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German-Ukrainian Efforts Towards Building Climate-Resilient Forests in Western Ukraine – First Results of Alternative Regeneration Systems

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ABSTRACT

Due to the current changes in the socio-ecological system in Ukraine, forest adaptation is of high importance. Continuous-Cover Forestry (CCF) is seen to be promising for Ukraine to provide the Ukrainian society with various ecosystem services from forests and to increase the adaptive capacity of Ukrainian forests. First, basic features of Ukrainian forests and the forest sector are outlined, and the regeneration systems of the major tree species with economic value are described. Moreover, the need for forest conservation in order to safeguard the biodiversity of Ukrainian forests is highlighted. Based on a joint Ukrainian-German research project called 'Resilpine', the first scientific results on the regeneration of major tree species in Ukraine with alternative silvicultural systems to clearcut are illustrated. The data show that natural regeneration in group (or patch) selection systems is abundant and sufficient compared to clearcut. Especially Scots pine, but also intermediate species, are establishing. Group selection cutting can therefore be recommended as a promising alternative natural regeneration system to clearcutting in order to convert Ukrainian forests.

Keywords: silvicultural systems; alternatives to clearcutting; natural regeneration; Continuous-Cover Forestry (CCF); forest conversion; national forestry strategy; Ukraine

INTRODUCTION

Forests are a natural wealth of Ukraine, and they have been managed sustainably for many decades. Recently, close-to-nature silviculture or Continuous-Cover Forestry (CCF) has been introduced in Ukraine in order to reconcile timber production and biodiversity conservation and to reduce forest vulnerability to adverse effects of climate change (Krynytskyy et al. 2014). Moreover, CCF is seen to be the most promising silvicultural approach in the current discussions in the Ukrainian national forestry strategy until 2035. The long-term goal is to establish and further develop mixed forests with high structural diversity from natural regeneration. Many scientists especially recommend natural regeneration as a rejuvenation method without using clearcuts.

Therefore, the goals of the present paper are to:

(i) provide an overview of the current state and new tendencies in Ukrainian forestry, and to

(ii) present first empirical results on the natural regeneration of the three main tree species, namely Scots pine (*Pinus sylvestris*, L.), pedunculate oak (*Quercus robur*, L.) and European beech (*Fagus sylvatica*, L.), with alternative cutting schemes to clearcut.

FOREST RESOURCES, FOREST TYPES AND FOREST OWNERSHIP IN UKRAINE

The total geographic area of Ukraine is 60,362,800 ha, whereas the forested land encompasses about 9.7 million ha. Thus, the forest share is 16.1%, which is much lower than average in Europe. The forest area per capita in Ukraine is 0.22 ha. The highest forest cover percentages can be found in the Carpathian region, with 42%, and in the north of Ukraine (Polissya). However, the steppe zone has a low forest cover of 5.3% (Figure 1). The total standing volume of

timber in Ukrainian forests in 2018 was 2.102 billion m^3, with an average stocking per ha of 216 m^3 (State Forest Resources Agency of Ukraine 2019). The average growing stock in Europe amounts to 169 $m^3 \cdot ha^{-1}$, with 255 m^3 in the Central-East region (Forest Europe 2020). The average standing volume in Ukrainian state forests increased significantly, from 171 in 1988 to 216 $m^3 \cdot ha^{-1}$ in 2018. This is in line with the increasing growth trends in Europe since 1950 (Spiecker et al. 1996). The average annual increment is 4 $m^3 \cdot ha^{-1}$ and ranges from 5.0 $m^3 \cdot ha^{-1}$ in the Carpathians to 2.5 $m^3 \cdot ha^{-1}$ in the steppe zone (State Forest Resources Agency 2019).

Ukrainian forests have a diverse tree species composition: pine forests occupy the largest areas with 35%, dominated by Scots pine (*Pinus sylvestris* L.), followed by oak forests (28%, mostly pedunculate oak; *Quercus robur* L.), beech (*Fagus sylvatica* L., 9%), spruce (*Picea abies* (L.) Karst., 8%), birch (predominantly *Betula pendula* Roth., 7%) and alder (mostly *Alnus glutinosa* (L.) Gaerth., 4%) forests (other species amount to 9%). Pine forests grow mainly in the northern part of Ukraine, the Polissya, oak forests in the central part of the forest steppe zone, while beech, spruce and silver fir are more common in the mixed mountainous forests of the Carpathians and in the west of the country. Moreover, 0.6% of Ukraine's forests are primary forests, among them some of Europe's most impressive beech primeval forests (Commarmot et al. 2013). According to the soil nutrition status and soil water content, and due to the leading tree species, more than 180 forest types are distinguished in Ukraine. The predominating forest types are pine forests on fresh, poor soils, oak-pine forests on fresh, relatively poor soils, hornbeam-oak forests on fresh, relatively rich soils and hornbeam-oak forests on fresh, rich soils (Ostapenko and Tkach 2002). Most forests in Ukraine are even-aged, with age classes not evenly distributed due to massive afforestation after the Second World War. The average age of forests is about 60 years. Middle-aged stands dominate with 45%, and mature and overmature stands only make up 17%. Currently about 50% of Ukraine's forests are planted and 50% have natural origin.

The extent and intensity of forest disturbances have been rising in the last decades in Ukraine. The area of dead forests increased from 4,000 $ha \cdot year^{-1}$ in the 1990s to above 20,000 $ha \cdot year^{-1}$ in 2015, mostly due to unfavorable weather conditions, insects, pathogens and fire. The predominant pests are the Scots pine disease complex with *Diplodia* in Northern Ukraine (Meshkova and Borysenko 2018) and a combination of drought and bark beetle attacks in spruce-dominated forests in the Carpathians (Debryniuk 2011, Kozlowsky et al. 2013).

The intensity of forest utilization in Ukraine is much lower than in Germany and most other European countries. Only about 19 million solid m^3 of wood are harvested annually in Ukraine. On average, this corresponds to a 2.0 $m^3 \cdot ha^{-1}$ forested area, with 45% coming from the final harvest and 55% from intermediate cuttings. Only around 55% of the annual increment is harvested. The reason are restrictions on use due to the high proportion of protection and recreation forests (together about 48% of the total forest area). Moreover, 16.1% of Ukrainian forests are already designated as conservation areas (Poliakova and Abruscato 2023).

The legal basis for managing Ukrainian forests is the Forest Code of Ukraine. This national law regulates the most critical issues of forest ownership, forest management, and

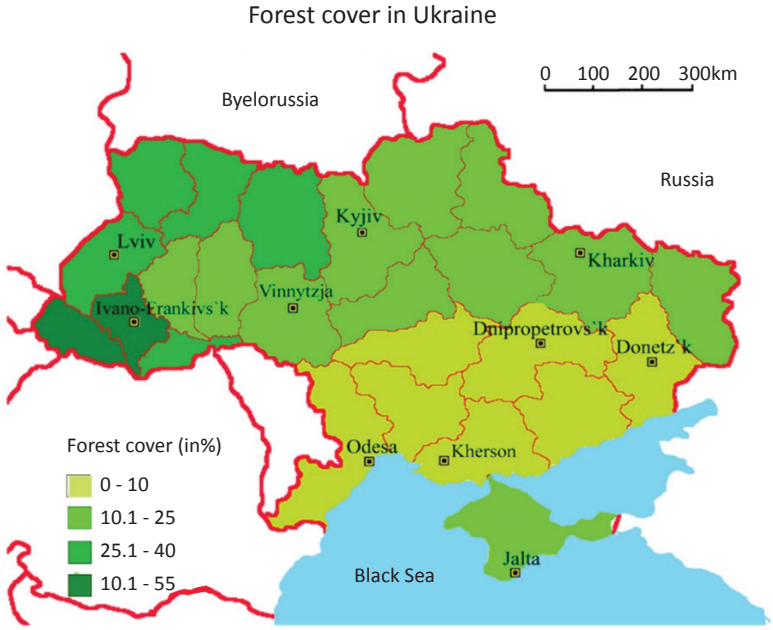

Figure 1. Map of Ukraine with forest cover (see Lavnyy and Spathelf 2018).

forest cadastre. Various ministries and state committees are responsible for the implementation of management. The largest and most significant 73% of forests belong to the State Forest Resources Agency of Ukraine. Considerable forest areas are finally assigned to other ministries (Figure 2).

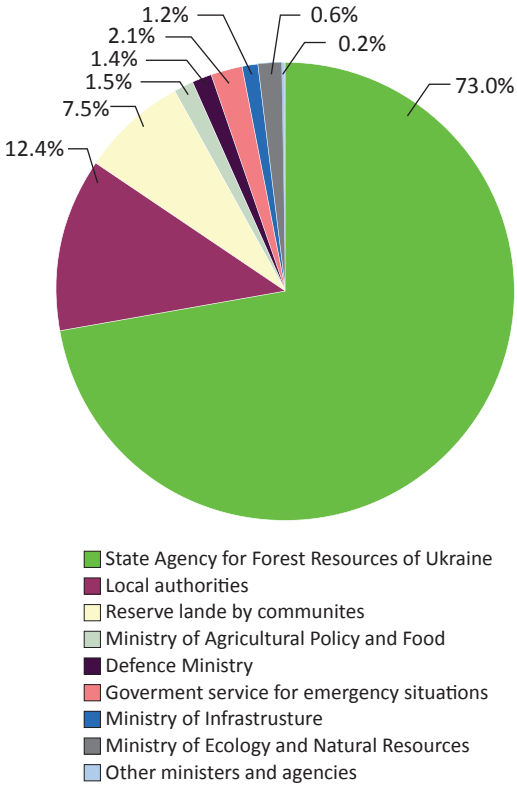

Figure 2. Forest ownership in Ukraine (in percentage), with the dominance of state-owned forests (State Forest Resources Agency of Ukraine 2019).

For obtaining more reliable and relevant data on Ukrainian forests, a National Forest Inventory (NFI) is currently being conducted; its results are expected in 2025. A major update will be obtained on forest areas (including natural succession), growing stock as well as tree species composition, age and quality aspects. Moreover, NFI will provide ecologically relevant forest data, e.g. deadwood volumes and sanitary conditions. The data will also be accessible to the informed public and civil society. In two test regions, Ivano-Frankivsk and Sumy, the first repetition of the NFI has delivered some interesting results: for example, standing volume has increased from 292 to 332 $m^3 \cdot ha^{-1}$ in Ivano-Frankivsk and deadwood volume from 16 to 23 $m^3 \cdot ha^{-1}$.

Since 2016, roundwood from Ukraine cannot be exported anymore. Moreover, manufactured timber can only be exported with an origin proof. The ban intends to ensure the processing of wood in Ukraine in order to increase the number of jobs in the forest sector of Ukraine's economy and gain added value.

MANAGEMENT CATEGORIES AND CONVENTIONAL MANAGEMENT OF ECONOMIC FORESTS

In the Ukrainian forest law, forests are divided into four categories according to their main functions or ecosystem services, respectively:

1. protection forests (e.g. water, soil),
2. recreation forests,
3. nature conservation forests (biodiversity),
4. economic forests.

The basis for the management of economic forests is forest planning with a management cycle of 10 years. Nevertheless, many communal forest owners do not have a management plan due to high costs. The forest management plan fixed the rotation period for the major economic tree species. For example, recently there has been a little shift to these more retention-oriented silvicultural systems (see also Gustafsson et al. 2020). The Ukrainian Forest Codex determines the maximum clearcutting area, which is 1-5 ha, depending on forest category and leading tree species (Cabinet of Ukraine 2009).

Also, 4.65 million ha of Ukrainian forests, which amounts to 48%, are currently certified by FSC, with a regional focus in the west and north of the country. Moreover, 373 Chain-Of-Custody certificates have been issued to date (FSC 2023). Since 2021, PEFC certificates have also existed in Ukraine.

PROTECTED FORESTS AND THEIR FUNCTIONS FOR BIODIVERSITY CONSERVATION AND AS LEARNING OBJECTS FOR CONTINUOUS-COVER FORESTRY

Maintaining biodiversity is a crucial goal of forestry all over Europe and supports the adaptation of forests to climate change (Spathelf and Bolte 2020). Therefore, employees of forest enterprises in Ukraine need to preserve micro-habitat trees in each taxation quarter, as well as to leave small areas of forest (10-20 hectares) without economic use to form habitat continuity there. In such set-aside areas, trees will be able to grow until the age of natural mortality and will become a home for many types of organisms (wood-destroying fungi, microorganisms, mosses, lichens, algae, insects, mammals and birds). It is also necessary to provide ecological corridors between areas of ancient forests so that there is a possibility for living organisms to migrate.

Ukraine possesses some of the most valuable primary forests of Central-eastern Europe (Figure 3). These forests are mostly protected under the World Natural Heritage Fund as biosphere reserves, national nature parks and nature reserves and comprise the following areas, among others:

- Kuzii-Trybushany
- Svydovets
- Chornohora, with Hoverla, the highest mountain in Ukraine with 2061 m asl
- Uholka – Schyrokyy Luh (the largest beech primeval forest in Europe)
- Carpathian National Park
- Nature Reserve Horhany.

The primeval beech-dominated forests in the Carpathian arc are structurally very diverse, but in terms of species distribution, they are dominated mainly by beech

(Uholka: 97%, with 3% distributed on 15 other more rare broadleaved tree species; Hobi, 2013). The standing volume of the living trees in the Uholka forest, on average, is 582 m^3 per ha, and the deadwood volume is 163 (±8) m^3. The relationship between standing and lying deadwood is 1:5. Another characteristic is the occurrence of very large and old trees. The dominant rejuvenation processes in these forests mostly include small gap regeneration (0.05 – 0.15 ha per gap), leading to a mosaic of different forest development stages. Larger canopy openings are quite rare events. The forests show all the features of true old-growth forests with small-scale forest disturbances (see 3). For an extensive compilation of relevant information on these forests, see Commarmot et al. (2013).

The main aims of these forests for Ukrainian silviculture are as follows:

- High relevance for biodiversity conservation,
- Important labs for the study of natural forest dynamics, and
- Demonstration areas to derive silvicultural approaches to manage continuous-cover forests.

It should be noted that over 40 years, the area of the territories and objects of the nature reserve fund on forest lands has increased four times (the area from 315 thousand ha in 1978 to 1327 thousand ha in 2019 and the reserve, respectively, from 5.5% to 16.8%) (Torosov et al. 2021).

THE PARADIGM SHIFT IN UKRAINE'S FOREST MANAGEMENT - THE NEW FORESTRY STRATEGY 2035 OF UKRAINE

The ministerial cabinet of the government of Ukraine adopted the Forestry Strategy 2035 on December 29, 2021. The revision of the strategy was necessary due to increasing problems with the health status of Ukrainian forests, the substitution of the outdated database on forests, the challenge of climate change and the necessity to adapt forests to climate change. Moreover, Ukraine strives to significantly increase its forest cover without privatizing it or granting concessions.

The purpose of the development of the Forestry Strategy is to ensure effective management of forests based on sustainable forestry, preservation of biodiversity in forests, and forest management adapted to climate change, among others.

The pathway and the instruments to do this will be forest conversion to forests composed of mostly native tree species from Ukraine, avoiding of clearcutting, and the strengthening of forest tending. Therefore, the legal framework for the implementation of silvicultural interventions and forest harvest in Ukraine will be further developed, considering the need to adapt forests to climate change. The planned paradigm shift in silviculture in Ukraine will consist of the following elements (Cabinet of Ukraine 2021):

- Conversion of even-aged pure stands by using climate-resistant native tree species,
- Use of natural regeneration for forest regeneration,
- Measures to maintain, restore and conserve the genetic diversity of forests,
- Measures to prevent and control the spread of alien tree species capable of invasion,
- Prevention of erosion during timber harvesting, especially in mountainous areas,
- Introduction of modern (innovative) technologies in forest management, forest harvest, forest protection and conservation,
- Protection of large and old so-called habitat trees, and
- Protection of all identified primary forests, including the establishment of the necessary protection zone around and its management, in accordance with the law.

Figure 3. Primeval forest Kuzii, with common ash, Norway maple, silver fir, European beech and Norway spruce.

It is expected that as a result of the strategy implementation, by 2035, Ukraine will have a forest coverage of the country's territory up to 18% and a total forest stock up to 2.5 billion m³. Consequently, there will be an increase in the level of carbon dioxide absorption by Ukrainian forests and an increase in forest productivity and sustainability. Moreover, forest fires will be reduced, and 100% of forest fires will be detected at an early stage. At least, forest roads will be improved, and forests will be promoted for tourism and recreation.

The most severe challenge of future management lies in the removal of ammunition and mines and the restoration of the war-destroyed forests in the occupied war zone in eastern and southern Ukraine. Otherwise, the pressure on forests, which were not impacted by the war, could increase dramatically. To tackle this endeavour and to focus on the transformation of the whole forest sector, a state forest enterprise was founded in January 2023 with 6.6 million ha of forest, comprising all the state forests. The intention of the government was to create a self-sufficient forestry enterprise that will not need subsidies (Poliakova and Abruscato 2023).

FOREST ADAPTATION TO CLIMATE CHANGE THROUGH CONTINUOUS-COVER FORESTRY

Forest adaptation to climate change has been recognized as an urgent need for Ukrainian forests, according to the new Forest Strategy 2035. The main pathway to achieve this goal is to change forest management towards close-to-nature forest management or continuous-cover forestry (CCF). CCF seeks to establish multi-layered stands with a high tree species diversity, which are regenerated preferentially by natural regeneration. Clearcutting is avoided as much as possible at this moment and substituted by selective cutting or irregular shelterwood cutting (Larsen et al. 2022). CCF is seen to be an appropriate management system to emulate natural processes from primeval forests (Lavnyy ad Willig 2011). By doing this, the resistance and resilience of the forests can be improved and productivity - in many cases - increased compared to even-aged monocultures (Pretzsch et al. 2015). Finally, CCF is an appropriate concept to improve the habitat quality of forests, thus conserving biodiversity (Larsen et al. 2022).

One of the biggest challenges in CCF is the conversion phase. Many Ukrainian forests to date are still even-aged and homogeneous. Conversion means actively initiating regeneration in a stand already years before the peak of value increment, either by natural regeneration or underplanting. Conversion is costly, due to underplanting, but also due to the reduction of revenues from the harvest of the overstorey. Nevertheless, the improved net present value of converted and, therefore, selectively harvested CCF stands is an economic advantage compared to age class forests (e.g. Knoke 2009).

Therefore, CCF presents the pathway of Ukrainian forestry to enhance ecological resilience. CCF is especially important for improving the ecological situation in the Ukrainian Carpathians, where recent forest damages have been intensified by climate change. In mountainous conditions, the focus on forest regeneration, mainly by using the method of natural seeds or planting to create mixed uneven-aged forests, has become a necessity. CCF is effective in the provision of diverse forest ecosystem services. Moreover, it helps to provide continuous forest interventions, even in small-scale forests of private owners.

DEMONSTRATION PLOTS AND INITIAL EMPIRICAL RESULTS

The analysis of the impact of different regeneration cuts on natural regeneration was conducted in the framework of a joint Ukrainian-German project called 'Resilpine', which was financially supported by the German government (Sachbericht 2022). The specific goals were:

1. to study forest conversion to near-natural forest management (CCF) in Ukraine, and
2. to establish demonstration areas in the field of silviculture and fire management to increase the resilience of pine forests to drought and fire.

Therefore, a series of demonstration plots for conversion cuts, i.e. shelterwood cuts and group (or patch) selection felling (as alternatives to clearcutting), have been established in the Stradch Educational and Production Forest Enterprise of the Ukrainian National Forestry University and in the Lviv State Forest Enterprise in the following three dominating forest types in Ukraine:

1. Scots pine forests – group selection cut, shelterwood cut and (small) clear cut, natural regeneration,
2. Pedunculate oak forests – group selection cut and clear cut, natural regeneration,
3. European beech forests – shelterwood cut, natural regeneration.

In some of the plots, soil treatments were conducted to study this effect on natural regeneration capacity. The fructification intensity of the three studied species differed slightly, with mast years for Scots pine and pedunculate oak in 2018 and European beech in 2020.

After the first vegetation period from the cutting, the number of seedlings was counted and the abundance rate was calculated.

The first scientific results are shown in more detail below (for methodological details and more results see also Lavnyy et al. 2022, Lavnyy et al. 2021).

Scots Pine Forests (Shelterwood and Group Selection Cutting, Natural Regeneration)

Current Management

Scots pine has to be cut at the age of 81 years, which is seen to be the year with the highest stand value in a pine rotation cycle. Intermediate cuttings are closely linked to stand age, and the prescribed thinning type is low thinning. Thinning intensity is low, and clearcuts dominate in final harvesting. They account for about 84% of the final cuts in Ukraine; the rest is either short-term shelterwood cutting with 15% or group selection cutting with 1%. Natural regeneration is hardly ever used (Lavnyy and Spathelf 2018).

Experiment and First Results

To determine the success of the natural regeneration of Scots pine and other tree species, two demonstration plots were established in the Stradch forest district, with alternatives to clear cut silvicultural methods:

a) group selection felling in a 95-year-old mixed oak-pine forest on relatively poor soils with seven circular gaps of different diameters (20, 30 and 40 m). The soil was treated with a harrow on four circular gaps to remove plant cover and stimulate litter decomposition and mineralization. For comparison, three circular gaps without soil mineralization were left.

After the group selection felling, natural regeneration of Scots pine was abundant. The total amount of regrowth ranged from 55.918 individuals·ha^{-1} to 183.513 individuals·ha^{-1}, with an average value of 113.842 individuals·ha^{-1}. On the plots with litter mineralization, the total amount of self-seeding and undergrowth was, on average, 80% higher than in areas without this measure. Analyzing the average composition of undergrowth on all sample plots, we found a dominance of Scots pine, which averages 94.8% of the total number of individuals. Most of the Scots pine seedlings were found in the gaps. This means that in the case of natural regeneration of these mixed beech-oak-pine stands, Scots pine will again become the dominant species under these conditions. Additionally, there is isolated natural regeneration of other species, such as pedunculate oak, rowan, willow, beech, birch and hornbeam.

b) shelterwood cutting in a 113-year-old mixed hornbeam-oak-pine forest on relatively rich soils with an intensity of 142 m^3·ha^{-1} (from 593 m^3·ha^{-1} = 24% of stand volume) on an area of 1.0 ha.

After the shelterwood cutting, the total amount of self-seeding at the end of the first vegetation period was smaller – 20,574 individuals·ha^{-1}. Here, Scots pine was also dominant in the tree species composition, with 54% of the total amount of natural regeneration (13,265 ind. ·ha^{-1}). The most significant admixture component was hornbeam with 3,846 ind. ·ha^{-1} and sycamore maple with 1,923 ind. ·ha^{-1}. The rest consisted of pedunculate oak, red oak, rowan and coat willow. The group selection cutting method led to higher amounts of natural seedlings compared to all other silvicultural systems applied, even compared to clearcut (for more details on the latter, see also Lavnyy et al. 2022).

Oak Forests (Shelterwood Cutting, Natural Regeneration)

Current Management

Oak forests grow in all regions of Ukraine, but predominantly in the forest steppe zone in Central Ukraine. Among the oak species, pedunculate oak dominates with a share of 82.6% (Table 1).

The rotation period is 111 years for pedunculate oak stands in commercial forests. The still relatively young oak forests are then already clearcut at a diameter at breast height of 36-40 cm.

Oak regeneration in Ukraine is almost exclusively done by planting, resulting in oak stands of the same age. The planting distance is usually 3-4 m between rows and 0.7 m in the row. Acorn seeding, on the other hand, is relatively rare. Occasionally, rows of black walnut (*Juglans nigra* L.), rowan *(Sorbus aucuparia* L.*)*, European larch (*Larix decidua* Mill.) or wild cherry (*Prunus avium* L.) are introduced between the oak rows. These tree species increase the productivity and also the value of the stands. The natural admixture is mainly hornbeam (*Carpinus betulus* L.), Norway maple (*Acer platanoides* L.), field maple (*Acer campestre* L.), linden (*Tilia cordata* Mill.) and ash (*Fraxinus excelsior* L.).

According to the 'Decree on the implementation of end-use felling in forests of Ukraine', the clearcut area in the oak forests belonging to the category of 'commercial forests' is restricted to 5 ha, and in other categories (protection, recreation and nature conservation) to not more than 3 ha. Accordingly, the maximum clearcut area in the mountain forests should not exceed 3 ha and 1 ha, respectively. The felling sequence is three years (Cabinet of Ukraine 2009).

Experiment and First Results

Within the framework of the joint research project 'Resilpine', the possibilities of oak natural regeneration during the final harvesting were investigated in the Stradch Educational Forest, District 17/5 (Lelekhivka forest district, 30 km west of Lviv). For this purpose, in February-March 2020, the first intervention of group selection cutting was carried out on an area of 1.0 ha (with an intensity of 31.7% - 103 m^3 from 325 m^3, Figure 4). The age of the stand was 138 years, and the tree species composition of the mature stand was 90% pedunculate oak, 6% hornbeam, 2% pine, and 2% birch. The forest type is a hornbeam-oak forest on fresh and relatively fertile soils.

In the same forest district, Lelekhivka, and the same forest type for comparison, we have investigated the natural regeneration of tree species in two clear cut areas. The 138-year-old stand before the clear cut on both areas had 70% pedunculate oak, 17% hornbeam, 10% Scots pine and 3% birch. In both areas, the clear cut was carried out also in February-March 2020.

Our research has shown that a good natural regeneration of tree species has developed under the forest canopy of both stands after the first group selection cutting, and in the two clear cut areas. After the first group selection cutting, the total amount of self-seeding and undergrowth changed from unsatisfactory (10,480 pieces·ha^{-1}) at the beginning of the 2020 vegetation season to good (41,528 pieces·ha^{-1}) at the

Table 1. Distribution of Ukrainian oak species.

Tree species	Area (ha)	Percentage
Pedunculate oak	1,538,819	82.6
Red oak	178,029	9.6
Sessile oak	116,313	6.2
Downy oak	30,514	1.6
Total	1,863,675	100,0

end of the 2020 growing season. A year later, the number did not change much and 42,693 individuals·ha^{-1} were counted. However, the share of pedunculate oak in the total number of undergrowth was only 1.7%. Natural regeneration of all tree species under the forest canopy was characterized by an uneven distribution in the area. Hornbeam had the highest abundance rate – 75.6%. Species such as Scots pine (*Pinus sylvestris* L.), birch (*Betula pendula* Roth.) and goat willow (*Salix caprea* L.) followed with a frequency of 30.8 to 39.7%. Other tree species were less common, including pedunculate oak (abundance from 1.3% to 12.8%).

In the clear-cut areas, the total amount of self-seeding and undergrowth varied from 175.6-275.3 thousand individuals·ha^{-1} at the beginning of the vegetation period of 2020 to 299.4 thousand ind. ·ha^{-1} at the end of that vegetation period, and a year later, in autumn 2021 it reached 461.2 thousand ind. ·ha^{-1}. Hornbeam here also had the highest abundance rate – 97.3-98.1%, followed by pedunculate oak (43.5-77.3%), birch (42.6-52.7%) and pine (29.6-34.0%). Other tree species, such as lime (*Tilia cordata* Mill.), goat willow (*Salix caprea* L.), sycamore maple (*Acer pseudoplatanus* L.), beech (*Fagus sylvatica* L.), Scots elm (*Ulmus glabra* Huds.) and aspen (*Populus tremula* L.) had a frequency of 0.7 to 20%.

In general, in all the studied areas, the composition of self-seeding was dominated by a small fraction up to 20 cm in height. To ensure the advantage of pedunculate oak in the naturally formed young stands in all areas, it is necessary to carry out silvicultural treatments such as tending and liberation thinning.

European Beech (Shelterwood Cutting, Natural Regeneration)

Current Management

Beech forests grow in Ukraine mainly in the western forest-steppe zone and in the Ukrainian Carpathians. On 1 January 2015, the area of stands with beech predominance in the tree species composition in the Ukrainian lowlands increased to 118,903 hectares from 104.,800 thousand hectares in 1996. Naturally regenerated stands are predominant among beech forests, with a share reaching 85.7% (Myklush et al. 2017). Beech forests grow mostly on fertile soils.

The rotation period is 81-90 years for beech stands in Ukraine in commercial forests. Final harvesting is dominated by clear-cutting and shelterwood cutting. According to the above-mentioned 'Decree on the implementation of end-use felling in forests of Ukraine', the clearcut area in beech forests belonging to the category 'commercial forests' should not exceed 5 ha, and in beech forests of other categories, not more than 3 ha. Accordingly, the maximum clearcut area in mountain forests should not exceed 3 ha in commercial forests or 1 ha in other forest categories. The felling sequence is three years, comparable with oak (Cabinet of Ukraine 2009).

Experiment and First Results

Within the framework of the joint research project 'Resilpine', the possibilities of natural regeneration during final harvest in the Stradch Educational Forest (Velykopoleh forest district, 25 km west of Lviv) were investigated. For this purpose, in February-March 2020 the first intervention of shelterwood cutting was carried out on the area of 0.9 ha (with an intensity of about 32.1% - 122 m³ from 380 m³). The age of the stand was 113 years, and the tree species composition was 100% beech. The forest type was hornbeam-beech forest on fresh and fertile soils.

Natural regeneration after cutting at the beginning of the vegetation period 2020 consisted of 8,658 individuals·ha^{-1}, mostly seedlings with the height of up to 50 cm. Among different tree species, beech dominated with 3,426 ind.·ha^{-1}, and sycamore with 2,130 ·ha^{-1}. After three vegetation periods in October 2022, the number of ingrowth increased to 21,847 ind.·ha^{-1} with 7,663 beeches·ha^{-1}. Moreover, an admixture of pedunculate oak (543 trees·ha) and Scots pine (924 trees·ha^{-1}) could be found.

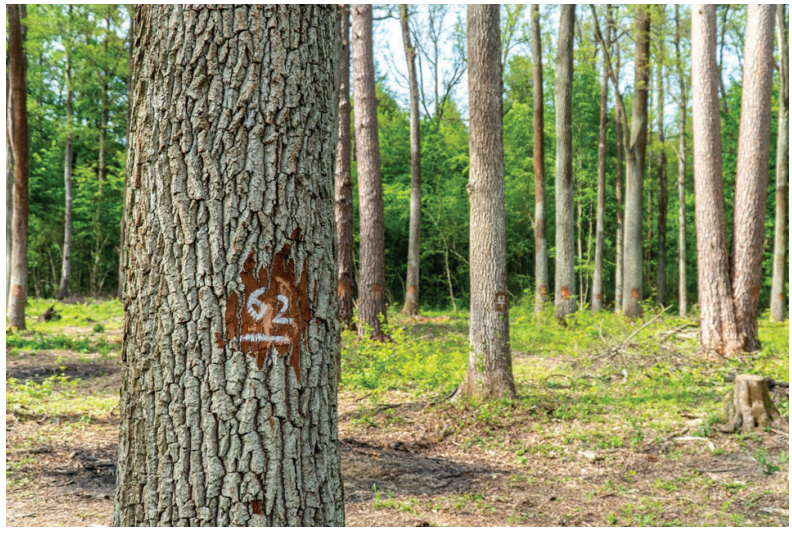

Figure 4. Pedunculate oak stand after the first intervention in shelterwood cutting.

DISCUSSION

In order to accompany forest conversion in Ukrainian forests, a series of experiments and permanent observation plots were laid out in the Lviv state forest enterprise and in the Stradch Educational Forest (project 'Resilpine', with financial support by the German government, Sachbericht, 2022). The first results of natural regeneration under alternative systems to clearcut are promising. Especially, they show that group or patch selection cuts facilitate the establishment of a large number of seedlings of light-demanding tree species (e.g. Scots pine, but also willow and pedunculate oak) as well as more shade-tolerant or intermediate species such as hornbeam in smaller gaps. Moreover, in terms of seedling density, group selection is better than clearcut and much better than shelterwood cuts, with respect to all tree species. Nevertheless, with shelterwood cutting a broader range of intermediate species occur, due to the uniform and shadier conditions. These results match quite well with research findings in Central Europe (Poland or Germany; see Aleksandrowicz-Trzcińska et al. 2018 or Lavnyy and Spathelf 2016). It is pointed out, however, that a large proportion of the variation in seedlings' abundance is due to factors other than canopy opening (silvicultural system), such as, for example, competing ground vegetation or topsoil conditions.

There has been an increasing recognition in Ukraine that natural regeneration provides many advantages for forest stability and climate resilience due to an undisturbed root development, better soil anchorage and a higher genetic variability in dense seedling populations (Spathelf and Bolte 2020, Brang et al. 2014).

The highest need for forest conversion in Ukraine was observed for Scots pine, due to its extensive distribution of 35% forest cover in the country and its homogeneity and thus vulnerability. Especially high-risk forests are the Scots pine forest landscapes in the northern steppe zone. They are very susceptible to forest fires and biotic pests due to their homogeneity and their continuity. The fragmentation of these conifer-dominated forest landscapes and the implementation of fire protection strips at the forest margins is crucial.

European beech, which was converted into Norway spruce in the 19th and early 20th century, especially in the Carpathian Mountains, has gained surface in the last decades due to an abundant natural regeneration.

An even more extended history in Ukraine exists with the management of oak (pedunculate and sessile oak). Oak forests, as in many parts of Europe, were advantageous in the context of settlement but also during industrialization, as they can be used for the production of timber for construction and fuelwood. However, oak forests in Ukraine often declined due to different reasons and were substituted by less valuable and sometimes degraded secondary broadleaved stands. The government wants to counteract this with an extensive programme called 'Dibrova' (oak forests) launched in 1996 to increase the area of oak stands.

CONCLUSIONS

In Ukraine, the preconditions for CCF and forest conversion are quite good, because forest policy acknowledges the need for this transformation (Cabinet of Ukraine, 2021). A significant species shift in favour of broadleaved tree species, the enhancement of structural diversity, and the abandonment of clearcutting is recognized as the primary goal in sustainable forest management and forest transformation in Ukraine.

CCF is a promising approach to using forest sustainably and preparing forests in times of climate change ('Climate-smart forestry', according to Bowditch et al. 2020). Moreover, it contributes to the improvement of the protective functions of forests, in particular, to the protection of water resources and the reduction of soil erosion. In addition, close (or closer)-to-nature forestry fosters adaptive forest management, which is becoming more and more important (Larsen et al., 2022; Brang et al., 2014).

Due to promising empirical results, we especially recommend the group selection system as a good alternative to clearcut in the conversion process of Ukrainian forests, at least for Scots pine and pedunculate oak; for European beech we do not yet have enough results.

Finally, we think that the Verkhovna Rada (the Parliament of Ukraine) should consider and adopt the law 'On National Forestry Policy', to implement the Forestry Strategy of the European Union in the state-owned forests, with the implementation of alternatives to clearcutting as one of its core elements. Scientists of the Ukrainian National Forestry University and the National University of Bioresources and Nature Management of Ukraine have already prepared the draft for this law.

Author Contributions

PS and VL developed and designed the research, OM and OD carried out and supervised the field measurements. Moreover, VL, OM and OD performed the analyses of field materials. PS and VL processed the data and performed the statistical analysis; PS secured the research funding, supervised the research and helped to draft the manuscript. Finally, PS and VL wrote the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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