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Concept for sustainable management of Oriental Hornbeam (Carpinus Orientalis Mill.) forests in Bulgaria

Konzept zur nachhaltigen Bewirtschaftung der Orient-Hainbuchen-Wälder (Carpinus Orientalis Mill.) in Bulgarien

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Keywords: *ecosystem adaptation, natural succession, regeneration, management plans, coppice, mixed forests, restoration, soil fertility*

Schlüsselbegriffe: *Ökosystemanpassung, natürliche Sukzession, Verjüngung, Managementplan, Stockausschlag, Mischwald, Wiederherstellung, Bodenfruchtbarkeit*

Abstract

The Oriental hornbeam (*Carpinus orientalis* Mill.) forests cover about 5 % of the Bulgaria's forest area. These forests were considered of low value from a forest industry perspective and during the last 60 years forestry in Bulgaria has put huge effort into their removal by clearcutting and subsequent afforestation with pines. The Oriental hornbeam forests survived nonetheless and gave us an opportunity to appreciate their important ecological role. The Oriental hornbeam is one of the most drought-resistant trees and is tolerant to very poor soil conditions. It forms forest ecosystems that supply a variety of ecosystem services from extremely poor and dry sites where other tree species cannot survive. The main aim of the present study is to define a scientifically based approach for management of the Oriental hornbeam forests in Bulgaria that takes into consideration their ecological role, sustainability and produc-

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tivity. A classification of Oriental hornbeam forests has been developed according to site conditions. Three groups of forests are identified depending on their site characteristics: Group I – on very poor sites; Group II – on poor sites; and Group III – on medium fertile and fertile sites. In each group the growth potential of Oriental hornbeam has been studied and compared to that of the alternative tree species. Forest regeneration and natural succession processes in the three groups of forests have been investigated. Based on that, long-term targets for sustainable management of the Oriental hornbeam forests in Bulgaria are proposed.

Zusammenfassung

Die Fläche der Orient-Hainbuchenwälder (*Carpinus orientalis* Mill.) macht etwa 5 % der Waldfläche Bulgariens aus. Diese Wälder wurden aus Sicht der Holznutzung als wertlos eingestuft und in den letzten 60 Jahren hat die bulgarische Forstwirtschaft große Anstrengungen unternommen, sie durch Kahlschlag zu beseitigen und mit Kiefern wieder aufzuforsten. Die Orient-Hainbuche überlebte trotzdem und gab uns Gelegenheit, ihre wichtige ökologische Rolle zu würdigen. Die orientalische Hainbuche ist eine der dürreverträglichsten und bodentolerantesten Baumarten. Sie bildet vitale Waldökosysteme und liefert eine Vielzahl von Ökosystemleistungen auf extrem armen und trockenen Standorten, wo andere Baumarten nicht überleben. Das Hauptziel der vorliegenden Forschung ist es, eine wissenschaftlich fundierte und differenzierte Methode zur Bewirtschaftung der Oriental-Hainbuchenwälder in Bulgarien unter Berücksichtigung ihrer ökologischen Rolle, der Nachhaltigkeit der Forstwirtschaft und der Waldproduktivität zu definieren. Es wurde eine Klassifizierung der Orient-Hainbuchenwälder nach den Standortbedingungen entwickelt. Drei Gruppen von Wäldern wurden in Abhängigkeit von ihrer Ökosystemanpassung identifiziert: Gruppe I – auf sehr armen Standorten; Gruppe II – auf armen Standorten; und Gruppe III – auf mittelfruchtbaren und fruchtbaren Standorten. In jeder Gruppe wurde das Höhenwachstum der orientalischen Hainbuche untersucht und mit dem der alternativen Baumarten verglichen. Naturverjüngung und Sukzession der Baumarten in den einzelnen Wäldergruppen wurden untersucht. Auf dieser Grundlage wurden langfristige Ziele für eine nachhaltige Bewirtschaftung der Orient-Hainbuchenwälder in Bulgarien vorgeschlagen.

1. Introduction

The Oriental hornbeam (*Carpinus orientalis* Mill., *C. duinensis* Scop.) is a small-sized tree which reaches a height of up to 18 m and a diameter up to 30 cm (Yurukov, 2003). On poor and dry sites it usually forms a bushy habit (Dodev, 2016). It is an early successional tree species which quickly occupies gaps. After cutting it forms numerous shoots from each stool and keeps this ability until an old age. The Oriental hornbeam is native to Southeastern Europe, Asia Minor (Anatolia), Caucasus, Northern Iran and a small part of Azerbaijan (Yurukov, 2003; Tsitsoni et al., 2013; Güney et al., 2013; Yoo & Wen, 2002, 2007; Yaltirik, 1975; Agardh, 1936; Walters, 1964; Mozaffarian, 2005). It is

widely distributed in the lowlands and low mountains in the Balkans and dominates in the composition of xerothermic forests (Popović et al., 1997).

The Oriental hornbeam occupies 197 909 ha in Bulgaria (EFA, 2015) which makes 5.1 % of the country's forest area. It is ubiquitous in the country except in high mountain areas. Distribution of the Oriental hornbeam forests in Bulgaria is presented on Figure 1. The green dots are forest stands with 50 % or more of Oriental hornbeam in the tree composition. Information was obtained from the Forest Management Plans of all forest departments in Bulgaria at the end of 2018. The administrative borders of studied three state forestry departments described below have been outlined.

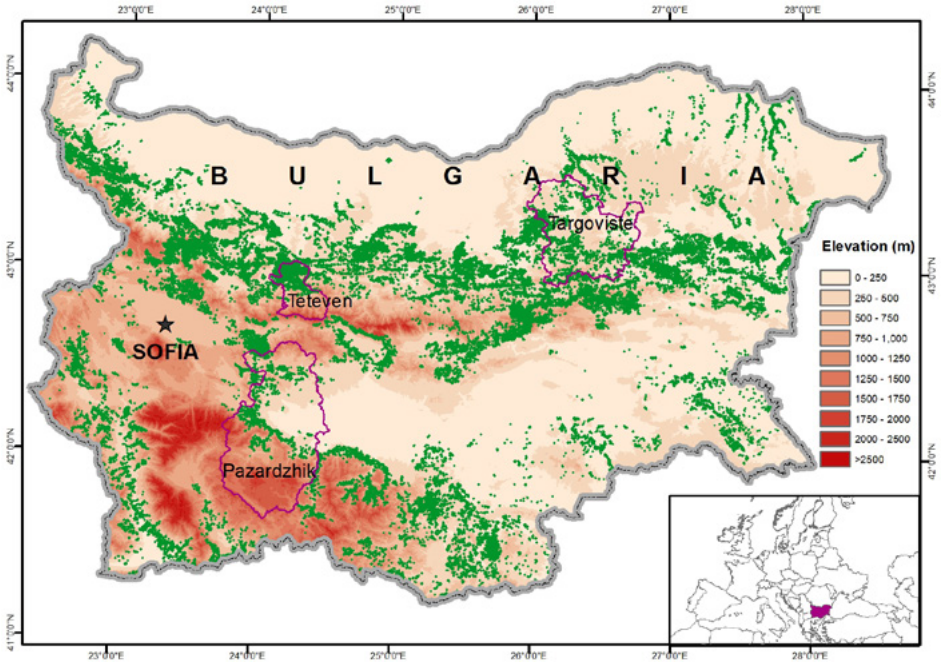


Figure 1: Distribution of the Oriental hornbeam forests in Bulgaria.

Abbildung 1: Verbreitung der Orient-Hainbuchenwälder in Bulgarien.

The Oriental hornbeam is one of the most drought-resistant and tolerant to soil conditions tree species known, which survives at both soil and atmospheric droughts (Bobrov, 1970; Browicz, 1982; Sabeti, 1976). It is also widespread on poor humus-carbonate soils (Rendzinas) developed on carbonate rocks.

Due to its small size and low timber productivity the Oriental hornbeam was considered by the Bulgarian foresters as a *"low-value"* and *"weed"* species. In 1960s the so called "reconstruction" (*from Latin: reorganization, transformation*) started in Bulgarian forests at a national level. Practically, it was clearcutting of all "low-value" broadleaved forests and afforestation in their place with more productive coniferous species, mainly Scots pine (*Pinus sylvestris* L.) and Black pine (*Pinus nigra* Arn.). All Oriental hornbeam forests were planned for "reconstruction" and huge efforts for its removal were taken. But the pine plantations were established mainly outside their natural range, which in Bulgaria extends from an altitude of 800 m upwards (Popov et al., 2018). Nowadays the coniferous plantations created in place of Oriental hornbeam forests are characterized by a poor condition and in those aged over 40 years a process of dieback is ongoing. In these plantations the Oriental hornbeam forms a dense understory and will inevitably dominate in the next forest generation (Popov et al., 2018). In addition, it aggressively colonizes the exposed areas in the oak forest zone (0-800 m a.s.l.). As a result of these natural degradation-recovery processes, the total area of Oriental hornbeam forests is nowadays close to its level before the start of reconstructions (Stiptsov, 1995).

The reconstruction policy in Bulgaria was officially revoked in 2007. Since then, the Oriental hornbeam forests are managed under simple coppice. But this approach is not working well. Because of the low timber production and lack of economic profitability, the planned clearcuttings are not implemented by the owners. Finding an alternative system is needed to ensure sustainable management of these forests under changing climatic conditions.

Bulgaria has one of the highest biodiversity in Europe and is the last country in the southeast with significant forest resources (World Bank, 1995). Forests cover 37 % of the country's territory (EFA, 2015). The forests fulfill multiple functions, including provision of wood and non-wood forest products and services, such as regulation of runoff, purification of air and water, carbon storage, protection from natural hazards, and provision of cultural services (MAES, 2013). The role of forests in providing a wide range of ecosystem services is increasingly acknowledged, especially in the context of climate changes. Preserving biodiversity is directly linked to the problem of climate change. According to the climate change scenarios (Alexandrov, 2007; Raev et al. 2015; Tsenov et al. 2015) the climate in Bulgaria will become hotter and drier in near future. The most negative impacts are expected to affect forests situated from 0 to 800 m a.s.l. Therefore, Oriental hornbeam, as one of the most drought-resistant and adaptable tree species, could be considered as a key species in mitigation of climate change impacts in the driest areas, ensuring survival of forests and providing ecosystem services. It could play a role of a "natural barrier" against the expanding semi-deserts emerging from the Mediterranean.

Considering the current silvicultural focus on multifunction forest management and ecosystem services, the Bulgarian forest policy is paying more attention to the import-

ant ecological significance of the Oriental hornbeam forests. Previous management of these forests was unsuccessful because it was focused only on timber production, without considering the high variability of growth conditions, the sustainability of the stands, as well as the direction of the natural succession processes.

The main aim of the present study is to define a scientific-based and differentiated approach for management of Oriental hornbeam forests in Bulgaria considering their ecological role, resilience and productivity.

The objectives of the study are:

1) To classify the Oriental hornbeam forests according to the site conditions;
2) To study growth, development and succession processes in each group of forests;
3) And specific long-term management targets for each group of forests to be proposed.

2. Material and methods

The Oriental hornbeam forests in Bulgaria are studied at national level based on official data. The last inventory data of all state forest departments in Bulgaria were collected and summarized. Based on the forest management plans published on the web-site of the Bulgarian Executive Forest Agency (http://www.iag.bg/), a database of single-stand level inventory data was compiled and used for analyses. All forest stands have been included. The information obtained was cross-referenced using the annual reports of the Executive Forest Agency (EFA, 2015). Because the study is based on comprehensive data, only descriptive statistics have been applied.

In order to study Oriental hornbeam forests' growth dynamics and development and to identify an appropriate management approach, a classification of these forests according to the site conditions was elaborated. The classification is based on the following objective and measurable indicators used in an integrated way – altitude, soil fertility, soil moisture and composition of forest stands. These data are available for each forest stand in Bulgaria. These are the main indicators which determine the natural distribution of tree vegetation in the country and each site's forest growth potential.

Almost all Oriental hornbeam forests in Bulgaria (98.5 %) are found below 1000 m a.s.l. A very small part (1.5 %) is located at a higher altitude (between 1000 and 1500 m a.s.l.). Due to their insignificant importance for the forestry sector they are excluded from the present analyses.

The nomenclature of Pogrebnyak (1955) is used for indication of soil fertility and soil moisture, as follows:

- Soil fertility: A – very poor; AB – very poor to poor; B – poor; BC – poor to medium fertile; C – medium fertile; CD – medium fertile to fertile; D – fertile.

- Soil moisture: 1 – dry; 1, 2 – dry to fresh; 2 – fresh; 2, 3 – fresh to moist; 3 – moist; 3, 4 – moist to wet; 4 – wet.

The same nomenclature is used in the Classification scheme of the forest habitats in Republic of Bulgaria (EFA, 2011) and is available for each forest stand in the country.

All combinations of soil fertility and soil moisture were identified for the county's forest area within an altitude of 0 and 1000 m a.s.l. The participation (percentile share) of Oriental hornbeam in the forest area was calculated for each combination of soil fertility and soil moisture through 100 m altitude. The combinations with area less than 0.3 % of the total area are not considered. Their total area is really small (1.2 % of the country forest area). By omitting this area the classification scheme is simplified with a view to its application to forestry practice. Thus, the scheme covers 98.8 % of the total forest area in Bulgaria from 0 to 1000 m a.s.l. and 98.5 % of the area occupied by Oriental hornbeam in the country.

Composition and growth of the Oriental hornbeam forests were investigated using a database containing recent inventory data for all state forest departments in Bulgaria. The database used was verified and additional information was collected by sample plots. A total number of 150 sample plots (circles with area of 100 m² each) were established and studied. The sample plots were established randomly in Oriental hornbeam forests in different age and on different Pogrebnyak's site types, covering the whole variability of these forests. The sample plots are distributed on the territory of three state forestry departments – Teteven, Targoviste and Pazardzhik (*see Figure 1*). Covering an area of near 10 % of the territory with Oriental hornbeam forests in Bulgaria as well as the range of characteristics of these ecosystems, these departments are considered representative of the whole variety of Oriental hornbeam forests in Bulgaria.

In each sample plot a sub-plot with an area of 25 m² was established to quantify the natural regeneration. All saplings in these sections were counted and differentiated according to the tree species, size and origin (seed or coppice).

3. Results and discussion

3.1. Classification of Oriental hornbeam forests according to the site conditions

The Oriental hornbeam is characterized by high plasticity and competitiveness. It is found on a great variety of sites – from very poor and dry to fertile and moist ones.

The species can be dominant or be an associate in the canopy of forest stands, or be a part of the understory. This variety of site conditions results in differences in the sustainability and productivity potential of both economically valuable tree species and Oriental hornbeam and determines different pathways and speed of natural succession.

It is important to underline that the Oriental hornbeam in Bulgaria occurs through natural processes (nobody plants it). So, its distribution is a key criterion for determination of its:

- stability to the environmental conditions;
- sustainability in the time through the natural regeneration;
- productivity compared to the other tree species - at the end of the nature succession the most sustainable and productive species occupy the territory (Gordon et. al., 1996).

Table 1 presents the participation of Oriental hornbeam in the forest area in Bulgaria according to the site conditions. All existing combinations of soil fertility and soil moisture are differentiated through 100 m altitude. Combinations, which are not present at some altitude and those with total area less than 10 ha are noted with "–" in the table. Such small areas would be dealt with through specific case-studies and are not taken into account in the analysis. The values in the table are percentages and represent the average share of the Oriental hornbeam in the forests within this class (e.g. forests on very poor and dry sites (A1) in 0-100 m a.s.l. have 37 % Oriental hornbeam and 63 % other tree species like oaks, beech, etc.).

Table 1: Participation of Oriental hornbeam in the forest area in Bulgaria according to the sites' conditions.

Tabelle 1: Teilnahme der orientalischen Hainbuche im Waldgebiet in Bulgarien nach den Standortbedingungen.

Altitude, m a.s.l.	Site conditions (combinations of soil fertility and soil moisture)											
	very poor and dry (A1)	very poor to poor and dry (AB1)	poor and dry (B1)	poor and dry to fresh (B1,2)	medium fertile and dry (C1)	medium fertile and dry to fresh (C1,2)	medium fertile and fresh (C2)	medium fertile to fertile and fresh (CD2)	medium fertile to fertile and fresh to moist (CD2,3)	fertile and dry (D1)	fertile and fresh (D2)	fertile and fresh to moist (D2,3)
	Proportion of Oriental hornbeam in the forest area (%)											
0-100	37	64	37	30	6	6	2	1	1	1	0,4	0,3
101-200	45	53	41	23	5	7	2	0,3	0,3	1	1	0,01
201-300	51	58	38	19	7	8	3	1	1	1	0,3	0,1
301-400	46	58	34	17	7	5	4	1	1	1	1	0,01
401-500	47	63	30	19	6	5	3	0,3	0,3	3	2	0,04
501-600	45	68	27	22	6	4	3	0,03	0,03	-	0	0,04
601-700	38	44	24	19	5	2	2	0,01	0,01	-	0,1	0
701-800	33	47	18	15	2	1	1	0,03	0,03	-	0,1	0
801-900	21	21	11	11	-	2	1	0,1	0,1	-	0,01	0
901-1000	31	17	8	9	0	1	0,3	0,01	0,01	-	0	0

Legend:

- Zone 1: Oriental hornbeam is a dominant tree species of the forest area
Zone 1: Orientalische Hainbuche ist eine vorherrschende Baumart im Waldgebiet

- Zone 2: Oriental hornbeam is not dominant but contributes significant part (over 5%) of the forest area
Zone 2: Die orientalische Hainbuche ist nicht vorherrschend, nimmt jedoch einen erheblichen Anteil (über 5%) an der Waldfläche ein

- Zone 3: Oriental hornbeam is a minor species (up to 5%) in the forest area
Zone 3: Orientalische Hainbuche hat eine geringe (einmalige) Beteiligung (bis zu 5%) am Waldgebiet

The results obtained show that:

- The Oriental hornbeam's abundance in the forest area is mainly related to the soil fertility of the sites – increasing soil fertility is related to a strong decrease in its abundance in the forest area;

- Soil moisture by itself is not the determining factor for abundance of Oriental hornbeam – within the range of one soil fertility class its abundance varies slightly at different soil moisture levels;

- The altitude is not a determining factor for the proportion of Oriental hornbeam within its natural range (0-1000 m a.s.l.).

Three zones could be determined in *Table 1*:

- Zone 1 - The Oriental hornbeam is the dominant tree species. It occupies the largest area compared to the other tree species. This zone covers mainly very poor (A) and very poor to poor (AB) sites.

- Zone 2 – The Oriental hornbeam is not a dominant but occupies a significant part (over 5 %) of the forest area. This zone covers mainly poor (B) and poor to medium fertile (BC) sites.
  Participation of 5 % in the forest area is the traditional limit of significance in Bulgarian forest inventory. If a tree species occupies less than 5 % in the stand area, its participation is indicated as "single" (insignificant) in the inventory form of the forest stand. If it occupies 5 % or more, its participation is considered significant and is denoted by an integer from 1 to 10 (where 1 means 10 %, 2 – 20 %, and so on).

- Zone 3 – The Oriental hornbeam covers a small part (up to 5 %) of the forest area. This zone covers mainly medium fertile (C), medium fertile to fertile (CD) and fertile (D) sites.

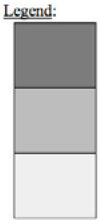
Table 1 shows that Zone 2 enters into medium fertile (C) sites at lower altitude. Usually the medium fertile (C) sites between 0 and 600 m a.s.l. are typical oak habitats. At the same time most of the settlements in the country are situated there. Oriental hornbeam has increased its abundance there due to the intensive anthropogenic impact on the autochthonous oak forests in the past – uncontrolled cuttings, intensive pasture, pollarding and shredding, damaging forestry activities, etc. The Oriental hornbeam has replaced the oaks due to its extraordinary ability to produce coppice. Nevertheless, these sites are not typical for Oriental hornbeam and in case of lack of anthropogenic pressure its abundance would be reduced by natural succession. It is assumed that where the proportion of Oriental hornbeam is over 5 % (Zone 2) on medium fertile (C) sites, which is a temporary effect (earlier stage in succession) caused by human influences.

Table 1 shows that the soil fertility of the sites is the main indicator which determines the abundance of Oriental hornbeam in the forest area in Bulgaria, and the three zones respectively. Based on the results obtained and with a view to application of the classification in the forestry practice *Table 1* could be simplified into the more practical *Table 2*. It presents the proportion of Oriental hornbeam in the forest area in Bulgaria according to soil fertility of the sites.

Table 2: Short classification of the zonal distribution of Oriental hornbeam in the forest area in Bulgaria according to soil fertility of the sites.

Tabelle 2: Kurze Einteilung der Zonenverteilung der Hainbuche im Waldgebiet in Bulgarien nach den Bodenfruchtbarkeit der Standorte.

	Soil fertility of forest sites						
	very poor (A)	very poor to poor (AB)	poor (B)	poor to medium fertile (BC)	medium fertile (C)	medium fertile to fertile (CD)	fertile (D)
Total forest area in Bulgaria (0-1000 m a.s.l.), ha	63708	35519	495056	6811	1493799	356863	469758
Proportion of Oriental hornbeam in the forest area (%)	42	57	21	18	3	1	1



Legend:

- Zone 1: Oriental hornbeam is a dominant tree species in the forest area
Zone 1: Orientalische Hainbuche ist eine vorherrschende Baumart im Waldgebiet

- Zone 2: Oriental hornbeam is not dominant but contributes a significant part (over 5%) of the forest area
Zone 2: Die orientalische Hainbuche ist nicht vorherrschend, nimmt jedoch einen erheblichen Anteil (über 5%) an der Waldfläche ein

- Zone 3: Oriental hornbeam is a minor part (up to 5%) of the forest area
Zone 3: Orientalische Hainbuche hat eine geringe (einmalige) Beteiligung (bis zu 5%) am Waldgebiet

Table 2 clearly confirms that the three zones depend only on the soil fertility of the sites. On very poor (A) and very poor to poor (AB) sites the Oriental hornbeam naturally is a dominant species. On poor (B) and poor to medium fertile (BC) sites it is not dominant but contributes a significant part (18-21 %) of the forest area. On medium fertile (C), medium fertile to fertile (CD) and fertile (D) sites it makes a small contribution (1-3 %) to the forest area. This applies in its natural range (0-1000 m a.s.l.).

The forests dominated by the Oriental hornbeam in Bulgaria occupy 232 296 ha. Based on the zones identified above three groups of forests are differentiated.

Group 1 – Oriental hornbeam forests on very poor sites

The sites are very poor (type A) and very poor to poor (type AB), dry, steep and sunny. Soils are mainly Rendzinas (WRB, 2015), shallow, dry, with high percent of stoniness, eroded, characterized by very low forest growing potential (EFA, 2011). Nearly 24 % of the forests dominated by Oriental hornbeam in Bulgaria (56 050 ha) are located in such terrain. On these poorest sites, the Oriental hornbeam is a dominant tree species – it covers the largest part of the forest area compared to the other tree species and perhaps it is the climax species. It is well adapted to the ecological conditions there and is characterized with good natural regeneration. Usually it forms sparse mixed xerothermic forests with other thermophilic species (mainly shrubs). Often these ecosystems are assessed as commercially worthless but actually they are very important

in terms of biodiversity and ecosystem services. If there is no anthropogenic impact, these formations are sustainable. Most of them are vulnerable to human activity, even at low intensity (Popov et al., 2007).

Group 2 – Oriental hornbeam forests on poor sites

The sites are poor (type B) and poor to medium fertile (type BC), dry and dry to fresh, steep to very steep, on sunny slopes. Soils are shallow, stony, eroded, with low content of soil organic matter and low forest growing potential (EFA, 2011). Mixed xerothermic oak forests dominated by pubescent oak (*Q. pubescens* Willd.), Hungarian oak (*Q. frainetto* Ten.) and Turkey oak (*Q. cerris* L.) are typical for these sites. Naturally, the Oriental hornbeam is quite frequent but not a predominant species in these forests. However, nowadays 52 % of the Oriental hornbeam forests (120 944 ha) are found on such sites. Usually they are secondary forests where Oriental hornbeam has replaced the oaks due to its better capacity for coppice formation. The main reason is negative anthropogenic influence on the primary oak forests - uncontrolled clearcuttings, intensive pasture, pollarding and shredding, poor forestry practices, etc.

Group 3 – Oriental hornbeam forests and understory on medium fertile and fertile sites

The sites are referred to as medium fertile (C), medium fertile to fertile (CD) and fertile (D). These are non-eroded habitats of various slopes and exposures, with medium-deep and deep soils, with low to medium stoniness and different levels of soil moisture (EFA, 2011). The forest growing potential of these sites is good. Naturally, the Oriental hornbeam takes very small (single) participation in the forest area. The oaks (they are late succession tree species here) are in their ecological optimum and they limit the long-term perspective of the Oriental hornbeam.

Nowadays, 24 % of the Oriental hornbeam forests (55 302 ha) are formed on such sites. These are secondary forests resulting from human activity. The reasons for their formation are the same as those described in the second group. The difference is that the habitats here are characterized by a higher forest growing potential. Besides, on these sites the Oriental hornbeam is the predominant tree species of the understory in all forest types in Bulgaria. It forms an understory across 650 000 ha which is 17 % of the total forest area in Bulgaria.

The main idea of the proposed classification is to consider simultaneously the sustainability and productivity of existing and alternative forest stands. It is within the line of the concept of Potential Natural Vegetation (Tuxen, 1956; Westhoff & Van der Maarel, 1973) and Ecosystem fit (Gordon et al., 1996). The classification allows the investigation of the growth and development dynamics of Oriental hornbeam stands according to environmental conditions, to compare them to alternative stands and to define management targets for each identified forest group.

3.2. Growth and development of the Oriental hornbeam forests

About 84 % of the Oriental hornbeam forests have mixed composition. Most often (in 67 % of cases) Oriental hornbeam has formed mixed stands with oaks, in particular with Turkey oak (*Q. cerris* L.), pubescent oak (*Quercus pubescens* Willd.), Hungarian oak (*Q. frainetto* Ten.) and sessile oak (*Q. petraea* Liebl.). The oaks are the main possible alternatives to Oriental hornbeam, if natural regeneration and succession processes are unhindered. They are autochthonous tree species, suited to the ecological conditions and with a higher economic value than the Oriental hornbeam. Moreover, in the past oaks have dominated many sites which today are occupied by Oriental hornbeam forests. Oaks exhibit different abundance in the different groups of Oriental hornbeam forests (*Figure 2*).

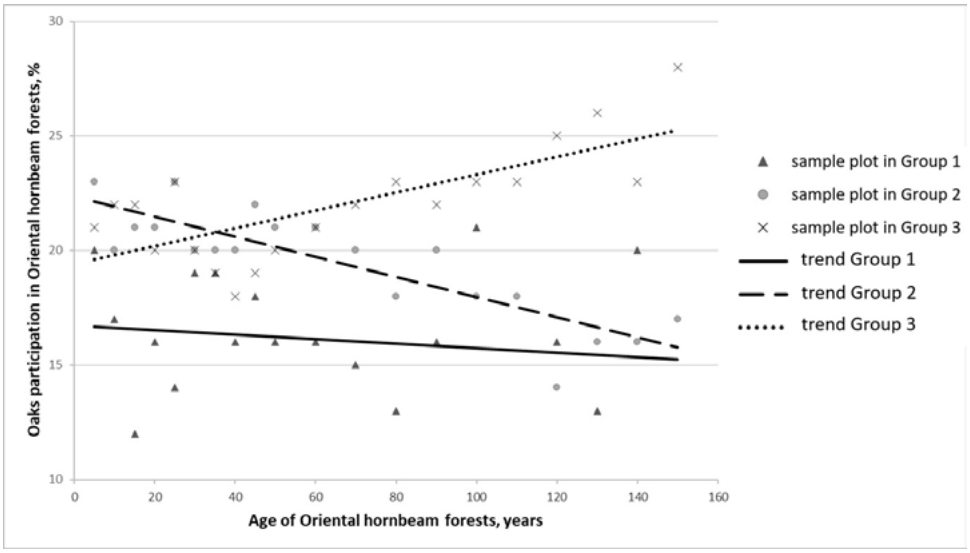


Figure 2: Proportion of oaks in Oriental hornbeam forests.

Abbildung 2: Flächenanteil der Eichenarten in Orient-Hainbuchenbeständen.

In Group 1 of Oriental hornbeam forests the oaks are found rarely and account for around 15 % in the stands' composition. Their proportion does not change significantly with increasing age of the stands. The conditions are not suitable for them which limits their abundance. The Oriental hornbeam is the best adapted species on these sites.

In Group 2 of Oriental hornbeam forests the proportion of oak is higher (around 20 %). With increase in the stands' age their abundance decreases. This indicates that

they are not competitive enough to replace the Oriental hornbeam in the canopy. Their proportion varies a lot from stand to stand but also within a stand. A lot of pure forest stands (mostly on very steep, stony and dry terrain) can be found, but also stands with a high proportion of oaks and other tree species. Even in such cases the oaks distribution is not uniform across the stand, but rather has a scattered mosaic pattern which depends on the specific micro conditions (Dodev, 2016).

In Group 3 of Oriental hornbeam forests the proportion of oaks is between 20-25 % and increases as forest age increases. They are competitive enough to replace the Oriental hornbeam from the main canopy to the understory. Usually they are uniformly distributed across the stand area (Dodev, 2016). Pure Oriental hornbeam forests are very rare.

The height growth of oaks is compared to that of Oriental hornbeam for the three groups of Oriental hornbeam forests in *Figure 3*. The figure is based on comprehensive data available for all Oriental hornbeam stands in Bulgaria (actual FMP). Each height plotted presents the average value formed from data of thousands of forest' stands and descriptive statistics have been used.

The difference between the mean height of the oaks and the Oriental hornbeam is about 2 m in forests of Group 1 (*Figure 3a*). The height difference does not increase with age. The growth of oaks is not significantly better than that of Oriental hornbeam. The very poor sites limit the oaks growth and they are not able to realize their potential.