0-20.53	0.80 (2.96) 0-13.64	13.94 (18.50) 0-69.51	1.48 (3.31) 0-7.40	6.41 (12.22) 0-37.29
Juglans mandshurica							
Density**	0	0.61 (3.67) 0-22	0	1.83 (6.21) 0-22	64.50 (209.750) 0-730	132.00 (111.10) 0-286	115.33 (256.89) 0-796
Basal area**	0	0.08 (0.48) 0-2.89	0	0.10 (0.34) 0-1.46	1.05 (1.92) 0-5.12	12.84 (8.98) 0-25.33	3.26 (3.45) 0-10.38
Volume**	0	0.74 (4.43) 0-26.58	0	0.74 (2.51) 0-9.33	6.43 (11.75) 0-28.59	92.41 (67.17) 0-189.67	21.37 (25.15) 0-76.04

Community Number of relevés	**VuQa** 19	**VcQa** 36	**AcQm** 15	**VpQm** 24	**CrQa** 12	**OgJm** 5	**LbCc** 9
Quercus dentata							
Density**	77.68 (164.94) 0-684	23.22 (68.36) 0-264	0	0	0	0	0
Basal area**	2.20 (4.12) 0-15.65	0.88 (2.50) 0-11.02	0	0	0	0	0
Volume**	10.81 (19.61) 0-68.92	5.32 (15.79) 0-68.31	0	0	0	0	0
Pinus armandii							
Density $^{-}$	60.53 (144.61) 0-442	47.83 (201.78) 0-1060	1.47 (5.68) 0-22	17.50 (72.93) 0-354	0	0	0
Basal area^{-}	0.36 (0.88) 0-2.88	0.49 (1.85) 0-8.50	0.05 (0.21) 0-0.81	0.19 (0.70) 0-3.11	0	0	0
Volume^{-}	1.74 (4.15) 0-12.25	2.93 (11.04) 0-52.37	0.43 (1.68) 0-6.49	1.32 (5.34) 0-25.77	0	0	0

Community	VuQa	VcQa	AcQm	VpQm	CrQa	OgJm	LbCc
Number of relevés	19	36	15	24	12	5	9
Betula albosinensis							
Density**	0	0	19.07 (43.9) 0-154	0	0	0	2.44 (7.33) 0-22
Basal area**	0	0	2.04 (5.05) 0-18.29	0	0	0	0.31 (0.92) 0-2.76
Volume**	0	0	17.00 (44.19) 0-163.32	0	0	0	2.27 (6.81) 0-20.42
Other species							
Density*	233.47 (321.72) 0-950	507.33 (696.78) 0-3628	542.80 (379.77) 22-1258	539.42 (432.39) 0-1854	521.00 (642.84) 22-2278	799.60 (461.48) 308-1370	409.11 (192.08) 176-684
Basal area**	2.45 (2.79) 0-7.23	4.78 (5.54) 0-24.40	7.65 (4.26) 1.50-15.11	9.09 (5.22) 0-19.58	5.03 (4.00) 0.78-14.98	9.37 (4.7) 3.55-15.57	8.65 (4.7) 1.57-16.46
Volume**	12.74 (14.71) 0-42.71	27.64 (33.08) 0-142.10	47.52 (28.99) 5.47-109.33	56.30 (33.97) 0-115.02	23.37 (16.56) 2.64-58.01	42.90 (29.55) 13.49-83.91	51.30 (33.92) 7.55-117.43

Annex 3.4. Life forms for the 7 different communities

Ranges of mean cover (%, 100 m^{-2}) of life forms of the herb layer for the 7 different communities (VuQa, VcQa, AcQm, VpQm, CrQa, OgJm, LbCc, abbrev. see Table 3.1) , and their std. deviation in brackets, from minimum to maxium. For each variable, values with * were significantly different (**: P < 0.001; *: P < 0.05).

Community / Number of relevés / **Life form**	**VuQa** 19	**VcQa** 36	**AcQm** 15	**VpQm** 24	**CrQa** 12	**OgJm** 5	**LbCc** 9
Phanerophyte**	**36.4** (21.21) 8.6-89.3	**45.6** (20.28) 3.5-94.9	**26.1** (19.4) 0-60.9	**45.7** (16.93) 13.6-93.3	**19.5** (9.23) 1.1-36.9	**3.9** (4.03) 0.6-10.8	**8.3** (7.18) 1.9-23.4
Chamaephyte**	**2.6** (3.38) 0-14.3	**0.4** (0.83) 0 - 3.0	**2.7** (5.66) 0 - 20.0	**0.1** (0.17) 0 - 0.5	**0.2** (0.26) 0 - 0.7	**0**	**0.2** (0.24) 0 - 0.5
Hemicryptophyte**	**12.3** (6.95) 2.7 - 27.5	**14.5** (11.12) 0.8 - 53.4	**22.9** (17.35) 3.7-72.1	**8.5** (11.02) 0.0-39.3	**53.7** (48.28) 7.5-168.1	**50.2** (16.58) 29.8-69.9	**60.9** (24.51) 40.8-117.8
Geophyte*	**23.4** (15.75) 9.3-72.3	**17.9** (14.92) 1.0-72.3	**26.9** (17.55) 1.8-53.3	**15.0** (10.52) 3.0-42.2	**21.1** (22.87) 2.2-82.6	**15.7** (6.98) 7.4-25.8	**31.4** (15.21) 16.3-62.5
Therophyte**	**0.03** (0) 0.1-0.1	**1.0** (3.62) 0-20.1	**5.2** (9.23) 0-23.6	**0.8** (2.07) 0-9.3	**6.6** (12.21) 0-40.1	**43.6** (19.1) 17.6-62.5	**4.8** (6.41) 0-18.6

Annex 3.5. The site index table with 3 groups of tree species adapted from the Forest Bureau of Xiaolongshan (FOREST BUREAU OF XIAOLONGSHAN 1982b)

The site quality index with absolute top height and age refer in particular to the *Quercus* and broad-leaved tree species in the stand-age of 40 years and to the *Populus*- and *Betula* species in the stand-age of 30 years (Forest Bureau of Xiaolongshan 1982b).

Bonitätszuordnungstabelle nach (Forest Bureau of Xiaolongshan 1982b). Die Absolute Höhenbonitäten entsprechen bei der Eiche- und Laubbaum-Beständen im Alter 40, bei der Pappel oder Birke Waldbeständen im Alter 30.

Site - Index (SI)	**Stand age** year									
	10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
	***Quercus* stand**									
9		4.53	7.36	9.00	9.93	10.70	11.08	11.31	11.38	11.43
10	0.46	5.42	8.30	10.00	11.01	11.82	12.27	12.57	12.72	12.82
11	1.30	6.31	9.24	11.00	12.09	12.94	13.46	13.83	14.06	14.25
12	2.14	7.20	10.18	12.00	13.17	14.06	14.65	15.09	15.40	15.66
13	2.98	8.09	11.12	13.00	14.25	15.18	15.84	16.35	16.74	17.07
14	3.82	8.98	12.06	14.00	15.33	16.30	17.03	17.61	18.08	18.48
15	4.66	9.87	13.00	15.00	16.41	17.42	18.22	18.87	19.42	19.89
16	5.50	10.76	13.94	16.00	17.49	18.54	19.41	20.13	20.76	21.30
17	6.34	11.65	14.88	17.00	18.57	19.66	20.60	21.39	22.10	22.71
18	7.18	12.54	15.32	18.00	19.65	20.78	21.79	22.65	23.44	24.12
	Broad-leaved tree species stand									
9		4.06	7.07	9.00	10.34	11.37	12.15	12.74	13.26	13.73
10		5.12	8.10	10.00	11.31	12.30	13.05	13.62	14.11	14.55
11	1.07	6.18	9.13	11.00	12.28	13.23	13.95	14.50	14.96	15.37
12	2.17	7.24	10.16	12.00	13.25	14.10	14.85	15.38	15.81	16.19
13	3.27	8.30	11.19	13.00	14.22	15.09	15.75	16.24	16.66	17.01
14	4.37	9.36	12.22	14.00	15.19	16.02	16.65	17.14	17.51	17.83
15	5.47	10.42	13.25	15.00	16.16	16.95	17.55	18.02	18.36	18.65
16	6.57	11.48	14.28	16.00	17.13	17.88	18.45	18.90	19.21	19.47
17	6.67	12.54	15.31	17.00	18.10	18.81	19.35	19.78	20.06	20.29
18	8.77	13.60	16.34	18.00	19.07	19.74	20.25	20.66	20.19	21.11
	***Populus*- or *Betula* stand**									
9	3.28	6.97	9.00	10.09	10.85	11.40	11.79	12.12	12.36	12.55
10	3.68	7.77	10.00	11.24	12.09	12.70	13.14	13.50	13.77	13.99
11	4.08	8.57	11.00	12.39	13.33	14.00	14.49	14.88	15.18	15.43
12	4.48	9.37	12.00	13.54	14.57	15.30	15.84	16.26	16.59	16.87
13	4.88	10.17	13.00	14.69	15.81	16.60	17.19	17.64	18.00	18.31
14	5.28	10.97	14.00	15.84	17.05	17.90	18.54	19.02	19.41	19.75
15	5.68	11.77	15.00	16.99	18.29	19.20	19.89	20.40	20.82	21.19
16	6.08	12.57	16.00	18.14	19.53	20.50	21.24	21.78	22.23	22.63
17	6.48	13.37	17.00	19.29	20.77	21.80	22.59	23.16	23.64	24.07
18	6.88	14.17	18.00	20.44	22.01	23.10	23.94	24.54	25.05	25.51

Annex 3.6. Frequence (%) of the tree species (dbh >5 cm) in 120 plots

ID	Frequence %	Adopte Name Latin	Adopte Name Chinese
1	62	*Quercus aliena* var. *acutiserrata*	锐齿槲栎 rui chi hu li
2	44	*Quercus mongolica*	蒙古栎 meng gu li
3	33	*Betula platyphylla*	白桦 bai hua
4	25	*Sorbus alnifolia*	水榆花楸 shui yu hua qiu
5	23	*Ulmus davidiana var. japonica*	春榆 chun yu
6	23	*Corylus chinensis*	华榛 hua zhen
7	22	*Lindera obtusiloba*	三桠乌药 san ya wu yao
8	19	*Toxicodendron vernicifluum*	漆树 qi shu
9	19	*Acer davidii*	青榨槭 qing zha qi
10	16	*Tilia paucicostata*	少脉椴 shao mai duan
11	15	*Cornus hemsleyi*	红椋子 hong liang zi
12	14	*Acer pictum subsp. mono*	五角枫 wu jiao feng
13	13	*Juglans mandshurica*	胡桃楸 hu tao qiu
14	12	*Sorbus hupehensis*	湖北花楸 hu bei hua qiu
15	12	*Cornus macrophylla var. macrophylla*	梾木(原变种) lai mu (yuan bian zhong)
16	11	*Carpinus turczaninowii*	鹅耳枥 e er li
17	11	*Quercus dentata*	槲树 hu shu
18	9	*Staphylea holocarpa*	膀胱果 pang guang guo
19	8	*Cerasus polytricha*	多毛樱桃 duo mao ying tao
20	8	*Pinus armandii*	华山松 hua shan song
21	8	*Amelanchier sinica*	唐棣 tang di
22	7	*Malus baccata*	山荆子 shan jiang zi
23	7	*Populus davidiana*	山杨 shan yang
24	6	*Acer ginnala*	茶条槭 cha tiao qi
25	6	*Tetradium daniellii*	臭檀吴萸 chou tan wu yu
26	6	*Cornus controversa*	灯台树 deng tai shu
27	6	*Tilia paucicostata var. dictyoneura*	红皮椴 hong pi duan
28	6	*Salix caprea*	黄花柳 huang hua liu
29	6	*Ostrya japonica*	铁木 tie mu
30	4	*Betula albosinensis*	红桦 hong hua
31	4	*Malus hupehensis*	湖北海棠 hu bei hai tang
32	4	*Fraxinus platypoda*	象蜡树 xiang la shu
33	3	*Meliosma cuneifolia*	泡花树 pao hua shu
34	3	*Acer caudatum*	长尾槭 chang wei qi
35	3	*Rhus potaninii*	青麸杨 qing fu yang
36	3	*Cladrastis delavayi*	小花香槐 xiao hua xiang huai
37	3	*Ulmus bergmanniana*	兴山榆 xing shan yu
38	2	*Quercus spinosa*	刺叶栎 ci ye gao shan li
39	2	*Populus purdomii*	冬瓜杨 dong gua yang
40	2	*Crataegus wilsonii*	华中山楂 hua zhong shan zha
41	2	*Tilia henryana var. henryana*	毛糯米椴(原变种) mao nuo mi duan (yuan bian zhong)
42	2	*Fraxinus bungeana*	小叶梣 xiao ye qin
43	2	*Salix wallichiana*	皂柳 zao liu
44	1	*Fraxinus chinensis*	白蜡树 bai la shu
45	1	*Acer ceriferum*	杈叶枫 cha ye feng
46	1	*Kalopanax septemlobus*	刺楸 ci qiu
47	1	*Rhamnus utilis*	冻绿 dong lü
48	1	*Padus brachypoda*	短梗稠李 duan geng chou li
49	1	*Morus australis*	鸡桑 ji sang
50	1	*Picrasma quassioides*	苦树 ku shu
51	1	*Prunus salicina*	李 li
52	1	*Pyrus xerophila*	木梨 mu li
53	1	*Carpinus cordata*	千金榆 qian jin yu
54	1	*Dipelta floribunda*	双盾木 shuang dun mu
55	1	*Acer stachyophyllum subsp. betulifolium*	四蕊枫 si rui feng
56	1	*Pinus tabuliformis*	油松 you song
	0	*Pyrus betulifolia*	杜梨 du li
	0	*Tilia oliveri*	鄂椴 e duan
	0	*Armeniaca vulgaris var. vulgaris*	杏(原变种) xing (yuan bian zhong)
sum	100		

Annex 3.7. Mean density, mean basal area, mean volume, and in percentage

Ranges of mean density (trees/ha), mean basal area (m^2/ha), and mean volume (m^3/ha) of the 7 communities (VuQa, VcQa, AcQm, VpQm, CrQa, OgJm, LbCc, abbrev. see Table 3.1) (dbh ≥5cm), their std. deviation in brackets, and all in percentage. The differences were tested with Kruskal-Wallis H-test, *: p<0.05, **: p<0.01, ¯¯: not significantly different.

Community Plots	VuQa 19		VcQa 36		AcQm 15		VpQm 24		CrQa 12		OgJm 5		LbCc 9		Total 120	
	%		%		%		%		%		%		%		%	
Total																
Density¯¯	*100*	**1301**	*100*	**1458**	*100*	**1024**	*100*	**1138**	*100*	**997**	*100*	**971**	*100*	**804**	*100*	**1199**
Basal area*	*100*	**18**	*100*	**24**	*100*	**27**	*100*	**30**	*100*	**19**	*100*	**25**	*100*	**21**	*100*	**24**
Volume**	*100*	**97**	*100*	**158**	*100*	**190**	*100*	**211**	*100*	**105**	*100*	**154**	*100*	**138**	*100*	**156**
Quercus aliena* var. *acutiserrata																
Density**	*63*	**819**	*25*	**360**	*0*	**0**	*6*	**74**	*23*	**226**	*0*	**4**	*4*	**29**	*20*	**277**
Basal area**	*66*	**12**	*29*	**7**	*0*	**0**	*9*	**3**	*31*	**6**	*1*	**0**	*10*	**2**	*18*	**5**
Volume**	*68*	**66**	*29*	**46**	*0*	**0**	*9*	**19**	*33*	**35**	*1*	**2**	*10*	**14**	*17*	**33**
Quercus mongolica																
Density**	*2*	**21**	*12*	**174**	*19*	**195**	*17*	**195**	*0*	**0**	*0*	**0**	*7*	**56**	*8*	**123**
Basal area**	*2*	**0**	*22*	**5**	*33*	**9**	*45*	**14**	*0*	**0**	*0*	**0**	*23*	**5**	*20*	**6**
Volume**	*2*	**2**	*25*	**39**	*34*	**65**	*50*	**106**	*0*	**0**	*0*	**0**	*26*	**36**	*24*	**44**
Betula platyphylla																
Density**	*2*	**21**	*11*	**156**	*20*	**202**	*1*	**6**	*3*	**31**	*0*	**0**	*0*	**0**	*5*	**80**
Basal area**	*2*	**0**	*17*	**4**	*25*	**7**	*1*	**0**	*14*	**3**	*0*	**0**	*0*	**0**	*9*	**2**
Volume**	*2*	**2**	*19*	**30**	*27*	**52**	*2*	**3**	*15*	**16**	*0*	**0**	*0*	**0**	*10*	**18**
Sorbus alnifolia																
Density**	*1*	**9**	*8*	**120**	*3*	**26**	*23*	**259**	*1*	**15**	*0*	**0**	*5*	**39**	*6*	**97**
Basal area**	*0*	**0**	*3*	**1**	*2*	**0**	*8*	**2**	*4*	**1**	*0*	**0**	*1*	**0**	*3*	**1**
Volume**	*1*	**1**	*3*	**4**	*2*	**3**	*6*	**12**	*4*	**4**	*0*	**0**	*1*	**1**	*2*	**5**
Corylus chinensis																
Density**	*0*	**0**	*3*	**49**	*3*	**35**	*4*	**44**	*7*	**72**	*3*	**31**	*2*	**15**	*3*	**37**
Basal area**	*0*	**0**	*1*	**0**	*2*	**1**	*5*	**2**	*6*	**1**	*9*	**2**	*3*	**1**	*4*	**1**
Volume**	*0*	**0**	*1*	**1**	*2*	**4**	*5*	**11**	*6*	**6**	*10*	**16**	*3*	**4**	*4*	**5**
Ulmus davidiana* var. *japonica																
Density**	*5*	**60**	*1*	**20**	*0*	**1**	*0*	**2**	*7*	**68**	*0*	**4**	*17*	**138**	*4*	**33**
Basal area**	*1*	**0**	*1*	**0**	*1*	**0**	*1*	**0**	*13*	**2**	*1*	**0**	*5*	**1**	*3*	**0**
Volume**	*1*	**1**	*1*	**1**	*1*	**1**	*0*	**1**	*13*	**14**	*1*	**1**	*5*	**6**	*3*	**3**
Juglans mandshurica																
Density**	*0*	**0**	*0*	**1**	*0*	**0**	*0*	**2**	*6*	**65**	*14*	**132**	*14*	**115**	*4*	**21**
Basal area**	*0*	**0**	*0*	**0**	*0*	**0**	*0*	**0**	*6*	**1**	*51*	**13**	*16*	**3**	*11*	**1**
Volume**	*0*	**0**	*0*	**1**	*0*	**0**	*0*	**1**	*6*	**6**	*60*	**92**	*16*	**21**	*12*	**7**
Quercus dentata																
Density**	*6*	**78**	*2*	**23**	*0*	**0**	*0*	**0**	*0*	**0**	*0*	**0**	*0*	**0**	*1*	**19**
Basal area**	*12*	**2**	*4*	**1**	*0*	**0**	*0*	**0**	*0*	**0**	*0*	**0**	*0*	**0**	*2*	**1**
Volume**	*11*	**11**	*3*	**5**	*0*	**0**	*0*	**0**	*0*	**0**	*0*	**0**	*0*	**0**	*2*	**3**
Pinus armandii																
Density¯¯	*5*	**61**	*3*	**48**	*0*	**1**	*2*	**18**	*0*	**0**	*0*	**0**	*0*	**0**	*2*	**28**
Basal area¯¯	*2*	**0**	*2*	**0**	*0*	**0**	*1*	**0**	*0*	**0**	*0*	**0**	*0*	**0**	*1*	**0**
Volume¯¯	*2*	**2**	*2*	**3**	*0*	**0**	*1*	**1**	*0*	**0**	*0*	**0**	*0*	**0**	*1*	**1**
Betula albosinensis																
Density**	*0*	**0**	*0*	**0**	*2*	**19**	*0*	**0**	*0*	**0**	*0*	**0**	*0*	**2**	*0*	**3**
Basal area**	*0*	**0**	*0*	**0**	*8*	**2**	*0*	**0**	*0*	**0**	*0*	**0**	*1*	**0**	*1*	**0**
Volume**	*0*	**0**	*0*	**0**	*9*	**17**	*0*	**0**	*0*	**0**	*0*	**0**	*2*	**2**	*2*	**2**
Other species																
Density*	*18*	**233**	*35*	**507**	*53*	**543**	*47*	**539**	*52*	**521**	*82*	**800**	*51*	**409**	*46*	**481**
Basal area**	*13*	**2**	*20*	**5**	*29*	**8**	*30*	**9**	*27*	**5**	*37*	**9**	*41*	**9**	*29*	**6**
Volume**	*13*	**13**	*18*	**28**	*25*	**48**	*27*	**56**	*22*	**23**	*28*	**43**	*37*	**51**	*25*	**36**

Annex 3.8. Mean density (trees/ha) of seedlings and Saplings of height- or dbh classes in the 120 plots, and their std. deviation in brackets

Species	Height or dbh class	Density
All species		
	<20cm H	**7509** (5815.5)
	20-50cm H	**4068** (3966.2)
	50-130cm H	**3311** (2660.5)
	1-2cm dbh, >130cm H	**2479** (2583.8)
	2-3cm dbh, >130cm H	**1321** (850.8)
	3-4cm dbh, >130cm H	**1205** (679.0)
	4-5cm dbh, >130cm H	**1207** (612.1)
Quercus aliena* var. *acutiserrata		
	<20cm H	**1773** (2802.1)
	20-50cm H	**1314** (2978.6)
	50-130cm H	**962** (2070.2)
	1-2cm dbh, >130cm H	**587** (2150.2)
	2-3cm dbh, >130cm H	**406** (876.3)
	3-4cm dbh, >130cm H	**296** (581.9)
	4-5cm dbh, >130cm H	**359** (644.7)
Quercus mongolica		
	<20cm H	**189** (585.4)
	50-130cm H	**57** (280.1)
	1-2cm dbh, >130cm H	**52** (407.7)
	2-3cm dbh, >130cm H	**17** (116.1)
	3-4cm dbh, >130cm H	**23** (134.5)
Betula platyphylla		
	50-130cm H	**28** (200.1)
	1-2cm dbh, >130cm H	**39** (226.4)
Sorbus alnifolia		
	<20cm H	**170** (567.9)
	20-50cm H	**51** (265.0)
	50-130cm H	**85** (339.5)
	1-2cm dbh, >130cm H	**117** (319.6)
	2-3cm dbh, >130cm H	**51** (257.4)
	3-4cm dbh, >130cm H	**114** (342.3)
	4-5cm dbh, >130cm H	**103** (271.3)
Corylus chinensis		
	<20cm H	**75** (514.6)
	1-2cm dbh, >130cm H	**13** (101.9)
	2-3cm dbh, >130cm H	**34** (162.4)
Ulmus davidiana* var. *japonica		
	<20cm H	**94** (484.2)
	20-50cm H	**51** (265.0)
	50-130cm H	**113** (387.8)

Species	Height or dbh class	Density
	1-2cm dbh, >130cm H	**52** (246.2)
	2-3cm dbh, >130cm H	**17** (116.1)
	3-4cm dbh, >130cm H	**23** (134.5)
Juglans mandshurica		
	20-50cm H	**51** (378.2)
	2-3cm dbh, >130cm H	**17** (116.1)
Quercus dentata		
	<20cm H	**57** (490.2)
	20-50cm H	**25** (189.1)
	2-3cm dbh, >130cm H	**17** (116.1)
Pinus armandii		
	<20cm H	**75** (395.7)
	20-50cm H	**76** (321.5)
	1-2cm dbh, >130cm H	**13** (101.9)
	2-3cm dbh, >130cm H	**34** (162.4)
	3-4cm dbh, >130cm H	**23** (134.5)
	4-5cm dbh, >130cm H	**26** (143.0)
Other species		
	<20cm H	**5075** (5391.1)
	20-50cm H	**2502** (2711.6)
	50-130cm H	**2066** (2124.1)
	1-2cm dbh, >130cm H	**1605** (1237.4)
	2-3cm dbh, >130cm H	**728** (660.4)
	3-4cm dbh, >130cm H	**728** (524.2)
	4-5cm dbh, >130cm H	**719** (518.1)

Annex 3.9. Density (trees/ha) of regrowth (dbh < 5 cm) of the 10 important species in the 3 community groups (QQ, SQ, JC, abbrev. see Table 3.1),based on trees with a dbh ≥5 cm, values reportet are mean and range, and in brackets their standard deviation. The differences were tested with KW H-test, *: $p < 0.05$, **: $p < 0.01$. Values with different letters in superscript were significantly different based on pairwise comparisons with MWU-test.

Species	Community group number of relevés	Density
All species		
	CG QQ	**13,111**[a] (9819.1) 796-44044
	CG SQ	**8,505**[b] (7800.4) 796-30865
	CG JC	**14,211**[a] (10629.0) 796-37233
Quercus aliena* var. *acutiserrata		
	CG QQ	**5,692**[a] (7228.3) 0-29363
	CG SQ	**202**[c] (1195.9) 0-7075
	CG JC	**1,476**[b] (2617.0) 0-8048
Quercus mongolica		
	CG QQ	**201** (801.1) 0-4776
	CG SQ	**323** 773.9) 0-2830
Betula platyphylla		
	CG QQ	**73** (429.3) 0-3007
Sorbus alnifolia	**CG QQ**	**265** (851.6) 0-4776
	CG SQ	**217** (533.4) 0-2211
	CG JC	**796** (1331.8) 0-5041
Corylus chinensis		
	CG QQ	**97** (699.1) 0-5041

Species	Community group number of relevés	Density
	CG SQ	**23** (134.5) 0-796
	CG JC	**116** (363.5) 0-1415
Ulmus davidiana* var. *japonica		
	CG QQ	**128**[ab] (404.1) 0-1592
	CG SQ	**81**[b] (478.4) 0-2830
	CG JC	**573**[a] (1159.6) 0-3626
Juglans mandshurica		
	CG JC	**191** (831.9) 0-3626
Quercus dentata		
	CG QQ	**124** (623.9) 0-4245
Pinus armandii		
	CG QQ	**158** (772.7 0-5041
	CG SQ	**162** (456.8) 0-1415
Other species		
	CG QQ	**6,373** (6382.7) 0-28477
	CG SQ	**7,497** (7880.8) 0-30865
	CG JC	**11,060** (8243.5) 796-27770

Annex 3.10. Mean density (trees/ha) of seedlings and saplings (dbh ≥5 cm) of the 10 important species in the 7 communities (VuQa, VcQa, AcQm, VpQm, CrQa, OgJm, LbCc, abbrev. see Table 3.1 and Annex 2.1), and their std. deviation in brackets, from Minimum to Maximum.

Sprecies	**Community** Number of relevés	**Density**	
		Mean density (trees/ha)	(std. deviation) Min. – max.
All species			
	VuQa	**19,398**	
	19		(12283.5)
			3184-44044
	VcQa	**9,783**	
	36		(6189.2)
			796-24232
	AcQm	**8,844**	
	15		(7044.8)
			796-22817
	VpQm	**8,305**	
	24		(8369.0)
			1415-30865
	CrQa	**19,707**	
	12		(9136.2)
			5660-37233
	OgJm	**6,226**	
	5		(4871.7)
			1592-13089
	LbCc	**1,194**	
	9		(562.9)
			796-1592
Quercus aliena* var. *acutiserrata			
	VuQa	**10,230**	
	19		(8602.5)
			0-29363
	VcQa	**3,290**	
	36		(5045.0)
			0-21402
	VpQm	**322**	
	24		(1508.4)
			0-7075
	CrQa	**2,336**	
	12		(3002.3)
			0-8048
Quercus mongolica			
	VuQa	**265**	
	19		(1125.7)
			0-4776
	VcQa	**166**	
	36		(579.2)
			0-2830
	AcQm	**653**	
	15		(1098.4)

Sprecies	Community Number of relevés	Density Mean density (trees/ha)	 (std. deviation) Min. – max.
			0-2830
	VpQm 24	**129**	(416.4) 0-1415
Betula platyphylla			
	VcQa 36	**112**	(529.4) 0-3007
Sorbus alnifolia			
	VcQa 36	**406**	(1030.5) 0-4776
	AcQm 15	**184**	(476.9) 0-1592
	VpQm 24	**237**	(574.1) 0-2211
	CrQa 12	**1,260**	(1504.7) 0-5041
Corylus chinensis			
	VcQa 36	**148**	(864.5) 0-5041
	VpQm 24	**36**	(169.7) 0-796
	CrQa 12	**184**	(450.1) 0-1415
Ulmus davidiana* var. *japonica			
	VuQa 19	**79**	(333.5) 0-1415
	VcQa 36	**153**	(439.4) 0-1592
	VpQm 24	**129**	(603.4) 0-2830
	CrQa 12	**840**	(1392.5) 0-3626
	OgJm 5	**159**	(356.0) 0-796

Sprecies	Community Number of relevés	Density Mean density (trees/ha)	 (std. deviation) Min. – max.
Juglans mandshurica			
	CrQa	**302**	
	12		(1046.7)
			0-3626
Quercus dentata			
	VuQa	**280**	
	19		(1007.1)
			0-4245
	VcQa	**42**	
	36		(242.7)
			0-1415
Pinus armandii			
	VuQa	**133**	
	19		(562.9)
			0-2388
	VcQa	**172**	
	36		(871.1)
			0-5041
	AcQm	**327**	
	15		(620.5)
			0-1415
	VpQm	**64**	
	24		(301.7)
			0-1415
Other species			
	VuQa	**8,412**	
	19		(8131.0)
			0-28477
	VcQa	**5,293**	
	36		(5043.3)
			0-18395
	AcQm	**7,681**	
	15		(7456.8)
			0-22817
	VpQm	**7,389**	
	24		(8291.4)
			0-30865
	CrQa	**14,784**	
	12		(7665.8)
			3626-27770
	OgJm	**6,067**	
	5		(4762.0)
			1592-13089
	LbCc	**1,194**	
	9		(562.9)
			796-1592

Annex 3.11. Mean density, mean basal area, mean volume, and in percentage

Density, basal area, volume of species in the 7 communities (VuQa, VcQa, AcQm, VpQm, CrQa, OgJm, LbCc, abbrev. see Table 3.1 and Annex 2.1, the number of relevés are in brackets), based on trees with a dbh ≥5 cm, values reportet are mean and their percentage of species. The differences were tested with KW H-test, *: $p < 0.05$, **: $p < 0.01$. Values with different letters in superscript were significantly different based on pairwise comparisons with MWU-test.

Species	Parameter	Unit	COMMUNITY VuQa (19)	VcQa (36)	AcQm (15)	VpQm (24)	CrQa (12)	OgJm (5)	LbCc (9)	Total (120)
All species	**Density -**	trees ha^{-1}	**1301**	**1458**	**1024**	**1138**	**997**	**971**	**804**	**1199**
	Basal area *	m^2 ha^{-1}	**18 ^{b}**	**24 a**	**27 ^{a}**	**30 ^{a}**	**19 ^{b}**	**25 ^{ab}**	**21 ^{ab}**	**24**
	Volume **	m^3 ha^{-1}	**97 ^{b}**	**158 ^{a}**	**190 ^{a}**	**211 ^{a}**	**105 ^{b}**	**154 ^{ab}**	**138 ^{ab}**	**156**
Quercus aliena* var. *acutiserrata	Density **	%	63	25	-	6	23	<0.5	4	**20**
	Basal area**	%	66	29	-	9	31	1	10	**18**
	Volume**	%	68	29	-	9	33	1	10	**17**
Quercus mongolica	Density**	%	2	12	19	17	-	-	7	**8**
	Basal area**	%	2	22	33	45	-	-	23	**20**
	Volume**	%	2	25	34	50	-	-	26	**24**
Betula platyphylla	Density**	%	2	11	20	1	3	-	-	**5**
	Basal area**	%	2	17	25	1	14	-	-	**9**
	Volume**	%	2	19	27	2	15	-	-	**10**
Sorbus alnifolia	Density**	%	1	8	3	23	1	-	5	**6**
	Basal area**	%	<0.5	3	2	8	4	-	1	**3**
	Volume**	%	1	3	2	6	4	-	1	**2**
Corylus chinensis	Density**	%	-	3	3	4	7	3	2	**3**
	Basal area**	%	-	1	2	5	6	9	3	**4**
	Volume**	%	-	1	2	5	6	10	3	**4**
Ulmus davidiana* var. *japonica	Density**	%	5	1	<0.5	<0.5	7	<0.5	17	**4**
	Basal area**	%	1	1	1	1	13	1	5	**3**
	Volume**	%	1	1	1	<0.5	13	1	5	**3**
Juglans mandshurica	Density**	%	-	<0.5	-	<0.5	6	14	14	**4**
	Basal area**	%	-	<0.5	-	<0.5	6	51	16	**11**
	Volume**	%	-	<0.5	-	<0.5	6	60	16	**12**
Quercus dentata	Density**	%	6	2	-	-	-	-	-	**1**
	Basal area**	%	12	4	-	-	-	-	-	**2**
	Volume**	%	11	3	-	-	-	-	-	**2**
Pinus armandii	Density -	%	5	3	<0.5	2	-	-	-	**2**
	Basal area -	%	2	2	0	1	-	-	-	**1**
	Volume -	%	2	2	0	1	-	-	-	**1**
Betula albosinensis	Density**	%	-	-	2	-	-	-	<0.5	**<0.5**
	Basal area**	%	-	-	8	-	-	-	1	**1**
	Volume**	%	-	-	9	-	-	-	2	**2**
Other species	Density*	%	18	35	53	47	52	82	51	**46**
	Basal area**	%	13	20	29	30	27	37	41	**29**
	Volume**	%	13	18	25	27	22	28	37	**25**

11.3 Appendix zu Kapitel 4

Annex 4.1: Expanded gap size (m^2) and their canopy gap (openness, %) of the 11 gaps

Plots of gap	Expanded gap m^2	Canopy gap %
1. (801#)	72.8	25.79
2. (805#)	133.1	16.35
3. (809#)	97.6	11.83
4. (813#)	103.0	35.16
5. (817#)	94.8	13.22
6. (821#)	94.9	10.99
7. (825#)	148.5	11.84
8. (829#)	148.5	12.50
9. (833#)	193.3	23.01
10. (837#)	176.7	11.85
11. (841#)	102.2	21.36

Annex 4.2: Nonparametric correlations (Speaman's rho) between the **density** (trees ha-1) of *Quercus aliena* var. *acutiserrata* (height 50 - 130 cm), to parameter of light (%) (**openness**, **PBCL direct:** below canopy direct solar radiation, **PBCL diffuse:** below canopy diffuse solar radiation) (n=44).

		Openness	Density of Oak
Openness	Correlation Coefficient	1.000	**0.383***
	Sig. (2-tailed)		.010
Density of Oak	Correlation Coefficient	**0.383***	1.000
	Sig. (2-tailed)	0.010	
		Density of Oak	**PBCL direct**
Density of Oak	Correlation Coefficient	1.000	**0.363***
	Sig. (2-tailed)		0.016
PBCL direct	Correlation Coefficient	**0.363***	1.000
	Sig. (2-tailed)	0.016	
		Density of Oak	**PBCL diffuse**
Density of Oak	Correlation Coefficient	1.000	**0.405****
	Sig. (2-tailed)		0.006
PBCL diffuse	Correlation Coefficient	**0.405****	1.000
	Sig. (2-tailed)	0.006	

Annex 4.3: Evaluation criteria of natural regeneration of the national forest inventory (SFA 2003), the classes of evaluation are after density (trees ha^{-1}).

Height class of juveniles cm	CLASSES OF EVALUATION		
	Good	Middle	Poor
		Density (trees ha^{-1})	
< 30	≥5000	3000 - 4999	< 3000
30-49	≥3000	1000 - 2999	< 1000
≥50	≥2500	500 - 2499	< 500