Università degli Studi di Padova

Corso di Laurea "Forest Science - Scienze Forestali –Forest and Land Management"

Comparison of natural regeneration of Fagus sylvatica and Picea abies in mountain areas of European National Parks and Nature Reserves

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Tesi di Laurea di

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Anno Academico 2021/2022

You will find more lessons in the woods than in books. Trees and stones will teach you what you cannot learn from masters.

(Bernardo di Chiaravalle)

Nothing is more beautiful than the loveliness of the woods before sunrise.

(George Washington Carver)

Un grazie speciale a Riccardo, la persona che più di tutte è stata capace di capirmi e di sostenermi nei momenti difficili. Grazie a Riccardo ho avuto il coraggio di sperimentare nuove idee, di mettermi in gioco e di capire che, in fondo, gli ostacoli esistono per essere superati.

Niniejszą pracę pragnę zadedykować moim wspaniałym, Rodzicom Romanie i Tomaszowi Kura, dzięki którym miałqam możliwość kształcić się i zdobywać cenną wiedzę, którzy stale mnie mobilizowali i wspierali przez okres trwania studiów.

Ringrazio il Prof. Mario Pividori, mio relatore e guida in questo percorso non privo di difficoltà. Il suo supporto è stato fondamentale.

Abstract

Natural forest regeneration is it still possible? How do biotic and abiotic factors affect the structure and vitality of forests? Is the correlation between the factors important? These are the questions I asked myself and I will try to answer them in this paper.These problems should be viewed from two perspectives of man and nature. For decades, man has been trying to restore the most natural structure of forests, appropriate care may contribute to this . On the other hand, it was human activity that led to the degradation of the present forest ecosystems, for example, highly developed industry and its waste are one of the causes of intense air pollution that lead to climate change. The other side of the coin is the biotic and abiotic factors that shape forests. Their activity destroys and at the same time creates the basis for the development of the next generation - (natural hazard, insect outbreak).

There is a high correlation between the occurrence of individual factors. The emergence of indirect and direct correlations between the factors will be considered in terms of the behavior of two tree species occurring in Europe- deciduous :Fagus Sylvatica, coniferous :Picea Abies. The area considered for the analysis is a mountain area in three different mountain ranges, the Carpathians, the Alps and the Sudetes. an important factor in the analysis will be the comparison of forests growing at about the same altitude, the assumed discrepancy is between 800 and 1200 m above sea level

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Introduction

Over the years, forest renewal was based on artificial afforestation with single-species forests, which has a negative impact on the conservation of biological diversity. Afforestation was usually carried out with the most available species, ignoring where and whether a species is appropriate for the climate in an area. And so we have hectares of pine forests in the lowlands where deciduous and mixed forests used to dominate long time ago. Widespread planting of spruce in montane level transformed the former beech and beech-spruce forests . the greatest changes that we can observe today took place in the area of former communist countries, especially from the eastern bloc, including Poland, Slovakia, the Czech republic, a much better situation in the western countries, where a few decades ago began to depart from monoculture and focus on natural forest renewal.

Forest renewal - the process of natural or artificial formation of the young generation of trees, which, as they develop and grow, in the future will have a significant impact on the formation of the forest environment in a specific space and time. Due to the degree of use of the forces of nature, as well as the contribution of human work, the renewal is distinguished: natural - spontaneous, self-seeding or from shoot regeneration, artificial - carried out by sowing or planting, always with human participation.

Many scientific publications and seminars are devoted to natural renewal. Natural regeneration is now one of the main goals of forest management (United Nations Conference on Environment and Development) especially in areas that were previously heavily degraded by human behavior and and poor management of forest resource

With the above in mind, the purpose of this paper is a comparative analysis of the natural regeneration of beech and spruce in the mountain zone of selected national parks and nature reserves in Europe. The purpose of the work arose from the need to determine the factors affecting the regeneration of the studied tree types. The essence of the purpose of the work resulted directly from the seriousness of the issue under study. Natural regeneration of a stand in the literature is determined by diverse factors. Therefore, within the decomposition of the main objective of the work, specific objectives were also specified, which are to determine the factors affecting the regeneration of beech and spruce and: to analyze the state of the regeneration of these trees in the studied mountain ranges, the main factors affecting the regeneration in the studied mountain ranges, to identify recommendations that can improve the regeneration processes.

The paper will present the processes of natural regeneration occurring in mountain spaces, so three European chains were chosen, which differ in their time of formation and geology. The area to be considered is the areas located at an altitude of 600 to 1,200 meters above sea level with characteristic mixed vegetation from deciduous, deciduous-needle forests to dense coniferous forest structures consisting of 100 spruce trees.

The Sudetes is a mountain range in Central Europe, shared by Germany, Poland and the Czech Republic. The igneous and metamorphic rocks of the Sudetes were formed during the Variscan orogenesis and its aftermath.

The Alps are the highest and most extensive system of mountain ranges that lies entirely within Europe (France, Switzerland, Monaco, Italy, Liechtenstein, Austria, Germany and Slovenia). The Alps are part of the Cenozoic orogenic belt of mountain ranges, known as the Alpine belt. This belt of mountain chains was formed during the Alpine orogenesis. A rift in these mountain chains in Central Europe separates the Alps from the Carpathian Mountains to the east.

The Carpathian Mountains are a mountain range in Central and Eastern Europe (Czech Republic, Slovakia, Poland, Hungary, Ukraine, Romania, Serbia). The area now occupied by the Carpathians was once occupied by smaller oceanic basins. The Carpathians were formed during the Alpine orogenesis in the Mesozoic.

The methods of empirical verification to answer the purpose of the work are: analysis, synthesis, deduction and case study.

The structure of this work is divided into four chapters, the content of which is as follows.

Chapter 1 discusses the essence of the functioning of parks and nature reserves in the context of environmental protection. Special attention of this chapter was paid to the legal aspects of the organization of parks and nature reserves in the European Union. In addition, the subject of environmental protection and pollution in the EU was also analyzed.

Chapter 2 focuses on the problems of Natural forest restoration. The chapter refers to forest restoration as a natural process, highlights the barriers and challenges in the process of forest restoration in mountainous areas, and describes the impact of environmental factors on the process in question.

Chapter 3, which is the empirical component of this work, presents an analysis of selected studies on natural forest regeneration in selected mountain ranges. In this chapter, attention is paid to the reports and results of studies on the processes of natural forest regeneration in selected parks and nature reserves.

Chapter 4, on the other hand, is a summary of the empirical verification, in which a discussion with other research materials and reports is developed, and final conclusions with the author's recommendation are elaborated.

Chapter 1 The essence of the activities of national parks and nature reserves

1.1 The role and function of nature parks and reserves in Europe

In considering the essence of nature parks and reserves in Europe, it is worthwhile at the outset to clarify the basic concepts related to the issue at hand. A national park is created in order to preserve biological diversity, resources, formations and components of inanimate nature and landscape values, to restore the proper condition of resources and components of nature and to restore deformed natural habitats, plant habitats, animal habitats or fungi habitats. There is a special legal regime in the territory of the national park, the manifestation of which are prohibitions in force by law. In accordance with the principle of sustainable development, these prohibitions are not absolute, as most of them can be repealed through the arrangements contained in the protection plan or protective tasks, as well as by decision of the minister responsible for the environment or the director of the national park[1].

The existence of a separate legal regime in the national park area means that the national park is a special area. Special area is a doctrinal concept and includes a designated space where a specific legal regime applies that excludes or at least limits the the existing legal order (universally applicable norms). It is created for the implementation of the state's overriding tasks in a separate area[2]. The establishment of a legal regime within a national park is aimed at protecting the park's nature from internal threats. An important issue is also the protection of national parks from external threats, understood as factors that can cause adverse changes in the physical, chemical or biological characteristics of resources, creations and components of protected nature, landscape values and the course of natural processes, resulting from natural causes or human activity, having their source outside the boundaries of areas or objects subject to legal protection[3]. Depending on the legal regulations, the buffer zone of the national park is also specified as an area and spatial instrument of nature protection. On the other hand, the buffer zone of a national park can be understood as a

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2 B. Zarska, *Landscape Protection*, Warsaw University of Life Sciences—SGGW Press: Warsaw, Poland, 2011, s. 129.

3 B. Poskrobko, *Environment Management in Poland*, PWE Publishers: Warsaw, Poland, 2012, s. 83.

protective zone bordering a national park and designated individually for a national park to protect it from external threats resulting from human activity[4].

In the buffer zone of the national park may (not necessarily) be created a game protection zone. Its task is to protect animals in the national park, since the area of the zone is not subject to inclusion in the boundaries of hunting districts, which results in a ban on the organization of hunting in this area.

Another issue related to ensuring the protection of nature national park from external threats is the establishment on the its buffer zone such forms of nature protection as landscape parks and areas of protected landscape. Prohibitions and restrictions imposed on these special areas can be considered effective instruments of nature protection. These are instruments of sovereign action, characterized by the highest degree of imperativeness, since they oblige the addressees of the norms directly and by force of law[5].

Prohibitions are a typical legal instrument of nature protection, it can be considered that in the EU law of nature protection the legislator has adopted a model in which the essence of a form of nature protection is a set of prohibitions, i.e., activities that, with respect to the object of protection, must not be undertaken in principle. It is fully permissible, for example, for a landscape park to function as a buffer zone around a national park, and, for example, an area of protected landscape was the buffer zone of a landscape park. In such a case, the prohibitions set forth in the catalog shaping the legal regime on the territory of, for example, a landscape park, may apply on the territory of the buffer zone of a national park. Such a way of protecting the nature of the national park from external threats requires cooperation with the authorities of the provincial government with the authority to create a landscape park and determine the prohibitions applicable on its territory.

National park as the most important form of legal nature protection is created to realize the public interest of protecting the most valuable natural resources. It can be considered that the public interest of protecting biodiversity within the national park takes precedence over public interests of a regional and local, as well as over individual interests. The principle of sustainable development dictates that when interpreting the law of nature

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[4] W. Radecki, Ustawa o ochronie przyrody. Komentarz, Difin, Warszawa 2016, s. 159.
[5] A. Swigost *The transformation of the natural environment of the Polish and Ukrainian Bieszczady mountains ´* due to tourism and other forms of human pressure. Curr. Issues Tour. Res. 2015, 5, s. 35.

conservation, a balance the conflicting interests of nature conservation and socio-economic development socio-economic development. The basic rule of conduct that should be applied by administrative bodies in situations that cause conflicts is to disclose all interests that may be affected, at the earliest possible stage, that is, in the case of national parks in the procedure for their establishment and definition of their boundaries. The next stage should be the adoption of a plan that takes into account the possibility of using the park's natural resources to the extent permitted by law. The most effective instrument for implementing the principle of sustainable development in the area of the national park national park and its buffer zone may become a local spatial development plan, therefore it should be postulated that its enactment is obligatory with regard to such areas. It should also be emphasized that for the protection of nature, it is important to undertake cooperation between authorities managing special areas and authorities responsible for the policy of spatial development of municipalities. It is the bodies of municipalities that can, in practice bring about the introduction into planning and zoning acts of spatial planning and development, appropriate prohibitions aimed at protecting nature within the national park from external threats.

Here it is worth referring to the solutions of the law of one of the EU countries, which specifically points to the essence of sustainable development of national parks. According to Article 45 (2) of the Constitution of the Kingdom of Spain, the public authorities shall see to the rational use of natural resources for the defense and improvement of the quality of life and the protection and restoration of the environment, relying on indispensable collective solidarity[6].

According to the aforementioned act, the purpose of establishing a national park is to protect the integrity of natural values and landscapes and, subject to its adaptation for public utility public, to promote environmental awareness, promote scientific research and sustainable population development, consistent with the maintenance of cultural values and intangible heritage. The area of a national park must not be fragmented and must be sufficient to ensure the undisturbed functioning of the natural system[7]. To this end, the area of a national park, except in duly justified cases, is to be at least 6,000 hectares for marine or land-

[6] https://www.lamoncloa.gob.es/lang/en/espana/stpv/spaintoday2015/environment/Paginas/index.aspx
[7] Ibidem.

sea national parks on islands, and at least 21,000 hectares for marine or land-sea national parks on the Spanish mainland and national parks of marine waters.

Previous considerations have pointed to the legal essence of the operation of parks and nature reserves. Therefore, it is worth noting their special role. National parks are one of the most important area-based forms while their main purpose remains the preservation of biological diversity of resources, creations of nature protection in Europe.

They cover areas distinguished by special natural, scientific, social, cultural and educational. And nd components of nature, activities related to making the park area available to tourists and carrying out activities related to environmental education ecological education are no less important. The aforementioned goals must remain the main ones indicated by the Law on Nature Protection. For social and educational activities, including, for example, expansion of educational infrastructure, increasing its accessibility for people with disabilities, building a museum etc[8].

One of the tasks carried out in national parks is environmental education, implemented, among other things, by organizing tourism. The emergence of tourist traffic however, causes a collision between the two basic functions of national parks, namely tourism and nature conservation. The negative impact of tourism can result in lowering of landscape values, in extreme cases devastation of the environment. In order to counteract similar results, research is being conducted in protected areas on the problem of the so-called tourist capacity, that is, the degree of resistance of the environment is assessed to the absorption and capacity of tourist traffic.

The parks sometimes house scientific units or museums and other cultural facilities culture that provide information about the specifics of the place, protected plant and animal species, research being undertaken.

In summary, national parks are natural areas protected for their unique landscape forms and endangered species of animals, plants and fungi. In addition to national parks, the forms of environmental protection are: nature reserves, landscape parks, areas of protected landscape, nature monuments, ecological grounds[9].

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[8] M. Sakellari, M.; Skanavis, C. *Sustainable tourism development: Environmental education as a tool to fill the gap between theory and practice*. Int. J. Environ. Sustain. Dev. 2013, s. 77.
[9] Ibidem, s. 80.

The functions of national parks are: nature protection, relic protection, cognitive and educational. On the other hand, groups of national parks include parks: coastal, lakeside, lowland, highland, mountain.

1.2. Environmental policy in the EU

The origins of the EU's environmental policy date back to the 1972 European Council meeting in Paris, where heads of state and government (following the first United Nations conference on the environment) pointed out the need to shape a Community environmental policy to support economic expansion and called for a program of action. The 1987 Single European Act introduced a new title, "Environment," which provided the first legal basis for a common environmental policy aimed at maintaining environmental quality, protecting human health and ensuring the rational exploitation of natural resources. Subsequent amendments to the treaties increased the Community's involvement in environmental protection, as well as the role of the European Parliament. The Maastricht Treaty recognized the environment as an official EU policy area, introduced the co-decision procedure and adopted the general principle that decisions in the Council are taken by qualified majority. The Treaty of Amsterdam established the obligation to integrate environmental protection into all EU sectoral policies with a view to promoting sustainable development. "Tackling climate change," as well as sustainable development in relations with third countries, became a specific objective in the Lisbon Treaty the new legal personality has enabled the EU to conclude international agreements[10].

The Union's environmental policy is based on the principles of precaution, preventive action and cleanup at the source, as well as the "polluter pays" principle. The precautionary principle is a risk management tool that can be used when a particular action or policy raises scientific concerns about a suspected risk to human health or the environment. For example, when there are suspicions about the potentially harmful effects of a product and - after objective scientific evaluation - there is still uncertainty, it is possible to issue instructions to stop distributing the product or to withdraw it from the market. Such measures must be non-

[10] M. Loennroth. *The Environment in the European Social Model*, [in:] A. Giddens, P. Diamonds, R, Liddle (ed.) Global Europe, Social Europe, Polity Press, Cambridge, Malden 2006, s. 43.

discriminatory and proportionate, and when more scientific information is available, they should be reviewed[11].

The "polluter pays" principle is implemented in the Environmental Liability Directive, which aims to prevent or otherwise remedy damage to the environment, protected species and natural habitats, water and soil damage. Operators engaged in certain professional activities, such as the transportation of hazardous substances, or activities that involve discharges into water, must take preventive measures in the event of an imminent threat to the environment. Where damage has already occurred, they are obliged to take appropriate measures to remedy it and cover the costs. The scope of the directive has been expanded three times to cover the management of waste generated during extraction, the operation of storage sites and the safety of offshore oil and gas activities, respectively[12].

Moreover, the integration of environmental aspects into other EU policies has been an important concept in European politics since the issue was first raised at the initiative of the Cardiff European Council in 1998. In recent years, environmental policy integration has seen significant progress, for example in the area of energy policy. This is reflected in the parallel development of the EU's climate and energy package and the Roadmap leading to a transition to a competitive low-carbon economy by 2050. In December 2019. The Commission announced the European Green Deal, which should help guide EU policy towards making Europe the world's first climate-neutral continent[13].

The European Community's environmental policy, and at the same time environmental law, have been shaped in line with progressive economic development, growing environmental threats and increasing environmental awareness. The new regulations have often met with resistance from some member states and economic sectors accusing environmental regulations of slowing down economic development. In general, the development of these policies had a twofold background. On the one hand, the growing influence of national environmental regulations on the functioning of the common market made it necessary to harmonize them at the Community level (different environmental requirements of member states affected the cost of manufactured goods and thus their

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[11] Ibidem, s. 45.
[12] http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1415352499863&uri%20=CELEX:%2052014DC0398R%%202801%29.
[13] Ibidem.

competitiveness). On the other hand, the environment was increasingly treated as an intrinsic value that requires protection from the threats posed by economic development.

According to the current wording of the Treaty on the Functioning of the EU (TfEU), the objective of the Union's environmental policy is[14]:

- preserve, protect and improve the quality of the environment,
- protection of human health,
- prudent and rational use of natural resources,
- promoting measures at the international level aimed at
- solving regional or global environmental problems, in particular combating climate change.

The provisions of the TfEU give rise to basic principles for conducting environmental policy. Although they do not have the character of legally binding norms, they form important guidelines when creating legal acts in the field in question. These are: the principle of a high level of protection It states that the Union will strive to introduce the most effective measures corresponding to the current level of scientific and technical knowledge. This means that new regulations lead to an increase in the averaged level of protection applicable in member states, rather than lowering it.

If the EU intends to meet its climate goals and contribute to limiting the average temperature increase to 1.5°C above pre-industrial levels, it must realize the crucial importance of forests to the implementation of the climate change mitigation plan climate. The EU therefore needs policies that guarantee:

- Reducing the amount of timber harvested,

- A several-fold increase in the area of strictly protected areas in forests,

- Restoration of forests through forest management with an ecosystem approach,

- Abandoning logging for energy generation,

- Drastically reducing the production and consumption of disposable wood and paper p products,

- Banning the manufacture of disposable products made from fresh wood fibers,

- Greater levels of recycling of paper and wood,

[14] https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:12012E/TXT:en:PDF

- Use of wood to a greater extent for long-life products (e.g., furniture and in construction),

- Ambitious climate change mitigation policies with separate, dashed targets for:

- Reducing emissions from fossil fuel combustion and land use change,

- Restoration and enhancement of forests and other natural CO2 sinks, in line with the EU's strategy for biodiversity.

The precautionary principle (prudence) It applies to any activity whose negative impact on the environment is not yet fully recognized. In accordance with this principle, the burden of proof of the harmlessness of the impact on the environment is shifted to entities and persons undertaking activities, that may endanger the environment. Principle of preventive action (prevention) Indicates the need to prevent negative impacts on the environment, and not just respond to damage that has already occurred. Its manifestation is the provisions on proceedings on environmental impact assessment. The principle of repairing damage at source. Requires that environmental damage be remedied first where they occur. The environment should be protected by avoiding concentration of pollution, use of protective devices, etc[15].

The "polluter pays" principle. It means that polluters bear the costs of activities aimed at achieving a state of compliance with applicable standards, and in a broader sense: polluters bear all the costs of removing the consequences of such activities.

In the creation of environmental policy, action programs played a special role in environmental protection. Although they did not (and do not) have a normative character, no less they are the basis for carrying out environmental policy, as they set strategic objectives strategic objectives and the stages of their implementation, they are also the basis for the preparation of draft legislation. The evolution of the programs has led over time to the elevation of environmental issues to the rank of one of the priorities of the EU.

The first action program was enacted in 1973 (it covered the years 1973-1977) and specified permissible values for environmental quality, particularly with regard to water and air. In the second program (1977-1981), the scope of environmental problems was already somewhat broader, program envisaged measures to protect nature (among other things, it

[15] http://eurofundsnews.eu/publikacje/siodmy-unijny-program-dzialan-w-zakresie-srodowiskanaturalnego-do-2020-r/

drew attention to the need to protection of habitats). However, the slowdown in economic development during this period made it impossible to implementation of many of the adopted assumptions. The third program (1982-1986) pointed to the role of environmental protection in the creation of the common market. Emphasis was placed on harmonization of emission standards pollutants into the air (the problem in Europe at the time was "acid rain" - the result of sulfur dioxide emissions)[16].

The Fourth Program (1987-1992) was created in a changed legal situation, when provisions on environmental protection became part of the TfUE. It emphasized the importance of integrated protection, breaking the sectoral approach, and the possibility of using economic instruments economic instruments. Environmental protection began to be treated as an integral part of economic decision-making. At the time, the global context for action is changing in environmental protection, including under the influence of the "Environment and Development" conference in Rio de Janeiro in June 1992, which promotes the concept of sustainable development[17]. There is a growing awareness of global environmental threats, the problem of climate change is emerging. The new policy approach found its expression in the Fifth Action Program (1993-2000), which as an overriding goal indicated sustainable development. It gave priority to the sustainable use of natural resources, integrated anti-pollution, reducing the consumption of non-renewable energy, and raising the quality of the environment in urban areas. The ambitious plans met resistance from member states. It was only in the late 1990s that there was an acceleration of the legislation: the adoption of, among others, the Water Framework Directive (2000/60), the End-of-Life Vehicles Directive (2000/53), on strategic environmental impact assessments environment (2001/42), on electrical and electronic waste (2002/96).

Therefore, it is worth discussing specific types of specifics of environmental protection by the EU. Water protection is one of the most developed branches of EU environmental policy, dating back to the 1970s. Currently, the main instrument of EU policy in this field is the so-called Water Framework Directive (WFD) adopted in 2000. It is guided

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[16] Directive 2008/1/EC of the European Parliament and of the Council of 15 January 2008 concerning integrated pollution prevention and control; http://europa.eu/ legislation_summaries/ environment/air_pollution/l28045_en.htm

[17] Directive 2004/35/EC of the European Parliament and of the Council of 21 April 2004 on environmental liability with regard to the prevention and remedying of environmental damage; http://europa.eu/legislation_summaries/environment/ general_provisions/l28120_en.htm.

by an ecological, holistic approach to water assessment and water management planning. It treats water not only as part of the economic system, but primarily as a factor creating habitats, the condition of which depends on actions taken throughout the catchment area[18].

The main objectives of European water policy are:

- to protect and improve conditions and, when this is not possible, to maintain the current condition of aquatic ecosystems, as well as terrestrial and wetland ecosystems directly dependent on aquatic ecosystems,
- promoting sustainable water use based on the long-term conservation of water resources, undertaking projects to improve the cleanliness of the aquatic environment; these projects should lead to a reduction of emissions and discharges of particularly hazardous substances, and in the long run to eliminate such activities,
- gradually reducing groundwater pollution and preventing their further degradation,
- striving to reduce the effects of floods and droughts

The goal of the WFD is to achieve good water status in all member states. This is to be achieved through integrated action programs implemented at the national level. The directive takes into account water quality issues and the problems of protecting aquatic and wetland ecosystems aquatic and wetland ecosystems, as well as the socio-economic effects of droughts and floods. The starting point for water planning should be an analysis of the characteristics of river basins and an assessment of the impact of human activities. The provisions of the WFD indicate that EU water policy should be based on a combined approach, taking into account such elements as reducing pollution at the source, establishing emission limit values, and compliance with environmental quality standards. It is necessary identify priority substances and agree on measures to be taken to counteract pollution of waters by these counteract water pollution by these substances. In view of the various needs

[18] Community guidelines of 1 April 2008 on State aid for environmental protection [Official Journal C 82 of 1.4.2008]; http://europa.eu/legislation_summaries/ environment/general_provisions/ev00 03_en.htm.

and regional conditions, as well as the principle of responsibility of individual member states, action programs should be tailored to the possibilities of local[19].

Another aspect of EU environmental policy is the issue of air pollution. Atmospheric pollution causes numerous damages - it affects adversely affects human health, weakens natural ecosystems, leads to deterioration of water and forest quality. Pollution of the air also brings tangible material losses resulting from increased rate of corrosion and deterioration of buildings, reduced crop yields, additional health and social welfare expenses. Concern for good air quality is one of the primary objectives of European environmental policy. Guaranteeing adequate air quality is served by an extensive system of EU regulations created since the late 1970s. The Union is also a party to and an active partner in broader international agreements, including the conventions on the reduction of pollution traveling over long distances (LRTAP Convention). Although air quality in member countries is improving steadily systematically improving, many problems still remain to be resolved. Analyses conducted as part of the CAFE program have shown that even full implementation of existing regulations will not lead to the achievement of adequate air quality. Therefore, one of the so-called thematic strategies of the Sixth Program of action has been dedicated to the further reduction of atmospheric emissions. To implement this strategy, the Union adopted several new pieces of legislation tightening existing requirements. The most important element of the changes was the introduction of standards for the control of PM2.5 (the finest dust with a fraction below 2.5 microns) and the extension of the pollution control regime to additional groups of industrial installations.

European legislation is directed at eliminating various types of pollution from a wide variety of sources, both stationary and mobile. EU air protection legislation:

- sets minimum standards for air quality and obliges to take remedial action when these standards are exceeded, introduces mandatory monitoring of selected pollutants at emission sources,
- introduces permissible emission standards for mobile sources and fuel quality standards fuel quality,

[19] Council Regulation (EEC) No 259/93 of 1 February 1993 on the supervision and control of shipments of waste within, into and out of the European Community.

- seeks to harmonize pollutant concentration measurement methods and air quality monitoring strategies of member countries,
- mandates that air quality information be made available to the public and all interested parties.

The next issue of particular relevance from the perspective of this work is EU nature conservation. The basis of the EU's nature protection policy are two legal acts: the Directive 79/409/EEC on the conservation of wild birds (the so-called Birds Directive) and Directive 92/43/EEC on the protection of natural habitats and wild fauna and flora (the so-called Habitats Directive). The Birds Directive is the first Community legislation dedicated to nature protection[20].

It was enacted in 1979. - eight years before regulations referring directly to environmental protection were introduced into the treaties. Many member states opposed the directive at the time, accusing it of being unrelated to the needs of the common market (the formal basis for the directive's enactment was Article 235 of the Treaty establishing the European Community. The enactment of this legislation, among other things, was a response to the First Action Program calling for the implementation of more effective protection of wild birds. The directive applies to all species of birds naturally occurring in the wild in the European territory of the member states. It sets out rules for the protection management and regulation of the numbers of these species. It prohibits the deliberate killing and capture of birds, destruction of their nests and eggs, and deliberate disturbance, but for some species (listed in Annex II of the directive) allows hunting. Member states are obliged to preserve, maintain and restore a sufficient diversity and area of habitat for bird species. They can carry out these tasks by creating special protection areas, appropriate management of bird habitats, and creating and restoring destroyed biotopes[21].

The Habitats Directive aims to preserve or restore natural habitatsand species of wild fauna flora important to the Community. It was adopted in 1992 and was modeled on the 1979 Bern Convention. Unlike the convention, however, the directive extends protection to

[20] Z. Wysokińska, *The "New" Environmental Policy Of The European Union: A Path To Development Of A Circular Economy And Mitigation Of The Negative Effects Of Climate Change*, Comparative Economic Research, Volume 19, Number 2, 2016, s. 58.
[21] Ibidem, s. 59.

habitats not only for the species of fauna and flora present in them, but also for the conservation value of the habitats themselves[22].

The directive refers to natural habitats that are threatened with disappearance in their natural area, occur in a small area or exemplify typical features of one or more biogeographical regions (their list is included in Appendix I). Covered animal and plant species (species important to the Community) are endangered, vulnerable endangered (i.e., those that are thought to be likely to move to the endangered species category, if the factors causing the threat continue to affect them continue to affect them), rare and endemic and requiring special attention due to the special nature of their habitat and/or the potential impact of their exploitation on these habitats. Under the directive, natural habitats and/or species populations in need of conservation or restoration should be included in special areas of conservation. States

Member States are obliged to take measures in these areas to avoid the deterioration of natural habitats and species habitats. They should plan the necessary conservation measures including, for example, management plans that meet the ecological requirements of the types of natural habitats or species for which such an area has been established such an area. The directive requires that plans or projects that may significantly[23].

Affect a special area of conservation must be evaluated from the point of view of their impact on the this area.

1.3. Problems of environmental pollution

One of the fundamental issues related to modern environmental policy is the attempt to combine socio-economic development with simultaneous environmental protection. Noticeable in recent years, the significant pace of change, caused primarily by major technological advances and rapid population growth, has contributed to a significant deterioration of the environment natural environment, the contamination of many ecosystems and, in the process, the occurrence of threats of an ecological nature. Depletion of resources of non-renewable raw materials, natural disasters, pollution, and industrial, nuclear and transportation accidents adversely affect the quality of life and health of people, and further

[22] https://ec.europa.eu/environment/nature/legislation/habitatsdirective/index_en.htm
[23] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A31992L0043

can pose a serious threat to state security. In recent years, the relationship between natural hazards and national security has been increasingly addressed in the security strategies of states. It is becoming necessary in this context to eliminate threats of an ecological nature and to prevent the negative consequences of civilization development. The above issues correspond to the concept of ecological security. At the same time it includes activities aimed at various areas of social, economic and political life.

Environmental safety, also known as environmental security, is a complex and ambiguous phenomenon that is defined in science in a variety of ways. It belongs to the issues whose content, nature and scope are subject to highly dynamized social relations, and are conditioned by the current political situation. According to the defiinition, environmental security is "such a state of social relations, including the content, forms and ways of organizing international relations, which not only reduces and eliminates environmental threats ecological threats, but also promotes positive actions, enabling the realization of values that are important for the existence and development of nations and states[24].

At the same time, ecological security can also be equated with a contractual system of "executive units and institutions united by a unified purpose, sets of tasks, etc., the functioning of which should bring the desired results in the event of various threats regardless of whether they are these are threats of peace or of a period of war .Thus, environmental security is the formation of natural and social relations in the Earth's biosphere, which takes into account the need to develop appropriate living conditions for all humanity, while taking into account the fundamentals of life on our planet[25]. Ecological security should therefore be associated with the state of the natural environment, which is free from threats that upset the equilibrium of the ecosystems occurring in it and biosphere. In attempts to define the concept of ecological security, two approaches can be distinguished - positive and negative. On a positive level, it means preventing the emergence of threats in the sphere of the natural environment. Thus understood in this way, ecological security emphasizes the huge role of prevention, forward thinking and international cooperation in developing norms for stabilizing the state of the environment. At the same time, emphasis is placed here emphasis

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[24] B. Wisner, *At Risk: natural hazards, people's vulnerability and disasters*, WEB 2013, s. 84.
[25] P. Liu, *Ecological Security Assessment Based on Remote Sensing and Landscape Ecology Model*, Advanced Sensor Technologies in Agricultural, Environmental, and Ecological, Volume 2021, s. 232.

on the precautionary principle. In the negative aspect, on the other hand, ecological security is a state in which efforts are made to eliminate already existing threats to the natural environment.

The issue of environmental security can also be considered through the prism of the social, political and scientific spheres. From such a perspective, it will at least mean the relationship between man and the environment, where its task will be to create conditions suitable for life. Among the most important types of environmental security, according to the subject criterion, there are biological security, chemical, technical-technological, sanitary, veterinary, emission, immission, nuclear, natural (including species safety and ecosystem safety), flood or epidemic safety.

Pollution of the natural environment, a condition of the environment resulting from the introduction into the air, water or land or the accumulation on the surface of the earth of solid, liquid or gaseous substances or energy in such quantities or in such composition that it may adversely affect human health, animate nature, climate, soil, water or cause other adverse changes, such as corrosion of materials[26].

Pollution of the natural environment can be caused by natural (e.g., volcanoes) or anthropogenic (i.e., artificial, resulting from human activity) sources; it occurs as a result of unintentional but systematic human activity (anthropopression), involving the continuous emission of factors that degrade the environment, or is a consequence of an accident that is the cause of a sudden release of pollutants into: the atmosphere (e.g. accident at the Three Mile Island Nuclear Power Plant, USA - 1979, and the much more dangerous in its consequences accident at the Chernobyl Nuclear Power Plant in Ukraine - 1986), water (e.g., pollution of the waters of the Rhine as a result of firefighting at the Sandoz chemical plant in Basel, tanker accidents) or land (e.g., spills of liquid fuels during rail transport).

The assessment of the state of the environment is made with reference to the natural (clean) state, regardless of whether its changes are caused by substances or impacts for which a level of concentrations (or intensities) of permissible limits has been established, or by other factors for which there are no such norms (e.g., microbiological pollution or odors in the atmosphere). Sometimes pollution of the natural environment is understood as exceeding

[26] V. Shcheblanova, *Ecologization and radicalisation of contemporary civic activism*, European Proceedings of Social and Behavioural Sciences, 2021/8, s. 555.

environmental quality standards or permissible emission rates of pollutants, i.e. the actual occurrence of an unacceptable level of pollution of the natural environment, e.g. clean air does not contain fluorine and its compounds, so any presence of them in the air constitutes its pollution (in turn, the law defines the permissible pollution of these substances by specifying the value of the permissible concentration of fluorine compounds in the air - the instantaneous concentration is 30 µg/m3, the 24-hour average 10 µg/m3 and the annual average 1.6 µg/m3).

The intensive industrial development and urbanization in the 2nd half of the 20th century caused the pollution of the natural environment to change its spatial scope from local (e.g., the occurrence of smog), through regional (e.g., pollution of the Rhine, Mediterranean or Baltic basin - 1960s and 1970s) to global (e.g., environmental acidification, the disappearance of the stratospheric ozone layer at an altitude of about 25 km, or pollution of the oceans)[27]. Therefore, according to UNESCO experts, today the most dangerous pollutants are carbon dioxide (CO2) - one of the causes of the greenhouse effect, carbon monoxide (CO), sulfur dioxide and nitrogen dioxide (SO2 and NO2), causing environmental acidification, phosphorus, causing eutrophication, mercury and lead, bioaccumulating, petroleum, DDT and other pesticides, and radiation. At the same time, many risks arise from contamination of the immediate human environment, including indoor air (the presence of CO2 and CO, NOx, volatile organic compounds, radon, cigarette smoke and oxygen deficiency), drinking water and food[28]. Knowledge of the state of the natural environment and the changes occurring in it, as well as the degree of degradation of its various elements, is necessary for making optimal decisions on its protection.

Although Europe's environmental and climate policies have helped improve the environment in recent decades, Europe is not making enough progress, however, according to environmental reports, and environmental forecasts for the coming decade are not positive. Over the past two decades, Europe has made significant progress in mitigating climate change and reducing greenhouse gas emissions. There are also signs of progress in other areas, such as tackling air and water pollution and introducing new policies to address plastic waste, as well as increasing adaptation to climate change and strengthening the circular

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[27] https://www.eea.europa.eu/themes/air/air-quality/resources/air-quality-map-thresholds
[28] Ibidem.

economy and bioeconomy. In addition, the EU Sustainable Finance Initiative is the first of its kind to address the role of the financial sector in driving the necessary changes toward a sustainable future[29].

Despite the significant successes described above, Europe will not achieve its sustainable development vision of "living well within the limitations of our planet" if it only continues to promote economic growth and seek ways to manage social and environmental impacts. The report calls on member states, leaders and policymakers to seize the opportunity and dramatically increase and accelerate efforts to put Europe on track to achieve medium- and long-term environmental policy goals over the next ten years to avoid irreversible change and damage. The current range of European policy actions provides the necessary basis for progress in the future, but they are not enough. Europe must do all it can, it must approach some challenges differently and rethink its investments. Achieving Europe's goals will require more effective implementation and better coordination of current policies. Additional policy initiatives will also be needed to achieve fundamental changes in the key production and consumption systems that underpin our modern lifestyles - food, energy and mobility - which have a significant impact on the environment.

Europe has made significant gains in resource efficiency and a circular economy. However, recent trends indicate a slowdown in the pace of progress in areas such as reducing greenhouse gas emissions, industrial emissions and waste generation, improving energy efficiency and the share of energy from renewable sources. Looking ahead, it is clear that the current pace of progress will not be enough to meet the 2030 and 2050 climate and energy targets. Protecting and preserving Europe's biodiversity and nature remains the most serious area where progress has been the least. Of the 13 specific policy goals set for 2020 in this area, only two are likely to be met: the designation of marine protected areas and terrestrial protected areas. Looking ahead to 2030, if current trends continue, they will lead to further environmental deterioration and air, water and soil pollution.

Climate change, the impact of air pollution and noise pollution on the environment and human health are also of concern. In Europe, exposure to fine dust causes about 400,000 premature deaths a year, and this problem is particularly exacerbated for Central and Eastern

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[29] https://www.eea.europa.eu/highlights/soer2020-europes-environment-state-and-outlook-report

European countries. There is also growing concern about hazardous chemicals and their associated risks. Opportunities to reduce health risks would be enhanced by better integration of environmental and health policies[30].

Realizing Europe's vision for low-carbon and sustainable development is still possible. Literature and reports indicate that achieving this goal is possible by:

Realizing the untapped potential of existing environmental policies. With the full implementation of existing policies, Europe would have to spend a lot of time to achieve its environmental goals by 2030.

Adopt sustainable development as a framework for policymaking. Developing a long-term policy framework with binding targets - from the food system to chemicals to land use - will stimulate and guide consistent action across all policy areas and society.

Drive international action toward sustainable development. The EU should use its considerable influence in the diplomatic and economic spheres to promote ambitious international agreements in areas such as biodiversity and resource use.

Promoting innovation in society. Reorientation will depend largely on the emergence and spread of various forms of innovation, bringing with them new ways of thinking and models of living.

Increasing investment and directing the financial sector to support sustainable projects and businesses. This direction calls for investing in the future by making full use of public funds to support innovation and solutions based on and inspired by nature, implement procurement with sustainability criteria in mind, and support vulnerable sectors and regions. It also involves engaging the financial sector in sustainable investment through the implementation and use of the EU Sustainable Finance Action Plan.

Managing risks and ensuring socially just transformations. A successful transition to sustainable development will require societies to consider potential risks, opportunities and trade-offs and develop methods to manage them. EU and national policies play a crucial role in carrying out "just transformations" so that no one is left out[31].

Expanding knowledge and the ability to use it. This involves placing additional emphasis on understanding the systems that are driving environmental pressures, the

[30] https://www.eea.europa.eu/highlights/why-does-europe-need-to
[31] https://caneurope.org/just-transformation-vision-principles/

pathways to sustainability, promising initiatives and barriers preventing change. To adapt to a rapidly changing world, further capacity-building efforts are needed by investing in education and skills.

1.4. Forest protection in Europe

Forests in the EU extend over 158 million hectares (5% of the world's forest area). Overall, they occupy 37.7% of the EU's land area, while the six member states with the largest forest areas (Sweden, Finland, Spain, France, Germany and Poland) contain two-thirds of the EU's forest areas [32]. At the individual country level, there are large differences in the size of forest areas: Finland, Sweden and Slovenia have almost 60% forest cover, while the Netherlands and the UK have only 8.9%. What's more, unlike in many areas of the world where deforestation remains a serious problem, forest area is increasing in the Union: between 1990 and 2010, forest area increased by nearly 11 million hectares, especially due to natural expansion, but also afforestation.

The different types of forests in the European Union reflect the diversity of its climatic zones (boreal forests, coniferous alpine forests, etc.), and their distribution depends especially on climate, soil type, altitude and topography. Only 4% of forests have not been transformed by human activity, 8% are plantations, and the rest fall into the category of "semi-natural forests", i.e. shaped by man. It should be noted that most European forests are in the hands of private owners (about 60% of the area, while 40% are public forests).Forests have a well-establi shed position in European culture and history, but beyond that they play a doubly important role in the areas of environment and regional development.

From an environmental perspective, forests play a variety of roles in the ecosystem: they contribute to soil protection (against erosion), participate in the hydrological cycle and regulate the climate at the local level (especially through terrain evaporation), and influence the global climate (especially through carbon storage). As habitats for numerous species, forests also protect biodiversity.

In socio-economic terms, forest use harvests resources, mainly timber. 134 out of 161 million hectares of forests are dedicated to timber production (the use of forests for this

[32] https://ec.europa.eu/eurostat/web/products-eurostat-news/-/edn-20210321-1

purpose is not restricted by law or other economic or environmental factors). In these forest areas, logging corresponds to only two-thirds of the annual increase in the volume of raw timber. These resources are used mainly for energy production, for which 42% of the mass is used, 24% is allocated to sawmills, 17% is used in the paper industry, while 12% is used for the production of wood panels. In the Union, wood is the source of nearly half of the renewable energy used. In addition, forests also provide products other than wood, such as food products (berries and mushrooms), cork, resin, oils, etc. They are also the basis for some services (hunting, tourism, etc.). The forestry sector (forest management, wood and paper industries) generates nearly 1% of the Union's gross domestic product (in Finland the figure is as high as 5%) and employs some 2.6 million people[33].

Among the abiotic factors (i.e., physical or chemical) that threaten forests, we can distinguish fires (especially in the Mediterranean zone), droughts, storms (an average of two major storms per year over the past sixty years), air pollution (emissions from traffic or industrial installations). In addition, the dispersion of forests, a consequence of the construction of transportation infrastructure, poses a threat to biodiversity. These elements add to biotic factors, which are animals, including deer, and insects and diseases, also capable of damaging forests. A total of 6% of the area records damage caused by at least one of these factors.

Climate change is currently challenging Europe's forests. Depending on the geographic location of forests, climate change is likely to have varying effects not only on their growth rate, forested area and species occurrence, but also on the occurrence of biotic agents (including some parasites) or the frequency and intensity of extreme weather events. Adapting forests to these changes and their contribution to counteracting them (e.g., by replacing energy and non-renewable materials with firewood) are two significant challenges.

Thus, different expectations, sometimes contradictory, are associated with EU forests, as illustrated by the tensions between their use and protection. One of the main challenges in forest management, then, is trying to reconcile sometimes conflicting goals[34].

Policies and initiatives for forests in the European Union: coherence as a challenge

[33] https://efi.int/forestquestions/q1
[34] https://www.euronatur.org/en/what-we-do/primary-forests-in-europe

Forests are not explicitly mentioned in the treaties, and the Union does not have a common forest policy. Forests are therefore essentially the subject of national policies. Meanwhile, many of the measures taken at the European level affect the forests of the Union and third countries.

The marketing of forest reproductive material is regulated at the European level by Directive 1999/105/EC. The European plant protection system, in turn, aims to combat the spread of organisms harmful to forests (Directive 2000/29/EC). In addition, the EU allocates funds for forest-related research, especially under the Horizon 2020 program. Energy policy, meanwhile, has set a legally binding target of achieving the use of 20% renewable energy in total energy consumption by 2020, which should increase demand for forest biomass (Directive 2009/28/EC). In addition, the European Union's new climate and energy framework foresees an increase in this percentage to 27% by 2030. Forestry projects can also be co-financed under the EU's Cohesion Policy from the European Regional Development Fund (in particular, fire prevention, renewable energy generation, climate change preparedness), in turn, is designed to assist member states in the face of major natural disasters such as storms or forest fires[35].

In addition, more than 37.5 million hectares of forests (i.e. 23% of Europe's forests) are part of the Natura 2000 network for nature conservation, created under the Union's environmental policy, and account for 30% of the areas covered by the network. Rethinking forest use is part of the thematic priorities of the European Union's new Environment and Climate Action program. As a follow-up to the EU Biodiversity Strategy which envisaged the introduction of sustainable forest use plans for public forests by 2020, the Commission's Communication on the EU Biodiversity Strategy 2030 specifically envisages the expansion of protected areas (30% of all land and sea areas, of which 10% must be strictly protected), which should expand the protection of Europe's forests, and envisages the planting of 3 billion trees.

The European Forest Fire Information System is used to monitor fire risks in forests. The Union is also promoting green procurement which can stimulate demand for wood produced using sustainable methods. It should also be noted that parquet, furniture and paper

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[35] https://www.lamoncloa.gob.es/lang/en/espana/stpv/spaintoday2015/environment/Paginas/index.aspx

products bear the EU's eco-label. In addition, the EU's Forest Law Enforcement, Governance and Trade (FLEGT) Action Plan provides for "voluntary partnership agreements" with timber-producing countries, and Regulation (EU) No. 995/2010, in effect since March 2013, prohibits the marketing of illegally harvested timber[36].

The European Union also participates in a number of international activities concerning forests (in particular, the UN Framework Convention on Climate Change). At the pan-European level, the main policy initiative for forests remains Forest Europe. It is already discussing a legally binding agreement on sustainable forest management and sustainable use of forests. In addition to its participation in global negotiations on reducing greenhouse gas emissions, the Union has taken the first steps toward including agriculture and forestry in its climate policy[37]. In addition, the Union has set a goal of halting the loss of forested land globally by 2030 at the latest

The European Parliament acts on an equal footing with the Council under the ordinary legislative procedure in many areas affecting forest areas, especially agriculture or environmental protection. In addition, Parliament adopts the European Union budget with the Council. Parliament has influenced many legislative issues affecting forests, in the field of the common agricultural policy or energy policy[38].

In its resolutions, the Parliament has long advocated greater coordination and coherence of the various instruments affecting European forests. On January 30, 1997, Parliament adopted a resolution on the European Union's forestry strategy and called on the Commission to present proposals for a European forestry strategy. The Commission responded to this call in its Communication on a Forestry Strategy for the European Union and was subsequently supported by the Council, which adopted the first EU Forestry Strategy on December 15, 1998.

In response to the report on the implementation of the EU Forestry Strategy from 1999 to 2004, Parliament reiterated the importance of the strategy and reaffirmed its support in a resolution of February 16, 2006 on the implementation of the European Union Forestry Strategy. In that resolution, the Parliament supported the implementation of the "European

[36] https://ec.europa.eu/eurostat/web/forestry/overview
[37] https://eur-lex.europa.eu/legal-content/PL/TXT/?uri=CELEX%3A32018R0841
[38] https://agriculture.ec.europa.eu/common-agricultural-policy/cap-overview/new-cap-2023-27_en

Union Action Plan for Sustainable Forest Management" presented by the Commission and proposed a series of coherent and specific goals and measures in various forest-related policies. The Commission developed this "EU Forest Action Plan" with a five-year (2007-2011) target, and its goal as a complementary instrument was to better coordinate 18 specific "core actions"

With reference to the Commission's Green Paper of March 1, 2010 titled. "Forest protection and information in the EU: preparing forests for climate change"[39] in a resolution of May 11, 2011, the European Parliament supported revising the Forest Strategy to address the specific challenges of climate change, sustainable forest management and conservation.

On September 20, 2013. The Commission presented a communication entitled. "A New EU Forest Strategy for Forests and the Forest-Timber Sector" which came out to address not only the growing demand for forests, but also major social and political changes. The Council endorsed this recast strategy in its conclusions of May 19, 2014, and the Parliament endorsed it in its resolution of April 28, 2015, on the new EU Forestry Strategy for Forests and the Forest and Wood Sector. In the resolution, Parliament calls on the Commission to supplement the strategy with a robust action plan containing concrete measures and to report annually to Parliament on progress in implementing the specific actions envisioned in the strategy[40]. Parliament also stresses that the implementation of the EU Forestry Strategy should be a multi-year, coordinated process. Parliament believes that priority must be given to promoting the competitiveness and sustainability of the forestry sector, supporting rural and urban areas, developing the knowledge base, protecting forests and preserving their ecosystems, improving coordination and communication, and increasing the sustainable use of timber resources and non-timber forest products[41].

On September 3, 2015. The Commission published a "Multiannual Implementation Plan for the New EU Forest Strategy". It lists a series of actions to ensure a coherent, coordinated approach to various forest sector policies and initiatives with specific stakeholder participation.

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[39]https://www.theguardian.com/world/2021/nov/12/trade-officials-taking-a-chainsaw-to-eu-forest-protection-plans
[40] Ibidem.
[41] https://eustafor.eu/

Chapter 2. Natural forest regeneration in mountain areas

2.1 Forest restoration as a natural process

Sustainable and balanced development of forest management requires a steady increase in forest resources. This process can take place as a result of an increase in the productivity of forests, expressed in terms of the increase in the current volume of forest stands, as well as through the constant renewal of forest areas and the afforestation of new land. The renewal of forest areas is a condition for the sustainability of forest management. The appropriate method of forest renewal is not only an ecological problem ecological, but also an economic one. According to the recommendations of the pro-ecological model forest management, natural forest regeneration should be preferred in those habitats where the there is compatibility of the parent stand with the habitat type of the forest. The parent stand is of known origin and of satisfactory breeding quality, and the condition of the soil creates conditions for the establishment and growth of natural regeneration. In contrast, artificial regeneration artificial regeneration should complement natural regeneration[42]

The basis for the existence of all living organisms are three main biological processes: birth, survival and death. In the case of the forest ecosystem, the counterparts of these processes that determine the permanence of the forest's existence are - regeneration (restoration), survival and depletion (separation and utilization) The process of regeneration is aimed at restoring forest structures lost in the process of depletion of timber resources, so it is a basic condition for maintaining the permanence of the existence of the forest. Depending on the use of current knowledge, the current generation will pass on to future generations of forests with a certain structure and biodiversity. The task of forest management in the restoration process is to develop indications on the size, time, place and manner of restoration (how much, where, when and how to restore). The renewal process refers to individual trees and stands, and not to the forest conceived as a whole, which means that foresters' activities

[42] J. Faliński, *Uprooted trees, their distribution and influence in the primeval forest biotope*. Vegetatio 38/1978, s. 176.

in this process are only one component of a broader process of maintaining the sustainability of the forest[43].

The process of survival involves the functioning of the forest over time, and thus the fulfillment by the forest on an ongoing basis of all its biological functions. Closely linked to the survival process is the the concept of stability, that is, the way the forest functions. The task of forest management in the process of survival is to develop indications on the size, time, place and manner of nurturing individual stands (how much, where, when and how to nurture). The survival process (like the regeneration process) refers to individual trees and stands, not to the forest conceived as a whole. This means that the activities of foresters in this process are also one (another) of the components of the broader process of maintaining the sustainability of the forest[44].

The process of depletion is the result of the natural depletion of trees, but primarily it is economic activity of the forester performing harvesting cuts. The task of forest management in the process of depletion is to establish indications for: the amount, time, place and the manner of harvesting wood from the forest (how much, where, when and how to cut). The process of attrition concerns individual trees and stands, not the entire forest, which means that in this process as well the activities of foresters concern only one (the third in turn) component of the broader process of maintaining the sustainability of the forest.

Thus, the concept of forest sustainability does not refer to individual trees and stands; it does not regenerate the entire forest at once, nor do all trees and stands survive and decline at once. Keeping the forest alive, and therefore the permanence of its existence, refers to the Instead, the forest conceived as a certain whole. Such collections of trees or stands in various modes of management are grouped into appropriate forest holdings[45].

Forest sustainability is understood as a dynamic state of equilibrium between the processes of regeneration, survival and decline of trees and stands at the forest management leve. While this definition of forest sustainability refers to the tree layer, it is not is a narrowing of this concept. This is because the forest as a plant formation is characterized by a dense layer of trees and is the basic and most important component of forest plant

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[43] A. Fischer, *Natural development of forest stands after windthrow: approaches to research on virgin forest in the German Federal republic*. Forstwis. Central. 109/1999, s. 309.
[44] T. Kozlowsky. Pallardy S. *Growth control in woody plants*. Academic Press, London 1997, s. 143.
[45] Ibidem, s. 144.

communities (biocenoses, ecosystems). Most important in the sense that in the event of permanent loss of the dense layer of trees there is also a permanent loss of the forest, i.e. loss of its sustainability[46]. In contrast, in the case of permanent loss of any other component of the forest biocenosis, the forest, although incomplete - poor, continues and will not lose the permanence of existence. This is because the compact layer of trees forms (in a natural forest and in a managed forest) larger or smaller clusters, population biogroups with the most favorable forms for their development. These biogroups in the science and practice of forestry are combined into higher-order units (e.g., strata, stands, developmental stages, farms). The basic condition for maintaining the sustainability of the forest is such a share of generational groups, which represent all stages of forest development (from the youngest to the oldest biogroups), For example, in age classes or thickness classes. The principle of sustainability of the forest, i.e. continuity of its existence, should not be equated with continuity of use or with the performance of various functions by the forest, because these principles are, in relation to it to it detailed, partial and subordinate postulates. The principle of sustainability of the forest, on the other hand, is absolute and superior, and applies even when sustainability of production, and production itself are not required. It also applies when the forest does not have to perform functions other than production, or when humans are not aware of this need[47].

It is therefore worth noting the types of forest restoration methods, namely natural and artificial. Natural regeneration is the emergence of a young generation of forest from self-seeding or regrowth. Any piece of forest that has been cut down must be renewed again. Thus, if one encounters felled but unrenewed forest fragments in the forest, it does not mean that they have been forgotten, but probably awaits the emergence of natural regeneration. In large open spaces, pioneer species such as birch, pine and aspen can more easily cope, while under the canopy of the parent stand, so-called heavy-seeded species such as beech and oak regenerate[48].

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[46] M. Schölch, *Natural regeneration without silvicultural intervention: a case-study from BadenWürttemberg. Schrift. Freib. Forst,* Berlin 1998, s. 99.
[47] Ibidem, s. 101.
[48] W. Schönenberger, *Post windthrow stand regeneration in Swiss mountain forests: the first ten years after the 1990 storm Vivian.* For. Snow and Land. Res. 77, 1/2/ 1999, s. 83.

Natural forest regeneration has a number of advantages. The root system of trees planted by human hand is, for obvious reasons, flattened, which is visible for many years, while the root system of seedlings from natural regeneration or even from artificial sowing is spread out spatially. This is more advantageous for the tree, providing it with better development, greater stability and also the ability to produce a tap root, so important in drought years[49]. By preparing the parent stand with appropriate cuts, the best and strongest individuals can be propagated and, importantly, adapted to local conditions. Self-sowing often occurs and develops under the canopy of the parent stand. In this way, the forest microclimate, soil cover and continuity of forest existence are preserved. Natural regeneration defends itself better against game pressure. Not without significance is also the fact that this is the cheapest way of forest renewal.

Unfortunately, this method of restoration also faces some difficulties. Young forest coming from natural regeneration grows more slowly. This is not beneficial because the first years of the young generation are the most difficult, requiring the most care and maintenance. Forest from planting grows faster which in practice means that it copes better with competition from weeds and seedlings of other tree species and with diseases. Nature often distributes very abundantly. Overcrowded natural regeneration of pine trees is exposed to fungal diseases, especially thistle, which can destroy whole areas of volunteer trees. The renewal of a given area depends on the fertility of seeds, and these can occur quite rarely: in pines on average every 3 years, in oaks every 5 years and in beech usually every 8 years. Therefore, there is a risk of weed infestation of unrenewed areas and then the introduction of a new generation is much more difficult[50].

Artificial forest regeneration, on the other hand, is the process of artificially creating a young generation of forest in place of a felled stand in the course of normal use or after its destruction by natural disasters, disease or pest gradations. The young stand, as it develops and grows, will exert a significant influence on the formation of the forest environment in a specific space and time in the future. Artificial regeneration involves sowing seeds on the

[49] S. Yamamoto, *Forest gap dynamics and tree regeneration*. J. For. Res., 5/2000, s. 224.
[50] M. Hartmann, *Resistance and resilience of the forest soil microbiome to logging-associated compaction*, ISME Journal, 8/2014, s. 226.

surface of a future crop or planting seedlings. Due to the characteristics of the area to be renewed and the requirements of the introduced species are used[51]:

- Forest restoration under the canopy of trees (under-canopy restoration) - involving the use of sowing or planting of seedlings under the canopy of the stand to be removed. It is used when the introduced tree species require cover, and the old-growth forest does not provide the desired self-sowing due to its species composition, origin, health.
- Restoration under shrub cover - involving the use of shrubs as cover for introduced tree species sensitive to sunlight or frost during the most difficult period of their life, until they emerge from the undergrowth (ground layer).
- Restoration in the open area.

Artificial restoration of the forest is always carried out through human action. Nature's participation in the restoration process is limited to creating growth conditions for planting or seeding. The entire process of preparation for planting (sowing), as well as the planting itself (seeding), is carried out either mechanically or manually.

- Compared to natural, artificial restoration is characterized by[52]:
- Lower biodiversity of offspring.
- Worse preservation of local genotypes in different species.
- Less complexity of species composition and vertical structure of the stand.
- Significant costs of planting material and restoration work.
- Lower costs and complexity of felling and maintenance cuts.
- Less demands on the competence of forest administration.
- Full coverage of the area with planting material.
- Restoration does not require supplemental plantings.
- Restoration does not require maintenance cuts.
- With artificial restoration, existing natural regeneration is used.
- Ability to achieve earlier compactness and adequate overstory structure.

[51] Ibidem, s. 229.
[52] H. Heinimann, *Forest operations engineering and management – the ways behind and ahead of a scientific discipline*, Croatian Journal of Forest Engineering, 28/2014, s. 109.

- Uniformity of seeding, with a small amount of seed sown, and uniformity of seedling height growth.

The impact of environmental factors on the forest causes a long-term deformation of its internal structure, and the regeneration of the forest depends more on external factors (natural, anthropomorphic), including the regulatory actions of foresters, than on the on the forest's self-regulatory abilities[53]. In particular, a cultivated forest has few internal regulators of its own and therefore has little homeostatic capacity, and is therefore an impermanent system, incapable of permanently meeting the needs of the society. With regard to cultivated forest, the essential regulator is the work of the forester. The activities of foresters in the field of forest management maintain the sustainability of the forest by designing a rational utilization, so that the increase in volume is not exceeded on a permanent basis[54]. This is because permanent use of the forest in excess of the increment leads to the destruction of the forest, and thus to its death. The basic tool for maintaining the sustainability of forest existence is regulation, which consists of such influence on the processes of forest development that will reduce deviations from its desired course.

Natural restoration has many advantage such as[55]:

- continuity of forest production is preserved,
- the favorable features of both microclimate and soil are maintained uninterrupted, and the specific forest environment is not nullified,
- there is an opportunity to reproduce the best trees in the stand and preserve local ecotypes,
- there is the possibility of building multi-story stands,
- the production cycle is accelerated, with this type of regeneration being the cheapest.

The use of self-sowing allows to maintain an uninterrupted production flow. Before the old stand is removed, a new generation already begins to grow. In this way, "idling" is avoided, and the forest habitat remains permanently in an active state. After the final clearing

[53] Ibidem, s. 110.
[54] J. Krieger, *Economic Value of Forest Ecosystem Services*: A Review, The Wilderness Society, Washington DC/2011, s. 93.
[55] Ibidem, s. 95.

of the sowing trees, the new production cycle is often already well advanced, the young trees reach a relatively large size, form dense clusters, shielding the soil well, continuing to keep it in working order.

By self-sowing, local varieties (ecotypes) of trees are perpetuated in a given area, developed in the course of a long-term process of natural selection, best adapted to local habitat conditions, hardy and vigorous. However, it should be borne in mind that negative stands in given habitat conditions will usually produce negative offspring, so they should be eliminated from the process of natural regeneration[56].

Restoration resulting from self-sowing consists of a great number of individuals, many times exceeding the number of young trees in artificial restoration. The abundance of self-sown trees makes it possible to make a tighter selection among the air raid by selecting the best specimens for further breeding. By remaining in a stronger density, the trees are more quickly cleared of branches and can provide high-quality, knotless and even-aged wood in the future. When different species of trees grow to different sizes in a stand, or when different species are of different ages, then multi-story stands are formed. With a multi-age and multi-species structure, the coexistence of all living organisms arranges favorably for the health and growth of trees. As a result of self-sown regeneration, the forest area constantly contains trees of different ages and sizes, growing side by side and distributed irregularly. Natural regeneration makes the most of the natural forces of nature, so it is more economical. Self-sowing is formed and develops gradually before or during the use of the parent stand. In this way, the flow of production is not interrupted but shortened[57].

2.2 Barriers and challenges to forest restoration in mountainous areas

Throughout its history, man has gradually increased pressure on forests and interfered with the natural processes of forest ecosystems, directing his activities mainly on timber production, the acquisition of new land for settlement, agriculture and industry. The forest environment has been transformed and it is now not justify a casual comparison of the current and potential proportion and distribution of forest habitat types and forest complexes.

[56] J. Socha, Effect of topography and geology on the site index of Picea abies in the West Carpathian, Poland. Scand. J. Forest Res. 23/2008, s. 203.
[57] Ibidem, s. 205.

Attempts at such comparisons make sense only on a macro-regional scale and in places where large forest complexes of primeval nature[58].

The breeding procedure should take into account both natural and economic conditions, as well as the legal requirements for conducting sustainable, sustainable and multifunctional management of forest resources. The basis for determining the breeding objectives and directions of breeding proceedings in forests are[59]:

- geobotanical regionalization of the country;
- natural-forestry regionalization;
- seed regionalization;
- recognition of the natural potential of forest habitats by typological method (in mountainous conditions taking into account altitudinal zones), using the achievements of natural sciences (including soil science, phytosociology, climatology)

in order to indicate the possibility of forming specific forest communities;

- recognition of forest protected natural habitats;
- natural conditions shaped by man in the closer and farther surroundings of the forest, which affect the state of the forest environment and modify the possibilities of
- silviculture

With the above in mind, it is worth discussing examples of barriers and challenges in forest restoration in mountainous areas.

The first challenge is water erosion. In most near-natural forests, as well as in typical commercial forests, infiltration capacity and hydraulic conductivity of the near-surface soil layers are relatively high. The high infiltration capacity is supported by the continuous input of organic matter into the soil. In forests free of disturbance rainwater usually infiltrates into the soil and moves to streams as subsurface flow. The rate of soil erosion in such a forest is extremely low and generally does not exceed 1 t/ha per year[60].

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[58] B. Wemple, , Forest roads and geomorphic process interactions, Cascade Range, Oregon, Earth Surface Processes and Landforms, 26/2001, s. 191.
[59] Ibidem, s. 192.
[60] B. Alexandrowicz, *Typologiczna analiza lasu*. PWN, Warszawa 1997, s. 54.

The amount of water erosion on forested slopes depends on the vertical extent of disturbance associated with the thickness of soil organic horizons, as well as the spatial extent or connectivity of the disturbance. Disturbances in the dynamics of the precipitation-drainage response (primarily associated with reduced soil infiltration capacity) in areas where timber is harvested, will determine the amount of potential water erosion[61]. Since the soils of mountain forests are mostly characterized by organic horizons of low thickness, above-ground skidding methods can disturb the soil structure, thereby increasing the risk of water point out that of all the forest management activities, it is skidding that contributes the most to the increase in erosion.

The most susceptible to erosion are forest roads, skid trails and logging depots, i.e. places where the soil is compacted, exposed and has deeply disturbed structure. Felling itself and subsequent stand restoration work have little impact on water erosion, unless severe and large-scale disruption of the functioning of the forest ecosystem. After heavy rainfall, water saturation of the soil results in surface runoff, which, especially on dirt roads where the soil is artificially compressed, assumes large proportions. This runoff is further fed by the interception of subsurface flow from road undercuts. Roads increase the rate of water erosion and accelerate the runoff of rainwater into streams[62].

In contrast to the rate/dynamics of water erosion, the rate of landslide erosion (mass movements mass movements) does not begin to increase significantly until several years after timber harvesting. Deep-rooted trees and shrubs increase the cohesiveness of the shallow soil cover soil and facilitate drainage, thus reducing the likelihood of shallow landslides Harvesting timber with subsequent regeneration of the stand reduces the strength of the stabilizing rooting strength (rooting strength) up to two decades after the trees are felled. In numerous field studies conducted around the world in steep, forested terrain have reported a significant (up to tenfold) increase in landslide activity over a period of 3-15 years after timber harvesting. The increase occurs in both frequency and volume of landslides and is largely related to the with the period when the stabilizing force of the roots reaches minimum

[61] Ibidem, s. 56.
[62] S. Rożek, *Kierunki doskonalenia metod rozpoznawania siedlisk leśnych*. Sylwan 151 (2)/2007, s. 26.

values, which is caused by the gradual deterioration of the root strength of felled trees while the root system of young trees is underdeveloped[63].

The products of weathering and erosion are carried out of the catchment by fluvial transport in the form of dissolved material, suspended solids and clastic weathering. The material transported by the waters of mountain streams consists of sediments supplied by tributaries, as well as material that builds up the bed and banks of the channel, fills the valley bottoms and is delivered from the slopes. Many researchers also point to unpaved roads as a source of delivery of transported material. In addition, roads also serve as a link between the slope and channel systems, delivering significant amounts of fine material directly to the riverbed[64].

2.3 Influence of environmental factors on forest restoration

Knowledge of natural processes and control of the state of the forest environment allow foresters to make an early diagnosis of threats that can negatively affect the state of the forest. Every year they take measures to preserve the sustainability of the forest and increase its natural resistance to pest factors.

Threats are divided into three groups[65]:

- biotic (e.g. harmful insects, pathogenic fungi, herbivorous mammals);
- Abiotic - extreme atmospheric phenomena (e.g., strong winds, snow, heavy rain, high and low temperatures);
- anthropogenic - caused by humans (e.g., fires, industrial pollution, littering of the forest).

Of the biotic factors, the greatest threat in recent years is posed by deer. The predominant type of damage is barking and gnawing, and the most common perpetrator of damage is deer.

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[63] Ibidem, s. 28.
[64] J. Koper, *Application of biochemical index to define soil fertility depending on varied organic and mineral fertilization*. EJPAU, Agronomy 6/2007, s. 199.
[65] Ibidem, s. 202.

Every few years in many areas of the forest there is a gradation-i.e. a mass appearance of insect pests. The most common causes of gradation are populations of: dandelion weevil, pine barbicide, Christmas tree bark beetle, cetacean weevil and borers[66].

Protection against harmful insects is based on constant observation and forecasting, among other things, by hanging pheromone traps to catch the pests - based on the amount of the pest, it is possible to determine whether there has been an increase in the population[67]. As long as there is an ecological balance in the forest there is no need for foresters to interfere with the environment. In order to maintain the ecological balance, reams are established - for the allies of the forest: birds, amphibians, reptiles, small mammals and spiders. Artificial nests for nesting and roosting birds and bats are hung around. Only when these methods fail and there is a gradation that threatens large complexes, foresters proceed to rescue operations through aircraft spraying.

Of the abiotic factors, droughts and low groundwater levels pose the greatest threat to the forest. The shortage of water in the forest district is partially compensated by the construction of artificial water reservoirs, using natural depressions in the area. Of the anthropogenic factors, littering of the forest poses the greatest threat[68].

According to the Principles of silviculture, care is to encompass the entire biocenosis and consist in creating favorable conditions for the balanced development of the entire forest flora and fauna. Nurturing the biocenosis includes activities related to the preservation of the entire natural biodiversity in the forest Thus understood, the concept of care fully corresponds to the concept of protection of habitats and species Preservation of natural habitat in a proper state of conservation state of conservation involves, among other things preserving the associated biodiversity, and in particular, preserving in good condition of the so-called typical species. This concept can also be applied to soil fauna, the richness of which, according to literature , reaches 1,000 species per square meter of soil. This can therefore sometimes give rise to some problems related to balancing the hierarchy of conservation goals, because on the one hand, as literature proves, the abundance of soil fauna drastically decreases after each clear-cutting, and on the other hand, for the preservation of, for example, the population of

[66] J. Lasota, *Siedliskoznawstwo leśne na nizinach i wyżynach*, Wydawnictwo Uniwersytetu Rolniczego w Krakowie 2014, s. 171.
[67] Ibidem, s. 173.
[68] E. Błońska, *Wartość siedliskotwórcza leśnych gleb niecałkowitych*. Sylwan 158 (1)/2007, s.10.

the woodlark (Lullula arborea), for example, carrying out clear cuts may prove to be the right way to protect its habitat. Thus, some compromise is needed again, that allows balancing the goals and effects of the action. Determining the goal one wants to achieve is here, as usual, paramount issue. For example, deciding early enough to exclude a stand from further use and leaving it to natural processes essentially closes any further discussion of its care, because it is no longer necessary[69].

However, if natural processes occurring in the stand were to contribute to the disappearance of the natural habitat or the deterioration of its condition, then in some cases it is possible, and in others even necessary, to take appropriate actions. If, for example, the goal were to preserve a several-hectare fertile beech forest damaged on the southern side by a hurricane, so that it formed a belt of open space, overgrown with sand reed, which prevents the natural regeneration of beech, and attacked by the gangrene the remaining trees are getting stronger and stronger, thus expanding the open space and shrinking the beech stand acreage is shrinking, it may be acceptable be allowed to create conditions for the natural regeneration of beech by[70]:

- soil preparation,
- mowing sand reed on the interrows,
- fencing the natural beech regeneration with netting,
- in order to protect it from animals,
- nurturing the young beech generation

As part of stand maintenance, the possibility of introducing undergrowth or introducing productive reforestation is often considered This treatment is mainly intended to improve the quality of the forest habitat, although the different significance. For brushwood forests it is a harmful treatment, leading, through the very soil preparation, followed by shading of the forest floor, as well as raising the fertility of the habitat, to the disappearance of lichens, which are an essential element of huckleberry forests[71].

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[69] T. Wanic, *Preliminary effects of fertilization on ecochemical soil condition in mature spruce stands experiencing dieback in the Beskid Śląski and Żywiecki Mt*s., Poland. Water Air Soil Pollut 225/2011, s. 197.
[70] J. Burger, *A review of physical and chemical properties as indicators of forest soil quality: challenges and opportunities*. Forest Ecol. Manag. 138/2009, s. 194.
[71] E. Sikorska, *Siedliska leśne. Cz. II. Siedliska obszarów wyżynnych i górskich*. Akademia Rolnicza im. H. Kołłątaja w Krakowie, Kraków 2006, s. 89.

The growing undergrowth of deciduous trees is also threatening the light oak habitat, eliminating from it the light-flowering plant species, characteristic of this natural habitat. The introduction of undergrowth due to protected animal species. Due to a different hunting pattern for lynx, a forest rich in undergrowth can have a positive significance, while the same forest for the wolf creates less favorable conditions.

In managed forests, the process of natural regeneration does not proceed spontaneously, but is usually directed by man. Natural regeneration is used under conditions that allow it to be obtained by available means and when the expected results correspond to the intentions regarding the species composition, quality and structure of the resulting young generations of the forest. The initiation of natural regeneration should be undertaken to a sufficiently wide extent, since its proper use affects the intensification of production and prevents the degradation of forest soils considerably. Natural regeneration is advisable wherever the introduction of artificial regeneration encounters great obstacles, such as in the regeneration of species that require cover (beech, fir in difficult-to-access terrain, as well as in forests that play a protective role, where it is important to preserve their natural character or maintain a permanent forest cover.

Therefore, it is worth detailing the factors that directly affect the processes of natural forest regeneration[72]:

- poor technical quality and health of the parent stand, resulting from the failure to adapt the species to the current state of the habitat or the transfer of seeds from other climatic conditions. In addition, stands of foreign origin should be excluded from natural regeneration
- The need to adjust the intensity of cuts to the rate of development of the regeneration makes it difficult to accurately plan the size of the eta several years in advance.
- The state of the cover may be unsuitable for natural regeneration, for example, due to a strongly developed layer of grasses (reed grass, hemlock) or shrubs (hemlock, heather).

[72] Ibidem, s. 92.

- Dependence on the variable and largely unpredictable pattern of meteorological conditions determining seed setting, maturation and germination, and seedling development.
- Uneven sowing, which can result in an abnormal form of the trees - slender and rachitic in overstocked areas or excessively branchy when sown too sparsely; this results in the need for early entry with careful care, and sometimes - artificial additions.

Moreover, both beech and spruce are characterized by different environmental factors that affect their natural regeneration processes.

Beech begins to harvest viable seeds at the age of several decades, but due to the rather high felling ages used for it (usually 120-140 years), trees over a hundred years old take part in effective natural regeneration[73].

Due to the outstandingly rare and irregular seed years, the beech stand requires preparation for natural regeneration many years before its appearance.

The warm and dry months of June and July promote abundant flowering the following May. Flower buds are visible as early as the end of July. Abundant flowering is not necessarily followed by abundant fruiting, as flowers and fruit buds are sensitive to a number of abiotic factors. Particularly dangerous are frosts in the flowering season: female flowers are damaged at -1.4 to -3.0 degrees, while male flowers are damaged already at -1.0 degrees.

Every 3-5 years can expect an average seed crop, while every 10 years it can expect an abundant crop. Seed years never occur in direct succession. In recent decades there has been a shaky rhythm of beech harvesting, and forestry does not have a good method of forecasting beech births.

Natural regeneration of spruce can be achieved by top or side seeding. Spruce yields abundantly every 3 - 5 years, in the mountains less frequently, even every 6 - 11 years.

[73] Ibidem, s. 95.

Chapter 3. Analysis of research results

3.1 Purpose and research problem

Methodology belongs to the discipline of science, which is concerned with activities undertaken by the researcher, the purpose of which is to achieve a certain kind of knowledge - true knowledge. Thus, methodology is interested in the type of activities performed by the researcher and their effect. It should be noted that this is, of course, a definition heavily simplified. In terms of the literature, there are many definitions of methodology. Methodology should be understood as the science that studies the following phenomena:

1. cognitive activities of scientific research;
2. the effects of the activities undertaken.

Methodology is simply the science of research methods, and the concept of general methodology should be understood in this way - as a scientific discipline that studies universal research methods. It is impossible not to mention that methodology is a subject of extremely extensive. The number of publications in this subject area can contribute to the difficulties in selecting information of value. However, the classic positions of researchers of the problems of the methodology of sciences, despite the fact that they are often decades old, still are not only up-to-date, but, above all, substantively valuable. With the above in mind, the purpose of this paper is a comparative analysis of the natural regeneration of beech and spruce in the mountain zone of selected national parks and nature reserves in Europe.

3.2 Analysis of beech and spruce restoration in the mountain zone

With the purpose of this work in mind, it is worthwhile to start the considerations with the characteristics of spruce and beech.

Spruce can exist in areas where the growing season lasts at least 60 days and the winter dormancy period is characterized by negative air temperatures over a minimum of 120 days[74]. The validity of the cited data is supported by the natural range of spruce, which does not include areas under the influence of the milder oceanic or Mediterranean climate, while

[74] M. Slodicak. Thinning regime in stands of Norway spruce subjected to snow and wind damage. In: COUTTS, M.P.; GRACE, J. (eds) Wind and trees. Cambridge, Cambridge University Press. s. 436.

beyond the disjuncture in Poland it extends far to the east and reaches as far as the northern border of the lasotundra. Thus, spruce corresponds to a cool, but still sufficiently moist climate, or even to a more severe, continental climate, but characterized by such an abundance of snowfall that it is a sufficiently abundant source of moisture throughout the growing season. The attachment of spruce to areas of more permanent snow cover in Poland is obvious[75]. The entire area of the spruce-free belt, for example, is characterized by poor and impermanent snow cover. It should be noted that the tree species in question in Europe, except for one large northeastern lowland refuge, is a mountain tree. In central Europe, the spruce covers all mountain and high-mountain forests[76].

In terms of light requirements, it shows a wide amplitude. It behaves as a shade-bearing species in milder (but not optimal) conditions and on fertile soils, or becomes more light-bearing at lower temperatures and worse trophic conditions (high mountain location and northern limit of occurrence). With age, light requirements increase (ETH Materials, Schmidt-Vogt 1977). Under optimal conditions, it is considered a shade-bearing (semi-shade) species. In its youth it tolerates shade for up to a dozen years, in the lowlands and lower alpine it is only slightly inferior to fir in this respect. However, it grows best with full access to light.

For proper spruce growth, a small amount of heat and a relatively short growing season are sufficient (compare climatic conditions). It shows high resistance to winter frosts and has low heat requirements during the summer. However, spruce in our climate tolerates poorly, on the exposed surface, late spring frosts. It has been found that with a gradual drop in winter temperatures (hardening off) it tolerates lower temperatures better than with sudden drops[77].

Spruce requires adequate moisture in both air and soil throughout its life. It also grows in areas with lower precipitation (e.g., in the Bialowieza Forest, with annual precipitation of 585 mm, it reaches 50 m in height on gleyic soil), but then it chooses local depressions of the terrain, places near watercourses, northern exposures, i.e. those conditions that provide it with

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[75] R. Petras, Changes in increment of spruce damaged by air pollution. Lesnictvi-Forestry 39 (3-4)/1998, s. 119.
[76] P. Paschalis, Protection o fForest Ecosystems. Selected Problems ofForestry in Sudety Mountains. Fundacja "Rozwój SGGW", Warszawa 2004, s. 93.
[77] Ibidem, s. 95.

the needed moisture. The cited example indicates, as confirmed by some ecologists, that spruce is less sensitive to atmospheric droughts than to soil droughts[78]

Spruce is sensitive to summer droughts (drought-induced cracks develop on the trunks and the tops of the trees wither). In terms of the trait in question, it is more demanding than pine (ETH Materials). Given the large area of spruce, it is reasonable to assume that there may be relatively drought-tolerant provenances within the species. Wood, Rohmeder and others put forward the hypothesis that spruce trees originating from areas relatively poor in precipitation are supposed to be more drought-resistant. Wood also found that spruce of lowland origin tolerate periods of drought better than spruce from the mountains or from the northern range, although relatively high drought tolerance is shown by Swedish origin (e.g., Unnaryd) (Precipitation also has a significant effect on thickness increment. Under the conditions of the upper regale (Tatra Mountains), a negative relationship was found between increments in tree ring width and precipitation during the months of V-VII[79].

The soil requirements of spruce are moderate, provided the soil moisture is high enough. It achieves optimal conditions for development on fresh soils, formed from sandy loam, deep, moderately rich, not too acidic with an average deep level of moving ground water. On compact, poorly aerated soil, it takes root particularly shallowly, so there is a danger here of trees being blown down by wind or snowfall (ETH Materials). In rich habitats, it does not take advantage of the abundance of the soil, while succumbing to competitive pressure from species that find optimum development in these conditions. Spruce's mineral requirements are relatively modest; moderately rich soils generally satisfy them fully[80].

Potassium supply is mostly completely sufficient on all soils. Potassium deficiency is to be expected on quartzite, quartzite-porphyry and chalky formations. Nitrogen deficiency is more common in spruce stands. Spruce can grow on soils with a very wide scale of pH variation, 3.4-6.7. It achieves its best growth at pH 5.3-6.0. On not very rich soils, such as fresh coniferous forest, spruce persists in the lower floor. It also does not suit waterlogged soils, characterized by poor airiness[81].

[78] Z. Sierota, Przerzedzenie koron jako efekt stresu i źródło stresu. Sylwan 8/1997, s. 71.
[79] C. Wood, Understanding wind forces on trees. In: Coutts M. P., Grace I. [red.]. Wind and trees. Cambridge University Press 1995, s. 139.
[80] P. Skawiński, Zanieczyszczenie drzewostanów w Tatrach. Tatry 1992. 3: s. 11.
[81] Ibidem, s. 12.

3.2.1 Sudetes

Sudetes, a mountain system on the northeastern edge of the Bohemian Massif, in Poland and the Czech Republic and Germany (western edge); include ridges, ranges and isolated massifs surrounding mid-mountain basins; they stretch in an arc about 300 km long and 50 km wide, from the Elbe Mountains in the northwest to the Moravian Gate in the southeast; they border (along the marginal fault line) the Sudeten Foothills in the north.[82]

As a tectonic unit, the Sudetes were formed as a result of numerous phases of Precambrian and Paleozoic orogenies; they were finally foliated and stiffened during the Hercynian orogenesis; each orogenic cycle was accompanied by very strong magmatism and metamorphism. As a result of the numerous phases of folding and deep erosion, which resulted in the exposure of the crystalline parts of the mountains, the Sudetes have a very complex structure, described as a mosaic; the oldest massif of the Sudetes are the Precambrian gneisses of the Owl Mountains; younger fold arcs run parallel to the massif, fusing together at its corners; Precambrian and Old Paleozoic gneisses, amphibolites, gabbro, marbles, quartzites and various crystalline schists, as well as Young Paleozoic greywacke, conglomerates, limestones, sandstones, granitoids and outcrop rocks dominate among the Sudeten rocks. Calcareous and crumbly rocks of the Upper Permian, Triassic, Cretaceous and Cenozoic were deposited on the levelled (denuded) surface of the Hercynian Sudetes. In the Tertiary, as a result of the Alpine orogenesis, the Sudetes were morphologically rejuvenated; they were tripped, the central part was uplifted in the form of a rift along the great marginal faults (in the southwest - the Sudeten fault, in the northeast - the pre-Sudeten fault); tectonic movements were accompanied by intense outpourings of basaltic lavas[83].

In the area of Poland, a distinction is made between: Western Sudetenland, Central Sudetenland and Eastern Sudetenland; the Western Sudetenland stretches from the Lusatian Neisse (in the west) to the Lubavian Gate (in the east); it includes: The Izera Mountains, the Karkonosze Mountains, with the highest peak of the Sudetenland - Sněžka (1,602 m), the Jeleniogórska Basin, the Kaczawskie Mountains and the Janowickie Ore Mountains; the

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[82] Z. Kwapis, Ocena degradacji drzewostanów świerkowych w Sudetach Zachodnich i Wschodnich oraz w Beskidzie Śląskim . Prace Inst. Bad. Leśn . 2005, 25/1, s. 83.
[83] Ibidem, s. 84.

Central Sudetenland stretches from the Lubavian Gate to the Klodzko Pass and the Międzyleska Pass; it includes the Klodzko Basin and the mountains: Kamienne, Wałbrzyskie, Sowie, Bardzkie, Stołowe, Orlickie (Orlica, 1084 m), Bystrzyckie; Eastern Sudetes stretch from the Klodzka Basin to the Moravian Gate (Czech Republic); they include: Sněžník Massif (Sněžník, 1425 m) with the Bialskie Mountains, and the Zlaté and Opavskie Mountains[84]. The Sudeten Mountains also include the Lusatian Mountains (in the Czech Republic and Germany), as well as the Jeseníky Mountains (Praděd, 1492m) and the Odra Mountains (in the Czech Republic). As a result of the long period of development of the relief of the Sudetes, long ridges with gentle slopes and flat tops prevail, above which rise gentle domes of peaks (hardwood hills); the activity of mountain glaciers during the last glaciation was marked only in the Karkonosze[85].

The Sudetes have a mountain climate with oceanic influences; the average temperature in July, at an altitude of 600 m, is 15 ° C, in January -3 ° C, on Śnieżka 8 ° C in July and -7 ° C in January; precipitation ranges from 800 mm (at the foothills) to 1200 mm (on the ridges), occurring throughout the year, but with a marked maximum in July; winter precipitation in the form of snow also has a large share. The watershed between the Oder, Elbe and Danube river basins runs through the Sudetenland; the larger rivers flowing out of the Sudetenland are: Lusatian Neisse, Beaver with Kwisa, Kaczawa, Bystrzyca, Nysa Klodzka, Opava, Elbe with Izera, Úpa and Orlice, and Morava; some of them (Nysa Klodzka, Kwisa, Beaver, Bystrzyca) are used for energy purposes.

The Sudetenland is arranged in distinct floors; in the lower alpine (450-1000 m) the place of the original fir and beech forests has been taken mostly by spruce cultures; the upper alpine (up to 1250 m) is formed by natural high mountain spruce forest; in the Karkonosze above the forest boundary extends the mountain-pine forest floor, on Śnieżka - the alpine floor; in the Eastern Sudetes above the forest boundary there are upland meadows; peat bogs (with glacial relics) are widespread; forests, especially in the western and southwestern parts of the Sudetes, heavily degraded (e.g. forests in the Jizera Mountains); 2 national parks have

[84] Ibidem, s. 85.
[85] Ibidem, s. 87.

been established in the Karkonosze Mountains - on the Polish and Czech sides, and in the Table Mountains - the Table Mountain National Park[86].

Major mineral wealth: coal and lignite, ores of copper, nickel, tin, chromium, iron, arsenic, barite, building stones, especially granite and basalt; major cities in the Sudetes: Jelenia Góra, Walbrzych, Nowa Ruda, Klodzko; numerous mineral springs (mainly oxalates). Well-known spas: Świeradów Zdrój, Cieplice Śląskie Zdrój, Szczawno Zdrój, Kudowa Zdrój, Duszniki Zdrój, Polanica Zdrój, Lądek Zdrój. The Sudetenland is one of the best developed tourist regions in Poland and the Czech Republic[87].

Spruce, fir, beech and larch are among the most important tree species of the Polish mountains. Spruce requires a lot of water in the soil and moisture in the air for optimal growth and development, which, together with its along with its high resistance to low air temperatures, has caused it to spread especially in the higher elevations of the Carpathians and Sudetes. It has won the competition with other tree species in the rangeland upper, as well as in the higher parts of the lower regiel[88].

Are not immune to industrial immissions, as well as other pest factors. This is evidenced by the process of spruce dieback in the 1970s and 1980s in the Jizera Mountains and the contemporary occurring process of decay of stands of this species in the Western Beskids[89]

Changing climatic conditions, especially the increase in air temperature in recent decades, are affecting, among other things, the deterioration of the climatic water balance thus not favoring the growth of coniferous tree species, which are also plagued by increasingly more frequent strong winds. In January 2007, Hurricane "Cyril" wrought great damage to the forests of the Sudetenland. The largest, estimated at 170,000 cubic meters of scrap and tipping volume, was found in the Kamienna Góra Forest District Monitoring of

[86] Ibidem, s. 88.
[87] Ibidem, s. 89.
[88] J. Malachowska, Ocena uszkodzenia lasu na Stałych Powierzchniach Obserwacyjnych Monitoringu Biologicznego w 1993 r. Inst. Bad. Leśn. Warszawa 2004, s. 94.
[89] A. Jaworski, M. Pach, Zmiany udziału buka, jodły i świerka w dolnoreglowych drzewostanach naturalnych w rezerwacie „Dolina Łupusznej" (Gorczański Park Narodowy), Sylwan, 2013, nr 157/3, s. 216.

Sudeten forests, formed mainly of spruce stands, which primarily perform soil and water protection, is therefore of great importance both cognitively and practically[90].

Beech, on the other hand, is a tree growing up to 30, and exceptionally up to 50 m in height and 1-1.5 m in breast height. It develops a dense crown, in specimens growing singly - spreading and low-set, in compactness - elongated and set high. The trunk in beech trees growing in close quarters has a clear main axis, visible up to the apex. On open sites, the trunk is short and has the character of a log, passing into thick branches[91]. The cross-section of the trunk is similar to a circle. The bark is smooth, thin, light gray and non-peeling, sometimes slightly cracked in old trees at the bottom (in the quercoides form the bark is cracked like that of an oak)[92].

Beech begins to bear fruit on open sites at the age of 40-50 years, in compactness between 60-80 years. It fruits abundantly every 5-8 years. Seed germination capacity in beech, determined during the winter, is about 75%; then it drops quickly and keeps within six months, i.e. until spring; seeds stored longer do not germinate. Sown in the spring, they germinate in 5-6 weeks. Above-ground germination. Leaves are large, broad, fleshy, kidney-shaped, dark green and glossy on top, whitish underneath. From a bud between the cotyledons, a shoot with two leaves with serrated edges grows. Only in the following year do normal leaves grow.

At first the beech grows very slowly, with age its growth in height increases; it reaches the climax of growth in height between 30 and 50 years of age; then the growth weakens and at about 150 years of age it almost completely stops; it lives up to 300 years.

It has high soil and climate requirements. It is an oceanic temperate climate tree. It hates continental climates, suffers from severe frosts and even perishes; it is also harmed by late spring frosts. It likes moderate but fairly significant humidity, and is best suited to an annual rainfall of 600-1200 mm. It grows on soils that are good, humus and rich in mineral salts, preferably on fresh or poorly moist, loamy or loamy-sandy soils. It is often found on

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[90] V. Šimůnek i wsp., Growth variability of European beech (Fagus sylvatica L.) natural forests: Dendroclimatic study from Krkonoše National Park, Cent. Eur. For. J. 2019, nr 65, s. 92–102.
[91] A. Gill, A review of damage by mammals in north temperate forests. 3. Impact on trees and forests. Forestry 65/1994, s. 365.
[92] Ibidem, s. 368.

calcareous soils, but the soil's abundance of calcium is not a prerequisite for good growth. Poor, dry soils, as well as permanently waterlogged soils do not suit it[93].

It is one of the most shade-loving tree species; in this respect it is second only to yew and fir. It produces a dense crown and can grow in strong compactness, so it has a very strong effect on the soil due to shading. In addition, it feeds the soil abundantly with mulch, which generally decomposes well and gives fertile humus. The beech's leaves contain a lot of calcium salts, so the beech's influence on the soil is usually beneficial, as the processes of podzolization are constantly inhibited[94].

The range of beech covers central and western Europe. It is found in the southern part of England, in the southern part of Scandinavia, reaches northern Bessarabia, and south to the Balkan Peninsula (excluding southern Greece), the Apennine Peninsula and Sicily, Corsica and northern Spain. It finds its habitat optimum in central France, western Germany, former Yugoslavia and Romania. In the Hungarian Lowlands and in the central parts of the Alps, beech does not occur (the central alpine valleys have a continental climate and therefore beech cannot grow there). Instead, it appears on the southern slopes of the Alps.

The westernmost range of the Sudetenland was the site not only of large-scale stand damage in the 1980s, but of the destruction and decay of the entire forest ecosystem. This phenomenon has been called an ecological disaster, although a more apt name is the spiral disease of the forest ecosystem. A complex of synergistic factors, in which the anthropogenic factor played the largest role, led to the removal of dying forest from an area of more than 15,000 hectares. In the process of dying forest stands in the Jizera Mountains, a particular pathogenic stimulus in the form of industrial immissions was revealed, although the whole process called ecological disaster in the Sudetenland consisted of three pathogenic (stress) factors[95]:

- anthropogenic
- biotic
- abiotic

[93] G. Regamey, subm.: Linking GIS-based models to value ecosystem services in an Alpine region, 2001, s. 55.
[94] L. Hamilton, The protective role of mountain forests. GeoJournal 27/2007, s. 13.
[95] K. Cummins, Ecology of coarse woody debris in temperate ecosystems. Adv. Ecol. Res 1991, 15, s. 301.

At the same time, the dying of forests in the higher mountain locations was very significantly influenced by the synergistic effect of air pollution with stressful biotope conditions, in which unfavorable pathogenic conditions intensified their impact, causing the dying of forest ecosystems[96].

Against the backdrop of weakened forests in the entire Polish mountains, the stands of the Sudetes present themselves particularly unfavorably. As early as the 1950s, Researchers pointing out the poor condition of the forests there, emphasized the importance of historical and economic factors, especially abnormal changes in the species composition and structure of tree stands and sanitary neglect from the war period[97]. Other research pointing to a significant reduction in the resistance of spruce stands to atmospheric damage, includes stands of the Jizera Mountains and the Giant Mountains to those damaged by wind to a catastrophic degree. Changes in the structure and relaxation of the compactness of the stands favored the formation of repeated damage from abiotic and biotic factors, including industrial pollution, causing a further increase in weakening and even the dying of spruce trees. Symptoms of forest damage became apparent earliest in the highest Jizera Mountains[98] The effects of wind and industrial pollution industrial pollution were superimposed there by severe damage to spruce crowns caused by the larch pointer The weakened stands were followed by a massive outbreak of secondary pests of forest amarcia over large areas[99].

The effect of external stress factors is reflected in the dynamics of tree thickness growth. Chwistek found a significant reduction in the growth of stands in the Low Tatras as a result of feeding by larvae of Indicator larch bark beetle; a similar phenomenon was also found in the Polish part of the Sudetes. Comparative studies on the growth of spruce stands severely damaged by emissions was conducted[100]. While different research observed a decrease in growth in spruce trees weakened by detergent plants, while excluding the influence of climatic factors. Literature showed that a significant reduction in growth of

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[96] Ibidem, s. 302.

[97] J. Zawada, Metoda oceny stanu zdrowotnego drzewostanów znajdujących się pod wpływem emisji przemysłowych. Las Pol. 10/1983, s. 9.

[98] J. Wawrzoniak, Pomiar zanieczyszczeń powietrza w lasach - monitoring techniczny. Sprawozdanie za okres letni 1986. Inst. Bad. Leśn. Warszawa 1987, s. 33.

[99] K. Chwistek, Zmiany wybranych cech taksacyjnych drzewostanów Gorczańskiego Parku Narodowego w okresie 1992–2002 na tle oceny naturalności lasów gorczańskich z 1932 roku. Roczniki Bieszczadzkie, 2008, nr 9, s. 92.

[100] Ibidem, s. 109.

radius of breast height in mountain spruces occurs with severe (exceeding 55%) defoliation, while other researchs described a relationship between the degree of defoliation of trees and the reduction of their growth, formulating the corresponding equations of regression. Such a relationship is already marked at weaker defoliation and sulfur content in needles exceeding 0.18% d.m.. According to literature in the first half of the 1980s there was a widespread collapse of the of mountain spruce growth in Poland, mainly related to the negative influence of industrial pollution. The condition of forest stands in the zone above 800 m above sea level was then described as catastrophic, while in the zone up to 800 m above sea level were found to be severely threatened stands. Recent measurements testify to the inhibition of this process[101].

Therefore, it is worth paying attention to the factors that affect the recovery of spruce and beech, and in the case of the Sudetenland, one of the biotic factors that has a significant impact on spruce recovery is the feeding of *Zeiraphera griseana* (figure 1).

Figure 1 Zeiraphera griseana
Source: *https://lepiforum.org/wiki/page/Zeiraphera_griseana*

[101] M. Rajmański Objawy zamierania drzewostanów świerkowych (uszkodzenia korony) na terenie Karkonoskiego Parku Narodowego. Las Pol. 4: 6-9/1999, s. 43.

Table 1 Occurrence of the tree pest on selected sites

RESEARCH STAND	ALTITUDE (m)	YEAR				
		2009	2012	2011	2015	2018
X1	680	0	2	1	0	1
X2	900	1	3	3	3	2
X3	800	0	2	2	3	3
X4	800	0	3	3	3	3
X5	640	0	1	2	2	1
X6	620	0	0	1	1	2

Damage: - none, 1 - up to 30%, 2 - 31-60%, 3 - more than 60% of this year's growth.

Source: M. Rajmański Objawy zamierania drzewostanów świerkowych (uszkodzenia korony) na terenie Karkonoskiego Parku Narodowego. Las Pol. 4: 6-9/1999, s. 57.

Many measurements were carried out in the Sudetes in Poland and the Czech Republic, for which permanent sample plots were used. The territory of interest which I take in considerations are Jizera Mountains and belongs to the Krkonoše-Jeseníky range system. The bedrock is composed of porphyritic medium-grained granite or granodiorite. The climate of the area is suboceanic. Average annual temperature is in the range of 5.2 – 6.5 °C relative to the altitude. Annual precipitation amounts are 1 200 – 1 300mm[102].

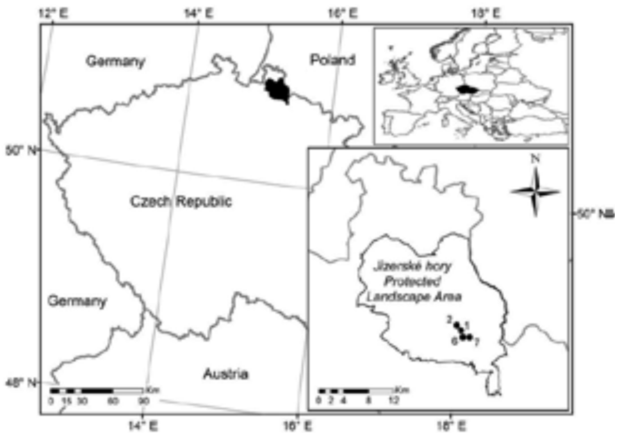

Figure 2 shows the location of .permanent research plots (PRP)

Source: W. Grodzki, Przyczyny obecnego stanu lasów w Górach Izerskich. Prace Inst. Bad. Leśn. S. B, 17, s. 49.

4 permanent research plots, of 50 x 50 m, (we can call them artifficialy gaps) were established in 1979 to determine the regereation structure. Measurements were carried out in 1979 and again in 2015. For the individuals of regeneration with breast-height diameter (dbh)

[102]W. Grodzki, Przyczyny obecnego stanu lasów w Górach Izerskich. Prace Inst. Bad. Leśn. S. B, 17, s. 49.

< 4 cm and height ≥ 150 cm these characteristics were measured on the whole plot: position, height, distance of live crown base to the ground level, crown width. Structural and growth, abundance, species diversity were evaluated for all individuals of regeneration on each plot. The results are shown in the table below it is clearly visible that over the years the natural increase of beech was significantly marked and the natural increase of spruce decreased. It is probably caused by several factors: first of all significant damage to young trees by forest animals in the first years of measurements, and significant pollution of the air (high concentration of compounds toxic to plants in this area in 1980-1990), resulting in climate change (warming of the air), which had a high impact on spruce growth, with a significant benefit to beech. The regenerated beech has returned to its natural habitats, previously occupied by artificial spruce trees (table 2)[103].

Table 2 Per-hectare numbers of natural regeneration (height ≥ 5 cm, dbh < 4 cm) specified according to tree speciesin 1979 and 2015.

PRP1	Fagus sylvatica		Picea Abies	
1979	248	26.1%	640	67.2 %
2015	19,804	79.3 %	3,852	15.4 %
PRP2				
1979	136	13.9 %	816	83.3%
2015	13,888	42.5 %	16,968	51.9 %
PRP6				
1979	168	14.6 %	932	80.9%
2015	58,372	75.8%	16,824	21.8 %
PRP7				
1979	88	12.9%	540	79.4%
2015	26,896 5,036	84.1 % 15.7		

[103] W. Grodzki, Influence of air pollution on the menace by bark beetles in spruce stand s of Sudety Mts. in . Poland. W: Air Pollution and Interactions between Organisms in Forest Ecosystems. Proceedings (eds.: M. Tesche, S. Feiler). TharandtlDresden, s. 275.

Source: W. Grodzki, Influence of air pollution on the menace by bark beetles in spruce stand s of Sudety Mts. in . Poland. W: Air Pollution and Interactions between Organisms in Forest Ecosystems. Proceedings (eds.: M. Tesche, S. Feiler). TharandtlDresden, s. 275.

As mentioned earlier, since the first half of the 1980s there was a significant deterioration of moisture-thermal conditions in the Western Sudetenland, with a condition of water deficit starting from the extremely dry year of 1982 until the end of the decade, a water deficit condition persisted, the effects of which were also observed in other mountain regions. It is therefore likely that on damage to crowns due to indicator feeding was compounded by the effects of moisture deficiency moisture, intensifying the weakening of stands and affecting the reduction of the trees' growth potential. Probably also due to the water deficit, the regeneration of reduced growth in the post-gradation period was relatively weak everywhere and proceeded unevenly, but in less damaged spruces it was more pronounced[104].

It is also worth noting the restoration of beech and spruce in the Sudetenland, as carried out by Glowacki in his study (table 3).

Table 3 Restoration of beech and spruce in Sudets

PRP	Age[1]	Height[1]	Density	Canopy[2]	Number of recruits /Relative proportion in regeneration									
					Beech		Spruce		Rowan		Maple		Other	
	year	cm	psc ha^{-1}	%/ha	pcs ha^{-1}	%	psc ha^{-1}	%	psc ha^{-1}	%	psc ha^{-1}	%	psc ha^{-1}	%
1	19.1	97.9	34 880	69/1.18	23 240	66.6	11 360	32.6	280	0.8	-	-	-	-
2	12.0	53.7	41 120	36/0.52	39 400	95.8	1 680	4.1	-	-	-	-	40	0.1
8	13.9	53.9	211 560	52/1.37	206 880	97.8	3 360	1.6	1 280	0.6	-	-	-	-
9	8.4	32.2	256 400	39/1.37	250 640	97.8	5 440	2.1	280	0.1	-	-	-	-
27	9.7	37.4	54 440	5/0.06	51 920	95.4	560	1.0	1 960	3.6	-	-	-	-
28	13.5	65.2	33 440	8/0.09	31 720	94.9	760	2.3	960	2.9	-	-	-	-
29	23.0	130.7	12 200	25/0.51	12 040	98.7	40	0.3	120	1.0	-	-	-	-
35	7.9	30.8	21 800	8/0.09	5 960	27.3	-	-	160	0.7	15 360	70.5	320	1.5
36	4.9	18.3	90 200	10/0.12	81 760	90.6	600	0.7	920	1.0	1 400	1.6	5 520	6.1
37	8.2	19.6	12 080	6/0.08	8 720	72.2	120	1.0	200	1.7	40	0.3	3 000	24.8

Notes: [1]Mean value of nature regeneration, [2]crown closure/crown projection area

[104] B. Głowicki, Charakterystyka pięter klimatycznych w Sudetach. Sprawozdanie naukowe, IMiGW Wrocław 2009, s. 53.

Source: B. Głowicki, Charakterystyka pięter klimatycznych w Sudetach. Sprawozdanie naukowe, IMiGW Wrocław 2009, s. 53.

The results of the multivariate analysis showed that microrelief and vegetation cover, compared to other factors, had relatively little significance for the density of recruitment and height and canopy. Compared to other factors had relatively low significance for the density of regeneration, height and canopy. Forest stands in the Sudetenland have a high capacity for natural regeneration.

3.2.2. Carpathians

The Carpathian Mountains are one of the largest mountain ranges in Europe, located in its central part, in Austria, the Czech Republic, Slovakia, Hungary, Poland, Ukraine and Romania. Stretch in an arc open to the west from the Danube Gorge near Bratislava to the Iron Gate (Danube Gorge near Orsova); separated from the Alps by the Vienna Basin, from the Sudetenland by the Moravian Gate; length about 1300 km, width 120-350 km; highest peak Gierlach (2655 m). Divided into the Western Carpathians and the Southeastern Carpathians; the border between them is the Lupkowska Pass (640 m). In the western part of the Carpathian arc, the Outer Western Carpathians and, separated by the Hron furrow and the Hornádskaya Basin, the Central Western Carpathians and the Inner Western Carpathians are distinguished; in the southeastern part, the Outer Eastern Carpathians are distinguished, Inner Eastern Carpathians (up to the Predeal Pass of 1,033 meters and up to the turn of the curve from southeast to west)[105]. the Southern Carpathians, the Western Romanian Mountains (Apuseni) and the triangular Transylvanian Highlands located between them. According to other divisions, the Eastern Carpathians and the Southern Carpathians (also called the Transylvanian Alps) are treated separately. The Outer Western Carpathians include: Chrziby, White Carpathians, Western Beskids (Moravian-Silesian Beskids, Silesian Beskid, Small Beskid, Makowski Beskid, Zywiec Beskid with Babia Gora 1725 m, Kisuckie Mountains,

[105] L. Kulig, Lasy i gospodarka leśna w XIX i XX wieku. Zeszyty Naukowe U. 1. Prace Historyczne. Kraków. 60: s. 45.

Orava Magura, Gorce, Sadecki Beskid, Czerchowskie Mountains, Beskid Wyspowy), the Central Beskids (Beskid Niski, Ondavskie Foothills), and the outermost Western Beskid and Central Beskid flissile foothills, leveled to a height of 400-500m. The Central Western Carpathians consist of 2 mountain sequences formed by isolated crystalline massifs with mantle covers of mostly carbonate rocks (limestone and dolomite) separated by tectonic basins (Nitrzanska, Turčanská, Liptovská, Popradská, Hornádská); The first of these sequences includes the Lesser Carpathians, the Inovec Mountains, the Strážov Mountains, the Lesser Fatra, the Choč Mountains, the Tatra Mountains (with the highest peak of the entire Carpathians), and the flysch Levoča Mountains; the second sequence includes: Tributary, Ptacznik, Kremnické Mountains, Great Fatra and Nízke Tatry (Dziumbier 2043m)[106].

The Inner Western Carpathians are separated from the Central Western Carpathians by the tectonic furrow of the Upper Hron valley; the nucleus of this part of the Carpathians is, made up of Paleozoic and crystalline rocks covered by Triassic limestone series, the Slovak Ore Mountains, and in their extension towards the north beyond the Hornád valley, the isolated Branisko rift; with the Slovak Ore Mountains are connected orogenically to the west by the volcanic massifs of the Štiavnica Mountains, Javoria and the Pol'any caldera; the vast South Slovak Basin, filled with Tertiary marine sediments, separates the North-Hungarian Middle Highlands (the last member of the Inner Western Carpathians) composed of the volcanic Börzsöny, Cserhát, Mátra and Slaño-Toká Mountains and the limestone Beech Mountains[107].

The outer (flysch) Eastern Carpathians are formed by the Eastern Beskids (Bieszczady, Gorgany, Pokucko-Bukovin Beskids and Poloniny Beskids with the Czarnohora range) and the Moldavian Carpathians (Ciucaş 1956 m); outwardly, they are connected by the geologically youngest part of the Carpathians - the foliated Pliocene sediments of the sub-mountainous trench called the Subcarpathians. The Inner Eastern Carpathians consist of the Marmara Carpathians, the Rhodnenské Mountains and the Bystřice Mountains, as well as extinct volcanoes stretching from Vyhorlat through the Gutyj Mountains, the Cybele Mountains, the Kelimen Mountains and the Harghita Mountains to the Brasov Basin. The Southern Carpathians lack a flush and volcanic belt; the core of the mountains consists of

[106] Ibidem, s. 46.
[107] Ibidem, s. 47.

high old crystalline massifs; 5 mountain groups separated by transverse valleys are distinguished here: the highest Fogaras Mountains (2543 m) between Prahova and Aluta, the limestone conglomerate mountains of Bucegi, Leaota, Jezer, Piatra Craiului and Cozia, the Parângu group (with the Sibi Mountains, Lotru and Şureanu), the Godeanu-Retezat group (Peleaga 2509m), the Banat Mountains separated by the Temesz-Cerna tectonic furrow, and the Poiana Ruscă massif, located north of the Southern Carpathians. The highest part of the West Romanian Mountains is the Bihor Massif, the Transylvanian Ore Mountains rise in the south; the Transylvanian Highlands are an uplifted Tertiary sinkhole, cut by the valleys of the Samosha, Marusha and Aluta rivers and their tributaries into several parts of 400-700 m height. Today's relief of the Carpathian Mountains began to form since the Miocene (before about 30 million years), in reference to the geological structure, neotectonic movements and changing climatic conditions (from a dry, hot climate in the Neogene to a temperate one with several cold periods in the Pleistocene)[108].

The Carpathian Mountains lie in a temperate climate zone. The Western Carpathians form a climatic boundary between cooler areas under the transitional influence of maritime air masses in the north and warmer areas with a more continental climate in the south (the Great Hungarian Plain). The Eastern Carpathians separate areas with a mild wetter climate in the west (the Transylvanian Highlands) from areas with a dry, continental climate in the east. Due to the varied relief of the area, there is a clearly developed climate stratification. The average monthly and annual temperatures show a decrease of 0.5°C on average for every 100 m of elevation; in the foothills, the average temperature in January ranges from -2°C to -4°C, in July from 18°C to 21°C, at an altitude of 800 m from -5°C to -7°C and from 14°C to 16°C respectively, at an altitude above 2000 m - from ca. -8°C to -12°C and from 6°C to 8°C; the average temperature of the year is below 0°C: at Lomnica in the Tatras (-3.9°C) and at Omul peak in the Southern Carpathians (-2.6°C); in the basins, the average annual temperature exceeds 8°C. Precipitation in the Carpathians is less than in the mountains of Western Europe and, depending on the exposure of the ranges and altitude, annual totals range from 800 to 1,200 mm, while in the basins it does not reach 600 mm; the highest values are reached in the Tatras (up to 1,800 mm), with maxima in the summer months; depending on the elevation

[108] Ibidem, s. 48.

above sea level, from 30 to 85 percent of the annual precipitation in the Carpathians is recorded. above sea level, from 30 to 85% of precipitation is in the form of snow; snow cover persists for more than 3 months, in the highest ranges it can remain all year (snowfall can also occur in summer)[109].

The Carpathian Mountains are the European watershed between the Baltic and Black Sea drainage basins. 10% of the area belongs to the catchment area of the Baltic Sea, the main basin of the upper Vistula River (its Carpathian tributaries are the Soła, Skawa, Raba, Dunajec, Wisłoka and San); to the Oder River flows from the Carpathians, the Ostravice and Olza. From the northern part of the Eastern Carpathians, water drains into the Black Sea via the Dniester and its tributaries (Strviąż, Stryi, Svitsa, Lomnica and Bystrica). The rest of the Southeast Carpathians and the southern slope of the Western Carpathians belong to the Danube basin (Morava, Vah, Nitra, Hron, Ipola); the largest Carpathian tributary of the Danube, the Tisza, which is fed in the east by the Samosha, Keresz and Marusha, originates on the southern slope of the Eastern Carpathians; from the Southern Carpathians flow into the Danube: the Temesh, Jiu, Aluta, Arjesha, Yalomica, from the Eastern Carpathians - the Seret and Prut. Carpathian rivers have a snow and rain regime with 2 surges per year (especially intense in the summer months), when the greatest precipitation occurs, sometimes causing catastrophic floods[110].

Energetic use of the water resources of the Carpathians is not large; the largest artificial lakes on the Danube at Zelazna Brama, Bicaz, on the Bystrica, Arjesha, Solina Lake on the San; cascades consisting of several smaller reservoirs have been built on some rivers (Vah, Soła, Dunajec, San). Natural mountain lakes (about 500) are small, mostly post-glacial, the largest and deepest in the southern part of the Tatra Mountains (Morskie Oko and Wielki Staw); in addition, there are landslide, karst and volcanic lakes; among glacial moraines and on low watersheds in basins there are high peat bogs (swamps) (e.g., in the Orava-Novotarska Basin).

In the Carpathians there are numerous deer, roe deer, wild boar, wolf, lynx, marten, squirrel, rarely - brown bear, wildcat; in the highest mountains there are island preserved chamois, marmot and golden eagle. For the protection of nature, a number of reserves and 18

[109] Ibidem, s. 49.
[110] N. Radoane, Carpatian Gravel Bed Rivers, A Regional Approach, 17/2001, s. 135.

national parks have been established in the Carpathians, including - the Tatra National Park and a corresponding park on the Slovak side[111].

Forests in Europe are generally no longer natural. According to the State of Europe's Forests report (2011), about 3/4 of the European forests are, to varying degrees, transformed by human activities, which generally negatively affects habitat quality and biodiversity. The Carpathian Mountains remain one of the last dense refuges of forests of high natural value in Europe. This vast mountain chain, crossing eight countries in Central Europe, has remained a kind of refuge for wildlife, due to its topography, inaccessibility, as well as cultural and historical conditions. The importance of the Carpathians in biodiversity conservation is determined primarily by the extent, diversity and good state of preservation of the local natural habitats. The specific features of the Carpathians, causing their exceptional natural value, can be considered at different scales. At the scale of the entire continent, what is important is the vastness and coherence of this mountain range, extending over a length of about 1,500 km. These parameters are a key factor enabling, among other things, the free migration of plants and animals, as well as promoting the peculiar stability of the habitats found here habitats[112].

The forests of the central part of the Carpathian Mountains form a transition between the low-variety spruce stands of the western part and multi-species forests of the eastern part with a predominance of fir and beech. The western part of the region is dominated by spruce stands, while moving eastward the frequency of spruce decreases in favor of fir and beech, and in the western part of the Low Beskid falls almost to zero[113].

Analogous to the review made in the analysis of the Sudetenland, it is worth noting research on the attack of pests on spruce and beech stands (table 4).

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[111] Ibidem, s. 136.
[112] A. Simon, The influence of wind throw microsites on tree regeneration and establishment in an old growth mountain forest. Forest Ecology and Management 262/2011, s. 1289.
[113] B. Šerá, Contribution to knowledge of natural growth and development of mountain Norway spruce seedlings. Ekológia (Bratislava) 19(4) 2004, s. 420.

Table 4 Pests attack

RESEARCH STAND	ALTITUDE (m)	YEAR				
		2001	2002	2003	2004	2005
X1	1190	0	0	1	2	1
X2	932	0	1	1	3	3
X3	1423	1	1	2	3	2
X4	1583	1	2	3	3	3

Source: B. Schieber, Vegetation dynamics of herb layer in managed submountain beech forest. Folia Oecologica 42/2005, s. 32

Carpathian forests forming large combined complexes in the Middle Ages remained uninterruptedly under the influence of human economy. This influence was decidedly negative. As a result of increasing settlement and the development of local industrieshl significant deforestation occurred. Very early on, commercial exploitation of timber, which was floated down the Dunajec and Vistula rivers. Completely free logging concerned the most valuable timber and accessible places, slowly encroaching on more remote and higher-lying areas. By the middle of the 19th century forest area had shrunk by more than half, many forest stands had been heavily thinned and their structure had changed. Often the place of forests of high-growth forests was taken by stands of regrowth. The species composition has changed less species composition, as the regeneration took place exclusively by self-sowing[114].

Spruce is throughout the area the weakest component of forests. Both the number of solid stands and the admixture of spruce in mixed stands accounts for their resilience. This is due to the high threat to spruce from natural and economic factors and the consequences of its elimination from the stands. The frequency of spruce decreases from west to east[115].

The main factors that have initiated and are increasing weakening include extreme weather events, fungal parasites, industrial pollution and massively reproducing insects. Most spruce stands are affected by the parasitic activity of the sapstem and root hubs (figure 3)

[114] B. Schieber, Vegetation dynamics of herb layer in managed submountain beech forest. Folia Oecologica 42/2005, s. 32.
[115] Ibidem, s. 33.

Figure 3 Hubs root
Source: lasypanstwowe/dhk294jpg.pl

Particularly the sapstem weakens systematically for more than 60 years The stands of the lower regale have been systematically weakened for more than 60 years. The first mentions from 1932 and 1933 concern the forest districts of Stary Sącz, Muszyna, Snietnica and Orawa at the time. Initially, a strong outbreak was marked . in the southeastern , part of the Beskid Sądecki, later the disease spread to further stands of trees and currently covers about 14,000 hectares. The period of greatest harmfulness is in the II and III age classes, later it weakens. A typical picture of the infestation shows a stand. 50-years-old with varying degrees of thinning, hatching with overexposed nd yellowed crowns, with steadily emerging deadwood. There is a strong weed infestation, and in places, in view of the early fruiting of diseased trees, dense natural regeneration is formed, which is already infected at the beginning of its life. At present, the dynamics of the disease are less than in the Western Carpathian Mountains[116].

[116] A. Rigling, Structural patterns of beech and silver fir suggest stability and resilience of the virgin forest Sinca in the Southern Carpathians, Romania. Forest Ecology and Management 356/2015, s. 189.

The forests of the Central Carpathian Mountains are quite remote from industrial regions, and the predominance of southwesterly winds blowing in the winter makes, that the main stream of pollution bypasses their area. Exposure to of diffuse emissions is continuous, although less than in the western part of the Carpathians. Also significant is the impact of local emissions, such as in the Tatra forests adjacent to Zakopane. Pollutants appear to stimulate the development of the firefly disease, and certainly the effects of the disease facilitate their penetration into the forest. The impact of emissions is significant in the highest and exposed positions, causing combined with frosty winds a significant reduction in needles. Together with scrap generated in the crowns due to snowfall, this reduces the overall surface area of the assimilation area and alters microclimatic conditions. In this context, it is possible also look for a connection between pollution and mass occurrences of leaf-eating insects[117].

Depending on year and location in Beech and Spruce mixed forest . Density ranged of beech seedling is between 0,75 and 3,90 its mean about 2,32 individuals per m2, instead density ranged of spruce seedlings between 0,08 and 0.47 individuals perm2 ist about o,23 individuals per m2[118].

Regeneration of beech and spruce responded diferently to the admixed species in the overstory stands. Spruce densities increased approximately proportionally to the percentage of this species in the overstorey.Spruce regeneration increased whit decreasing stand densities.

For beech regeneration, the strongest positive interaction occurred in the range where the presence of trees beech is between 50 and 70%[119].

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117 Ibidem, s. 190.
118 T. Vrška, Breaking through spruce A three-decade rise of sycamore in old-growth European forest. Forest Ecology and Management 366/2015, s. 106.
119 Ibidem, s. 107.

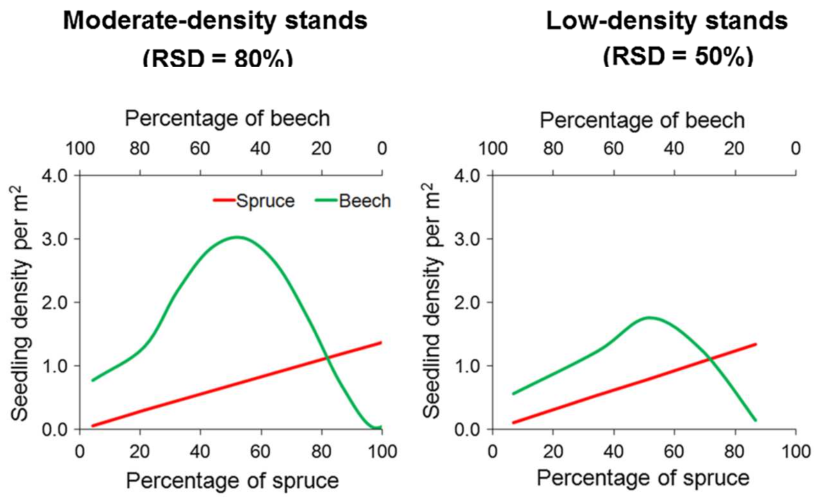

Figure 4 Expected seedling densities
Source: T. Curt, Competition for water and light between beech seedlings and the surrounding vegetation in abandoned pastures colonized by woody species. Annals of Forest Science 60/2005, s. 69.

Beech, being the most "Atlantic" species in mountain forests, it is sensitive to low temperatures and drought, causing disruption of water management. These factors are likely the cause of "beech slime mold." This disease, common periodically in western Europe, in the Carpathians appears only occasionally. During particularly cold winters there is cracking of trunks and formation of false heartwood. In trees with crowns exposed to drying, cold winds, the outer shoots wither. Wind also causes individual uprooting, and late spring snowstorms occurring sometimes already after the leaves have developed, crushes young trees, especially in unmanaged poles[120].

In the central part of the Western Carpathians, beech shows great resistance to the above-mentioned natural factors and great vitality , manifested in dominance in competition with fir and taking the place of fallen spruce stands. The good health of beech stands of this region is evidenced by the small amount of sanitary use, which in 1988- 1993 amounted annually to about 4 to 8 thousand. The share of beech in mixed stands and the number of beech stands should be considered to be a stabilizing factor in forest health. This is not in contradiction with the supposed influence of air pollutants from distant emission sources[121].

[120] T. Curt, Competition for water and light between beech seedlings and the surrounding vegetation in abandoned pastures colonized by woody species. Annals of Forest Science 60/2005, s. 599.
[121] Ibidem, s. 601.

In beech forests, the expression of this influence can be seen in the numerous occurrences of *Phyllaphis fagi* on the leaves (figure 5).

Figure 5 Phyllaphis fagi
Source: lasypanstwowe/hhdy738/jpg.pl

The healthiness of the Carpathian forests, which determines their versatile utility, is due in a special way to the diversity of the natural environment and the way forests have been used throughout history, and in modern times - from the way forest management. The resultant influence of these two groups of factors, to which industrial pollution has been added over time, is the weakening of stands of varying intensity, taking the extreme form of dying. Insects, which are a permanent element of the forest environment, play an important role in this process. Under conditions of temporary or permanent deformation of the environment, expressed in the reduction of self-regulatory capacity, they can increase the set of factors that weaken trees and stands. Insects that feed on the needles or leaves of trees are characterized by a tendency to periodic reproduction punctuated by diapauses of varying lengths, in which their occurrence is negligible[122].

[122] M. Barna, Tree species diversity change in natural regeneration of a beech forest under different management. Forest Ecology and Management 343/2015, s. 93. .

3.2.3. Alps

The Alps are the highest mountain area in Europe. They stretch in an open arc towards the south, from the Gulf of Genoa to the Little Lowlands. Hungary, on the territory of: Germany, Italy, France, Switzerland, Monaco, Liechtenstein, Austria and Slovenia; 1200 km long, 150-260 km wide; highest peak Mont Blanc, 4807 m. Divided into the Western Alps, higher and more massive, and the Eastern Alps, lower, more cut by river valleys; the dividing line runs in a transverse depression from Lake Constance, through the upper Rhine valley, over the Splügen Pass and the San Giacomo valley to Lake Como. They were formed in the Alpine orogenesis, eventually uplifted in the Tertiary. The Alps are characterized by fold and mantle structure. In the Western Alps, a distinction is made between the outer mantle zone - the Helvetic (Mesozoic and Paleogene sediments, in places as a phyllite, with crystalline massifs: Pelvoux, Mont Blanc, St. Gothard) and the inner mantle zone - the Pennine (Mesozoic crystalline schists). In the Eastern Alps (Austrian zone), a distinction is made between the axial part (Mesozoic magmatic and metamorphic rocks) and the mantle zones (dolomites and limestones) flanking it from the north and south. Adjacent to the north and south are pre-mountainous sinkholes filled with Tertiary molasse (conglomerates, sandstones, clays)[123].

Alps is the climatic boundary between the temperate and subtropical zones; on the northern side of the Alps the cooler polar-maritime air from the northwest and west prevails, while on the southern side comes (especially in spring and autumn) the warmer air from the Mediterranean Sea, and from the east the drier, cooler continental air in winter from the Pannonian Basin. The average monthly temperature in January reaches its highest values in the foothills: in the Maritime Alps about 8 ° C, on the south side about 0 ° C, on the north side - about -2 ° C; at an altitude of 2,500 m, the average temperature in January drops to about 0 ° C; in the basins and valleys in winter often form stagnant pockets of colder air, where strong temperature drops occur (below -30 ° C); in the depression on the Gstettner Alm (in the Dürrenstein massif) the absolute minimum is -53 ° C. Average temperature in

[123] Beghin, R., Lingua, E., Garbarino, M., Lonati, M., Bovio, G., Motta, R., Marzano, R., 2010. Pinus sylvestris forest regeneration under different post-fire restoration practices in the northwestern Italian Alps. Ecol. Eng. 36, 1365–1372.

July: about 24°C in the Maritime Alps, about 20°C in the south and 19°C in the north, at an altitude of 2500 m about 5°C. The Western Alps receive the most precipitation, up to 3,000 mm, in places up to 4,000 mm per year; in the Eastern Alps, the outer ranges exposed in the north and south - 2,500-3,000 mm[124].

The driest are the interior valleys with a meridional course and basins: the total precipitation decreases below 1000 mm (locally to 500 mm). Above 2300 m, precipitation occurs almost exclusively in the form of snow (which, combined with its abundance, leads to the formation of a thick and permanent snow cover). The perpetual snow limit runs from 2500 m on the northern slopes to 3200 m in the south and in the dry interior areas. Due to the influx of air masses of different characteristics over the Alps and the varied relief of the terrain, the Alps have characteristic regional and local winds: fen, bise, mountain-bottom, glacial; cool air flowing down from the mountains is the cause of cold winds in their vicinity, such as the mistral in the Rhone valley. The modern glaciation of the Alps covers about 4,000 square kilometers, 2/3 of which is in the Western Alps; the most heavily glaciated parts of the Alps include: Monte Rosa, Finsteraarhorn, Mont Blanc, High Taury; the largest glaciers in the Western Alps: Aletsch (area 86.8 km2, length 24.7 km), Gorner, Mer de Glace, in the Eastern Alps - Shepherds.

Thanks to the high humidity and high runoff rate (60-90%), the Alps are an important hydrographic node of Europe; the Rhine, Rhone, Po and tributaries of the upper Danube (Lech, Inn, Isar, Aniza) originate from here; The rivers flow in deeply incised valleys, in the Western Alps mostly in transverse, in the Eastern Alps in longitudinal, with gorge sections; fed by meltwater and in places also by glaciers, they show high water levels in mid-summer and low in winter; their large energy resources are exploited by numerous power plants. Their large energy resources are exploited by numerous power plants. The largest lakes lie at the foot of the A., on the northern side: Geneva, Bodensee, Four Cantons, Zurich, on the southern side: Garda, Maggiore, Como[125].

The Alps are located in the territory of 9 countries, so it is quite difficult to have unified studies that show average amounts of ozone. An example in this work will be the

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[124] Delarze, R., Caldelari, D., Hainard, P., 1992. Effects of fire on forest dynamics in southern Switzerland. J. Veg. Sci. 3, 55.
[125] Bolli, J.C., Rigling, A., Bugmann, H., 2007. The influence of changes in climate and land-use on regeneration dynamics of Norway spruce at the tree line in the Swiss Alps. Silva Fenn. 41, 70.

Italian Alps, where in a similar period that I took into account, observations and ozone measurements were carried out.

The area covered by the monitoring campaign is located in a mountain area south of the Alps in Italy. The monitoring campaign for this research was conducted by means of passive samplers from May to August 1998[126].

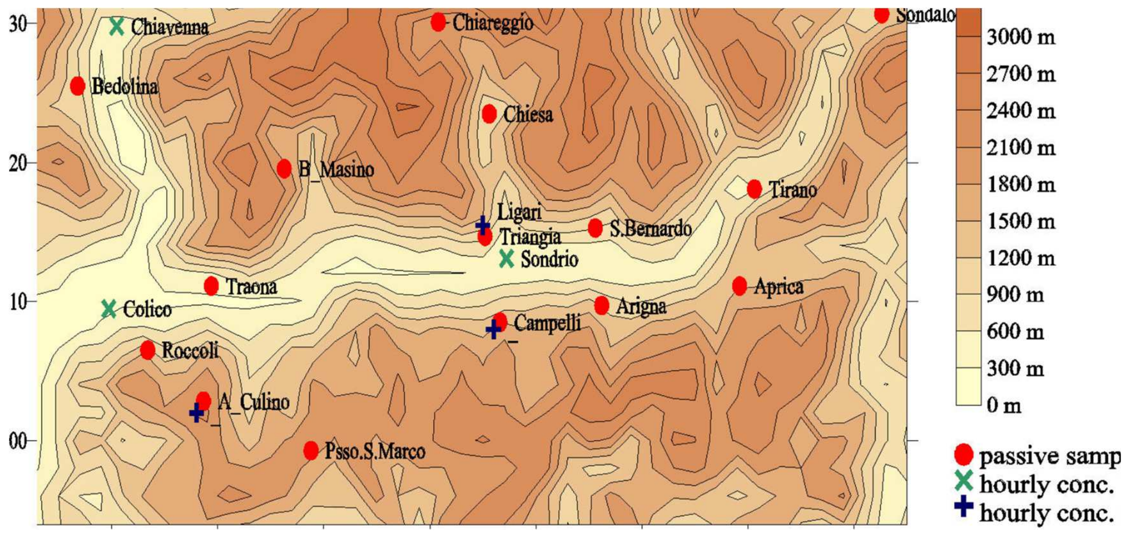

Figure 6 Site location map
Source: europeanforests/odj2849/kdj3/com

Table 5 Ozone Weekly Concentrations (ppb) Measured by Passive Samplers at the 15 Selected Sites

	Traona	Tirano	Bedolina	Triangia	Arigna	Chiesa	Sondalo	S. Bernardo	Bagni Masino	Campelli	Alpe Culino	Roccoli	Aprica	Chiareggio	Psso. San Marco
11/05-25/05	46,8	21,8	57,7	52,4	50,1	51,55	56,55	46,65	48,55	66,1	61,95	50,35	37	54,5	61,15
25/05-01/06	42,2	24,95	38	38,55	44,15	37,15	41,1	77,8	37,2	49,4	52,45	43,5	45	55,3	59,1
01/06-08/06	57,55	32	48,8	47,45	49,7	45,7	48,3	47,45	33,55	56,2	59,35	51,9	43,9	45,1	87,35
08/06-15/06	47,05	34,25	54,95	57,2	54,2	47,35	54,95	55,65	49,35	77,45	72,95	60,45	55,9	53	48,75
15/06-22/06	57,45	28,65	52,05	53,1	55,75	47,15	48,6	57,95	39,5	69,3	63,1	60,25	47,65	42,95	49,7
22/06-29/06	66,75	35,7	56,65	57,15	47,85	57,05	58,3	59,4	49,7	61,95	72,4	58,5	59,15	50,9	88,95
29/06-06/07	35,4	29,2	55	42,3	49,2	45,9	52,7	50,35	24,4	59,45	56,35	46,05	45,95	53,25	34,85
06/07-13/07	48,4	29,5	57,05	51,1	53,3	48,3	55,15	56,9	40,05	57,4	62,3	47,05	48,35	60,95	59
13/07-20/07	54,1	26,5	59,3	53,85	45,75	48,85	54,6	52,25	40,3	72	62,65	53,9	44,8	39,2	73,6
20/07-27/07	55,65	34,45	62,8	58,7	55,95	49,9	61,95	60,2	48,85	77,8	77,7	56,95	46,8	54,8	73,7
27/07-03/08	44,85	32,5	58,05	48,1	48,6	37,85	51,25	50,7	36,45	49,4	67,65	53	46,1	35,15	70,15
03/08-17/08	29,8	7,1	39,8	36,3	24	31,45	31,45	40,45	29,95	48,4	51,35	22,25	35,65	39,15	43,3
17/08-31/08	32,5	15,7	40,15	43,2	49,75	30		40,3	32,7	47,6	52,65	35,6		35	35,6

Source: Brang, P., Moran, J., Puttonen, P., Vyse, A., 2003. Regeneration of Picea engelmannii and Abies lasiocarpa in high-elevation forests of south-central British Columbia depends on nurse logs. For. Chron. 79, 271

[126] Brang, P., Moran, J., Puttonen, P., Vyse, A., 2003. Regeneration of Picea engelmannii and Abies lasiocarpa in high-elevation forests of south-central British Columbia depends on nurse logs. For. Chron. 79, 273.

As it was shown in the example of research in the Carpathians, also in the Italian Alps, an increase in ozone concentration was found along with an increase in height. (In other parts of the alps the concentration varies between 20 to 100 mg/m3 in Swiss Alps- 43 and 95 mg/m3 in Austrian Alps).

In general, the region of northern Europe is under the influence of air masses bringing along O3 formed in the downstream plumes of the main European industrial areas and population centers. Potential phytotoxic effects of O3 on forest trees and understory plants may be expected in almost the entire territory of the Europe. Ozone damage should be considered spatially[127].

The ozone-induced disturbance can be seen not only in old stands, but also in young individual who are more susceptible to pollution. That can lead to premature death or a decrease in growth. In old stands, apart from pollution (it significantly reduces the vitality and health of trees), pest attack is also of great importance as an intermediary factor leading to forest degradation.

Over the past hundred years, the Alpine climate has changed significantly with a 2°C rise in temperature: twice the global average. As a result, Alpine glaciers are melting. Since 1850, they have lost about half their volume, and since the mid-1980s, the rate of change has definitely increased[128].

The snow limit is also moving upward, the pattern of precipitation (rain, snow, hail, sleet) is also changing. Many medium and small glaciers are likely to disappear later in the first half of the century. It is predicted that regions currently experiencing snowfall will receive more and more rain in the winter instead, making the snow cover shorter. This will affect the way water is collected and stored in the mountains in winter and how it circulates during the warm summer months. Water runoff is expected to increase in winter and decrease in summer[129].

During winter in the Alps, water is collected and stored as snow and ice in glaciers, lakes, groundwater bodies and soil. It is then slowly released as ice and snow melt in spring and summer, feeding rivers, including the Danube, Rhine, Po and Rhone - the upper reaches

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[127] Bründl, M., Rickli, C., 2002. The storm Lothar 1999 in Switzerland – an incident analysis. For. Snow Landsc. Res. 77, 215.

[128] Müller, J., Bütler, R., 2010. A review of habitat thresholds for dead wood: a baseline for management recommendations in European forests. Eur. J. Forest. Res. 129, s. 981.

[129] Rochefort, R.M., Little, R.L., Woodward, A., Peterson, D.L., 1994. Changes in sub- alpine tree distribution in western North America: a review of climatic and other causal factors. Holocene 4, s. 89.

of each of these rivers are in the mountains. This makes water available - it reaches the lowlands at the time of peak demand[130].

The subtle interrelationships that condition this ancient process of storing and releasing resources are now threatened by climate change. Changing climatic conditions in the region, such as rising temperatures, will directly affect water availability and quality through intense evaporation and changes in precipitation. Climate change also indirectly affects water resources by changing the vegetation cycle[131].

Two-thirds of the conservation zone is covered with forests. As in agriculture, forest management in the region is carried out with the aim of protecting drinking water. "Currently, the biggest threat caused by climate change is increased erosion, which threatens forests. Without trees and proper mulch, the soil will be washed away, and this is the soil that purifies water. Rising temperatures will mean the emergence of new tree species. Climate change means uncertainty, new factors, and that's always a risk[132]

Interesting data on the peculiarities of trees in the Alps, and in this case spruce, is thrown up by the research seen in Figure 7.

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[130] Ibidem, s. 91.
[131] Ibidem, s. 92.
[132] Wermelinger, B., 2004. Ecology and management of the spruce bark beetle Ips typographus - a review of recent research. Forest Ecol. Manag. 202, s. 68.

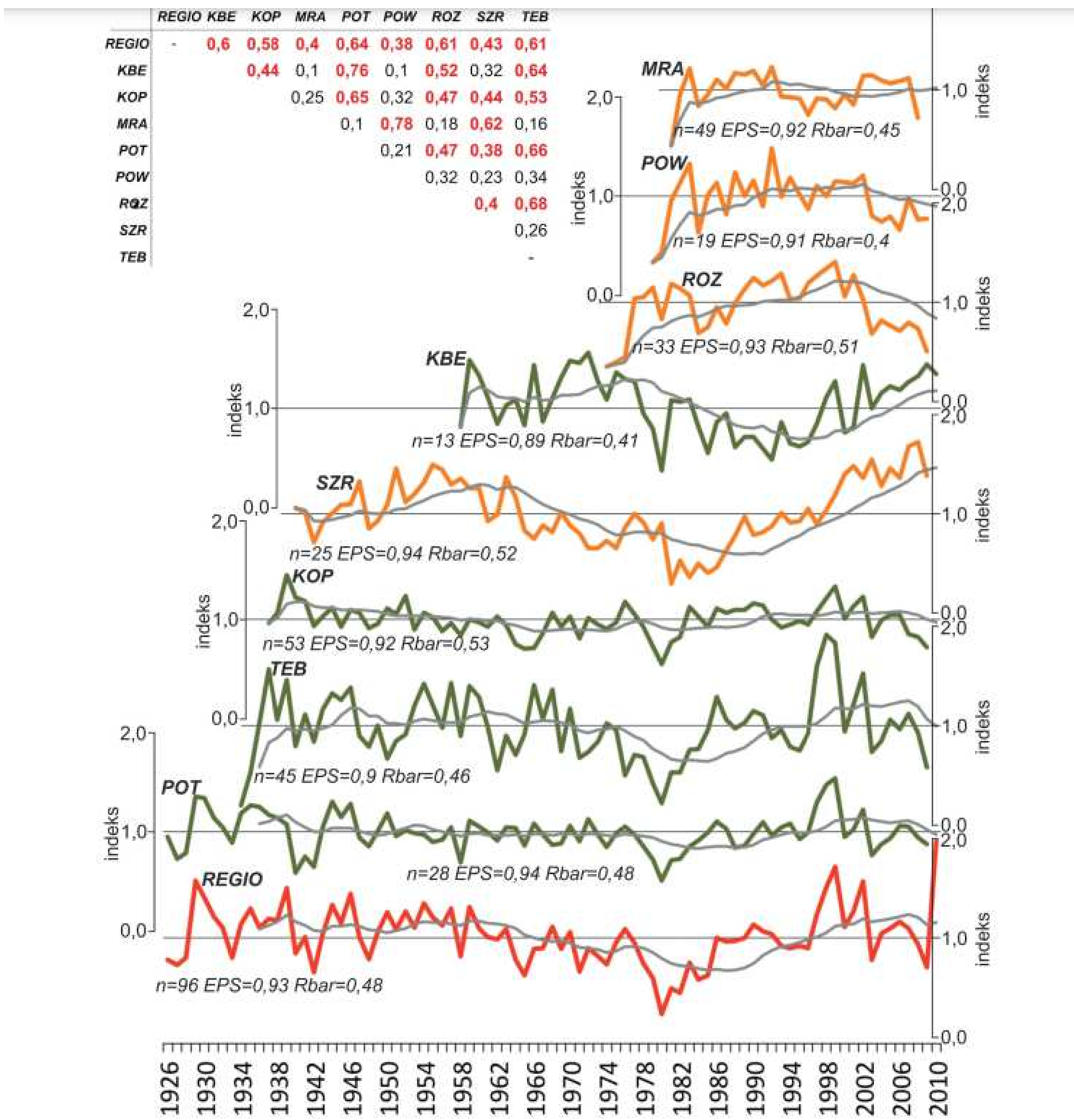

Figure 7 Standard site chronologies (orange line >1000 m above sea level, green line <1000 m above sea level) and regional chronologies (red line).
Source: Rochefort, R.M., Little, R.L., Woodward, A., Peterson, D.L., 1994. Changes in sub-alpine tree distribution in western North America: a review of climatic and other causal factors. Holocene 4, s. 101.

With regard to the maximum age of the spruce trees studied, three types of sites can be distinguished. The youngest spruces (sites MRA, POW, ROZ) come from monoculture plantings and are 25 to 33 years old. Slightly older trees (69-73 years old) can be found in SZR and KOP stands, where spruce trees, growing in various clusters, are an admixture in a natural fir and beech forest. The third group is clearly older trees (TEB), where the age of the oldest spruce is 133 years, and (KBE) - 101 years. These sites are located in the area of the oldest natural alpine spruce tracts The average age of the trees growing there is similar (70 years - TEB, 55 years - KBE). The average width of annual increments of the studied trees is 3.46 mm. A large discrepancy was found of increment widths between sites, from 4.05 (TEB) to 9.81 mm (KBE), which is due to the variation in age and growth conditions of the studied trees[133].

Conservation forests in the Alps experience both large and small disturbances, but the latter predominate (ZUKRIGL 1991), with individual disturbances affecting areas which are usually smaller than 0.1 hectares. This is especially true in cool and moist habitat conditions (e.g., in many subalpine forests near the coastline). The small-scale disturbance regime leads to the continued dominance of shade-tolerant species. Large-scale disturbance is rare in the European Alps for several reasons. First, disturbance propagation is often limited because large, contiguous forest areas are rare. Forests occur in patches in association with avalanche tracks, upper forest boundaries and agricultural land agricultural land. Second, the terrain is often very uneven, resulting in small-scale variation in conditions

Second, the terrain is often very uneven, resulting in small-scale variation in field conditions, and consequently in tree species composition and development stages. Third, the high summer precipitation, low intensity of storms, and low fuel load resulting from intensive forest use in the past mean that large-scale damage from forest fires, storms and bark beetles is not experienced. intensive forest use in the past, mean that large-scale fires are a rare occurrence in the Alps.

The impact of phenomena on mountain-type forest varies widely. While fires have the potential to weaken trees in adjacent areas, snow load usually leaves many surviving trees. The impact of storms on trees also varies greatly. Some storms cause only thinning, while others destroy entire stands. In the first decades after a storm, uncleared windbreaks can provide even more protection than the former forest (e.g., against rockfall).

Nevertheless, one of the most danger for trees in Alps is effects of climate change in the Alps is the recession of glaciers. As temperatures rise, glaciers at middle altitudes are shrinking at an alarming rate. Since 1850, glaciers in the Alps have lost 30 to 40% of their area and half of their volume, and another 10 to 20% of their volume has disappeared since 1980. Studies predict that 52% of Switzerland's small glaciers will disappear in the next 25 years. As moraines are exposed after glacier retreat, they are subject to strong colonization

[133] Biczyk T., Kaczka R.J. 2014. Klimatyczne uwarunkowania powstawania anomalii drewna wtórnego na przykładzie świerka pospolitego (Picea abies L. Karst) w Tatrach. Studia i Materiały CEPL, Rogów, 40 (3): s. 19.

pressure from vegetation, contributing to the significant landscape changes seen in mountainous regions[134].

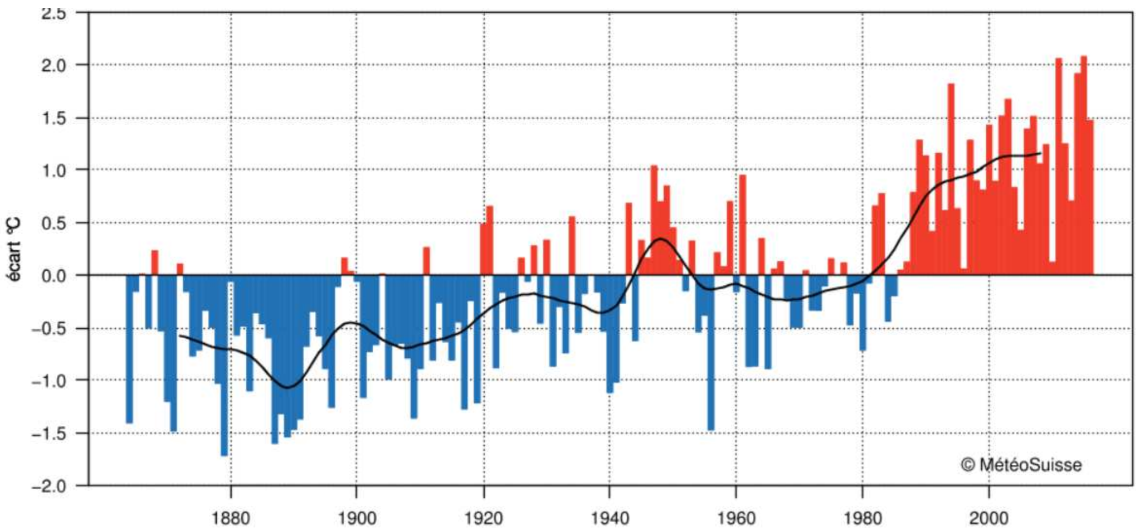

Figure 8 Average annual temperatures in Switzerland: based on 1961-1990 average, blue bars indicate years in which annual temperatures were below average and red bars indicate years above average.
Source: temperaturestatistic/switzerland/k93.com

The biggest threat currently posed by climate change in the Alps is increased erosion, as it threatens forests. Without trees and adequate foliage, the soil will be washed away, and it is the soil that purifies water

[134] https://creamontblanc.org/en/climate-change-and-its-impacts-alps/

Chapter 4 Discussion and Recommendations

4.1 Discussion

The considerations undertaken so far in this paper allow us to conclude that forest restoration is a process determined by numerous factors. Of particular importance, however, are the dependencies that directly and indirectly affect the state of forest management. Therefore, it is reasonable to summarize the mentioned factors and thus determine which of them have the greatest impact on forest regeneration.

Fires are the most dangerous process for forest regeneration. Fires are considered as one of the main disorders of forest ecosystems, annually causing huge economic, natural and social losses. They affect 40% of forested areas worldwide, 65% in Europe. They are the cause of a decline in biodiversity in the areas affected by them, microclimate changes, unfavorable soil geochemical changes and violation of water relations.

They also cause changes in the undergrowth, litter and soil, inhibiting the development of vegetation in a given area, thereby changing living conditions for fauna. Forest fires also have a negative impact on humans, posing a threat to their health and even life, and to his possessions. Various types of forests growing in all climates. In some forests, such as the rainforests of the tropical and temperate zones, fires have serious and long-term consequences Forest fires also contribute significantly to the increase in greenhouse gas concentrations in the atmosphere and can affect tropospheric anomalies. Identification of factors that significantly affect fires on forest areas forest areas is therefore an important issue, for natural, economic and safety.

Natural factors consist of abiotic and biotic conditions. There is no doubt that the most important abiotic factors affecting on the occurrence of fire are meteorological conditions - mainly wind speed, air temperature and its relative humidity, litter moisture, cloud cover, precipitation totals and the type of atmospheric. The linear effect of meteorological factors on fire occurrence in different forest regions may be slightly different in value, but is usually identical in as to the nature of this relationship. Low wind speed (up to a few m/s) usually increases the risk of fire but when, once a fire is initiated, the wind speed will determine the manner of spread of fire and size of fire - the higher it is, the more fire will spread more Rising air temperature, lower

precipitation and falling relative humidity generally contribute to the likelihood of fire by increasing the flammability of vegetation. Prolonged warm and dry anticyclonic system coming from the north, preceding the arrival of a southern warmer highland circulation, conditions the occurrence of large-scale forest fires in few Europeans countries. Conditions weather (or more broadly, climatic characteristics) affect the susceptibility to ignition of forest materials and the ease and intensity of the spread of fires. In addition, various climatic indexes as a combination of meteorological factors. The most common index used in forest fire research is the Forest Fire Weather Index calculated on the basis of relative humidity (at noon, then it is at its lowest value), air temperature (measured in the afternoon, when it is at its highest), total precipitation during the day (from noon of a given day to noon of the following day), and maximum average wind speed.

Among the abiotic factors studied in the context of influencing the occurrence of fires are topographic attributes that affect local thermal and moisture variation - elevation above sea level, slope, their shading and exposure. Various types of topographic indexes are also used, such as the index of roughness of the terrain. As altitude increases (especially in the mountains), fire danger decreases due to a decrease in air temperature and increased precipitation, which changes the also the type of stand, as well as the water content of the trees. Slope is considered an important factor in increasing fire danger - as slope increases, soil erosion becomes more intense, and combustible material dries out faster. It was also found that risk of fire in the northern hemisphere decreases when exposure is changed in the following order: south > west > east > north, due to the difference in the delivery of solar radiation to the slopes while in the southern hemisphere the greatest fire danger is characterized by northern exposure Topographical factors strongly influence both the probability of fire occurrence and the size of the area burned. Steep slopes not only cause rapid water runoff, but also increase the rate of fire spread. If there is anabatic wind at the time of fire initiation, the fire spreads faster than if the wind is coming down the slope. An abiotic factor studied in the context of forest fires is also the soil type. Poor soils, especially sandy soils with high permeability, increase the risk of fire Some researchers suggest that the aforementioned topographic variables are even more important factors in fire occurrence than climatic or weather variables weather Which, in the case of the forests discussed in this paper, is particularly relevant for forests in the Alps.

The group of natural biotic factors includes vegetation type - in the case of forest fires, this is understood as the characteristics of the habitat characteristics of the stand, . tree species, type of vegetation ground cover, diameter of tree trunks, their age and height. It is related with the overall condition of the stand and determines its susceptibility to fire transmission. The greater the density of vegetation cover and the compactness of the tree crowns, the greater the risk of fire. Vegetation condition can also be estimated based on, for example. normalized differential vegetation index or indices of moisture content of vegetation. In addition, some types of forest stands are less susceptible to fire occurring in them than others for example, an increase in the proportion of deciduous trees generally reduces this risk. Another subset of factors is the presence of fauna - both large animals such as wild ungulates, livestock (sheep, goats), and cattle, whose foraging and grazing reduce the the risk of fire as well as small entomofauna (e.g., bark beetles) the impact of which is in turn, consists largely of weakening the condition of the stand, and thus on increasing its susceptibility to fire.

Another element that affects forest regeneration is the threat from pests - insects. The forest environment is exposed to a number of harmful factors that significantly reduce the resistance of forest stands, often leading to their dying out. In addition to inanimate and anthropogenic factors (prolonged droughts, high temperatures, industrial pollution) significant threats to forests are insects herbivores. Particularly dangerous to the sustainability of forest stands are pests that tend to periodic mass occurrence, the so-called gradations. They then cause damage covering hundreds, or even thousands of hectares of forest.

Pest insects can we divided into two basic groups:

- primary pests, which are the first to attack healthy stands (not damaged by other biotic or abiotic factors) and, by eating their assimilative apparatus, bring about them to a significant weakening;
- secondary pests - attacking previously weakened trees, e.g. by primary pests, prolonged drought.

Primary pests that pose a threat to forests primarily include: Christmas tree bark beetle, pine barnacle and dandelion weevil. These species during increased occurrence can lead to the complete extinction of large areas of forest stands (lodgers). During feeding, they are very voracious and can eat large amounts of needles (e.g., one caterpillar of the dandelion weevil during its life can damage about 300 pine needles or about 1000 spruce needles; one female lays down a single caterpillar of the dandelion weevil. spruce; one female lays 200 - 250 eggs in deposits of 20 to 100).

The basis for deciding on the control of primary pests are forecasts of incidence developed on the basis of autumn searches for insects overwintering in the litter. A very good natural indicator of the occurrence of primary pests of pine are wild boars, which in search of overwintering pupae and caterpillars can bulldoze the entire forest floor. The best period to carry out the control of the number of nun warblers is its swarming season, which falls in the period from VII - IX and takes place in the afternoon. During the day, the butterflies sit motionless on tree trunks.

The most dangerous secondary pests attacking previously weakened stands

and causing them to die out over large areas include: the granulate bark beetle, the bark beetle, print bark beetle (spruce), marked smolike (pine crops). These species, in dry and warm years, tend to multiply en masse and aggressively attack both weakened and healthy trees. In a short period of time, they can lead to the complete extinction of large areas of forest stands.

One of the factors that in the study area under analysis may affect the ability of a stand to regenerate naturally is the activity of wild animals. Damage caused by wild animals in 1979 in the analyzed area was severe and multiple. The stands were damaged by ungulates, especially deer (Cervus elaphus L.) and roe deer (Capreolus capreolus L.). However, the greatest damage was caused by gnawing, which primarily attacked the front shoots of sycamore, rowan and fir (100%), beech 93%, spruce 69%, and in the case of birch 66%. Thinning of lateral shoots of sycamore averaged 100%, rowan 94%, fir 90%, beech 82%, spruce 48% and birch at 45% .

Over the 36-year period of the analysis, damage due to underbiting significantly decreased ($F(1, 34) = 35.0$, $p < 0.01$) in all tree species due to the high density of natural regeneration. Comparing individual tree species, significant differences ($F (4, 31) = 3.6$, $p < 0.05$) were observed in the amount of damage as a consequence of underbiting. The statistically significant highest damage to ungulates was observed in maple, while the significantly lowest damage occurred in spruce ($p < 0.05$) .

At this point, one can also point to the analyses undertaken by the researchers. They pointed to two aspects. The first is the epidemic of the print bark beetle in Carpathian forests in Poland and Romania. The impact of this pest has negatively affected the development of beech and spruce forests, but the problem has affected adult specimens to a higher degree than young trees in the area of conducted restoration. Another issue, however, is the impact of deer, which bite smaller individuals of beech and spruce trees. Deer are less interested in adult individuals. Thus, on this basis, it can be indicated that deer eating the regenerating summer are a greater threat to these plants than pests such as the printworm .

The bark beetle affects spruce trees in an exceptionally strong way. The impact of this pest translates into the death of adult individuals of this tree, and consequently the formation of gaps and poles between the stand. The above gaps are quickly filled by new individuals. These regenerations are dominated by spruce, even if a mixed forest, such as spruce-beech, previously existed in the area. These authors point out the process of regeneration begins to be characterized by its random / random nature. These gaps through the activity of various types of pests are constantly evolving .

The literature also shows some correlations that exist between the microorganisms living in the soil in the areas that are subject to regeneration. In this case, there is a clear link between the number of animals in the soil and the level of forest regeneration. The more beech and spruce forest regeneration is advanced, the number of organisms in the soil increases. There is also a relationship between the level of natural regeneration of spruce and beech forest and the humus content of the soil where the regeneration is taking place. It is also worth noting that the better the soil is mineralized, at the same time the new individuals of trees will have more favorable conditions for development .

Further, it can be pointed out that in European beech forests, the aphid can be a very serious problem. It can very severely affect beech restorations primarily in the first year of restoration . Aphids can significantly affect beech development. This applies both to adult individuals, as well as those young ones that are in the regeneration phase. According to the literature, aphids, as a representative of a pest that feeds on the sap found in trees, significantly disrupt water and micronutrient management in beech trees. Aphid invasions, which have occurred, for example, in forests on the Czech side of the Sudetenland, can significantly slow down the beech regeneration process, but do not stop it at all.

Another issue that needs to be analyzed is the impact of the formation of various types of gaps and plots on the generation of beech and spruce forest. Forest gaps can be defined as a place where the forest opens up as a result of the displacement of one or more trees in a stand. Naturally formed forest gaps can be easily identified. Naturally formed forest gaps can be recognized through natural disturbances such as windstorms, fires, insect or pest outbreaks. In addition, there are artificially formed forest gaps what is formed by logging. The formation of forest gaps strongly influences forest regeneration and stimulates the coexistence of different tree species. Studies of gap dynamics have contributed significantly to understanding the role of small-scale disturbance in forest ecosystems. The size of the opening is also important because of the effect of microclimate on available light and soil conditions. Large and wide gaps are good for light-tolerant species, while small gaps generally favor natural regeneration for shade-tolerant species.

Studies conducted by various authors on beech and spruce forests in the Sudeten and Carpathian Mountains, make it clear that the spatial arrangement of a particular forest fragment is very important for its regeneration process. The horizontal structure of stands greatly influences the competitive relations between tree individuals and plays an important role in the dynamics of the stand, including during its natural regeneration. . The spatial arrangement of the tree layer was regular in the lowest parts of the beech altitudinal gradient, random in the middle parts, and aggregated in the beech under the apex phenomenon and extreme edaphic habitat. Nevertheless, the trees in the lower tree layers showed a tendency to aggregate, as did the strong aggregation of natural regeneration. In most cases, the parent stand had a significant negative impact on natural regeneration at shorter distances (up to 0.8-4.2 meters). The spatial arrangement of dead wood was mostly random. Due to the high plasticity of beech crowns, crown centroids were distributed more regularly than tree trunks. The average displacement of the crown centroids from the base of the trunk was 1.5 meters with a predominant direction of 52.7% down the slope. The projected crown coverage was on average 10.7% higher compared to the crown simulated by the circular crowns . In this regard, it should be pointed out that the plots and gaps that are created between beech trees and where the natural regeneration of the beech forest takes place translate into the fact that the trees created there have difficult growth conditions. The crowns of the trees fill the open spaces, which limits the access of sunlight to the regenerating part of the forest. Thus, if the plot or gap is too small then the tree crowns can completely obscure it and definitely hinder the process of natural regeneration. According to the presented study, common beech trees can shift the crown centroids by up to 1.5 meters on average in such a situation.

It should also be noted that when the distance between trees is more than 2.1 meters (in spatially planned forests) and more than 3.8 meters (in naturally growing forests), statistically significantly better opportunities for natural forest regeneration appear . It can be assumed that access to light for new individuals, for example, is significantly higher and allows for effective regeneration of the stand.

The spatial arrangement of the tree layer was random in the lower parts below the peak and aggregated under the hill top phenomenon at the extreme edaphic position, such as aggregated horizontal structure of natural regeneration. In most cases, the relationship between the spatial arrangement of the tree layer and natural regeneration was significantly negative ($\alpha = 0.05$) at shorter distances (from the trunk to 0.6-6.1 meters), except for stands under the strong hilltop phenomenon (positive effect up to 2.1 meters). Stand density ranged from 440 to 760 trees ha-1, and the number of natural regeneration was 4,584-6,360 harvests ha-1. Dominant height decreased as the effect of the elevation phenomenon increased ($P < 0.001$). The volume of live trees was 239-536 cubic meters ha-1. The radial growth of the dominant beech (from Latin Fagus sylvatica L.) indicated a relatively balanced long-term trend in ring width from 1900 to 2014, but the diameter increment of the admixture of common spruce (from Latin Picea abies /L./Karst.) decreased significantly ($P < 0.001$) after 1978, while the radial increment of spruce has increased markedly since 1998 . Therefore, too little air of the gap or plot where natural forest regeneration takes place may translate into that the distance between the adult tree and the young one will be too small. The crown of the adult individual will obscure the open spaces, which will limit the development of the next stand, in the lower parts of the forest. Regeneration will be greatly reduced in such a situation.

4.2. Analysis of the differences between the studied mountain ranges

For the purpose of this study, the comparative review compared selected forested areas in the Sudetes, the Carpathians and the Alps. These areas very often experience a wide variety of natural disturbances (for example, as a consequence of windstorms and pest impacts).

In the case of the Alps, which is characterized by a continental climate. The average annual precipitation is about 705 mm (maximum in October and minimum in January). The dominant rocks are shale, while the soils are classified as entisols. Common spruce is the dominant tree species, while European beech, European larch and common fir are common companion species. Other tree species are located mainly in gaps or in localized dry patches of soil.

Sudenty, on the other hand, is characterized by temperatures hovering around 5.2 degrees Celsius with annual total precipitation of 870 mm. The growing season lasts about 120 days with an average temperature of 11.9 degrees Celsius and total precipitation of 640 mm. The so-called Köppen classification refers to a humid continental climate with warm summers. In the 1960s, natural stands of beech and spruce were left to develop spontaneously.

Precipitation in the Carpathians is less than in the mountains of Western Europe, and depending on the exposure of the ranges and altitude, annual totals range from 800 to 1200 mm, while in the basins they do not reach 600 mm; the highest values are reached in the Tatras (up to 1800 mm), with maxima in the summer months; depending on elevation.

Therefore, it is reasonable to put together a comparison of the analyzed factors affecting forest regeneration in the studied mountain ranges, the first of which is the incidence of pests (table 4).

Table 6 Analysis of damaged trees in Sudetland

RESEARCH STAND	ALTITUDE (m)	YEAR				
Carpathians		2009	2012	2011	2015	2018
X1	680	0	2	1	0	1
X2	900	1	3	3	3	2
X3	800	0	2	2	3	3
X4	800	0	3	3	3	3
X5	640	0	1	2	2	1
X6	620	0	0	1	1	2
RESEARCH STAND	ALTITUDE (m)	YEAR				
Sudets		2001	2002	2003	2004	2005
X1	1190	0	0	1	2	1
X2	932	0	1	1	3	3
X3	1423	1	1	2	3	2
X4	1583	1	2	3	3	3
RESEARCH STAND	ALTITUDE (m)	YEAR				
Alps		2011	2012	2013	2014	2015
X1	1083	2	1	3	2	1
X2	1353	1	1	2	2	3
X3	1783	1	2	3	2	3
X4	1432	2	2	3	1	3

Source: own by previouus reserchers

As can be seen from Table 6, the highest number of insect damage to trees over the various years studied was observed in the Sudetenland.

While ozone concentrations are presented in Table 7.

Table 7 O3 in analysed mountains

LOCATION	ALTITUDE (m)	MEASUREMENT MIN-MAX	2011	2012	2013
Carpathians	1120	63-122	90	63-122	90
Alps	1050	53-102	72	53–102	76
Sudets	960	54-92	78	54–92	69

Source: own by previouus reserchers

As can be seen, an increase in O3 is observed as the measurement height increases. There were no consistent trends in the concentrations of NO2 and SO2.

While the forest gap analysis is shown in table 8.

Table 8 Fagus sylvatica and Picea Abies

Location	Fagus sylvatica		Picea Abies	
Alps				
1971	248	26,1%	640	67,2%
2016	19804	79,3%	3852	15,4%
Carpatians				
1971	136	13,9%	816	83,3%
2016	13888	42,5%	16968	51,9%
Sudets				
1971	168	14,6%	932	80,9%
2016	58372	78,8%	16824	21,8%

Source: J. Slanař Long-term transformation of submontane spruce-beech forests in the Jizerske Hory Mts.: dynamics of natural regeneration, Cent. Eur. For. J., 2017, nr 63, s. 212-223.

It is clear that over the years there has been a clear increase in the natural growth of beech, while the natural growth of spruce has decreased. This is probably due to several factors, namely: first and foremost, significant damage to young trees by forest animals in the first years of measurements, and significant air pollution (high concentrations of compounds toxic to plants in the area in 1980-1990), resulting in climate change (air warming), which had a major impact on spruce growth to the significant benefit of beech. The regenerated beech returned to its natural habitat, previously occupied by artificial spruce trees.

The health of the forests of the Alps, the Carpathians and the Sudetes is determined by a number of factors, both internal and external, which affect the stands

Biotic threats include: hailstorms of forest insects, the action of pathogenic fungi, damage caused by game and rodents.

Abiotic threats include a number of factors, related to climatic conditions, prevailing in the area. The most important of these include the occurrence of: low and high temperatures, winds and hurricanes, excessive or insufficient precipitation, unfavorable soil properties.

Table 9 The occurrence of biotic, abiotic and anthropogenic factors in the studied mountain forest

LOCATION	BIOTIC	ABIOTIC	ANTRHOPOGENIC
Carpathians	+	+	-/+
Alps	+	+	+
Sudets	+	+	+

Source: own

In all the mountain ranges studied, there are factors that harm forests. In both the Carpathian Mountains, the Alps and the Sudetes, there are insects and other pests that have a direct impact on the condition of the trees. In all the areas studied there are also atmospheric conditions that can have an indirect effect on the occurrence of fires. It is reasonable to conclude that in each mountain range of the three studied there are biotic and abiotic factors that have direct and indirect effects on the condition of trees and their regeneration. However, in the case of the Alps, a more effective situation was observed in terms of anthropogenic factors. In terms of pollution of soil, water, the effects of climate change, economic pressure on the forest, etc., the impact of Alpine management has little impact. On the other hand, the activities described as "forest pest" consisting, for example, of illegal logging, poaching, littering of forests, excessive penetration and increase of fire danger, etc. already do, which is probably due to better forest management.

4.3. Recommendations

Widespread spruce plantings at the regal level have transformed former beech and beech-spruce forests. The biggest changes that can be observed today took place in Poland, Slovakia, and the Czech Republic, among others. The situation was much better in Western countries, where several decades ago they began to move away from monoculture and focused on natural forest regeneration. The very concept of forest regeneration is defined as the process of natural or artificial formation of a young generation of trees that, as they develop and grow in the future, will have a significant impact on shaping the forest environment in a certain space and time. It is in this case that a distinction is made between the degree of use of natural forces, as well as the contribution of human labor, in terms of regeneration, namely: natural factors - self-sown, self-seeded or from shoot regeneration, and artificial factors - performed by sowing or planting, always with human participation .

In research work devoted to the study of the structure and dynamics of forests, the main emphasis is primarily on detailed measurement of the old-growth layer . As a rule, the analysis of natural regeneration is limited to quantitative estimation of species composition, as well as visual assessment of tree vitality. Relatively rare are more detailed analyses, taking into account dendrometric characteristics and positioning of individual specimens, which, during subsequent measurements, provides an opportunity to study the dynamics of tree development as well. Meanwhile, a thorough understanding of the structure and structure of the regeneration layer of the stand, its spatial organization and growth potential can contribute to a better assessment of the growth conditions and development trends of the young generation, as well as more accurate design of protective indications and forecasting of forest management directions in the future. The phenomenon of natural regeneration of the forest is an indispensable part of the development cycle of forest stands, above all, having to fulfill, in particular, non-productive functions (protective and reserve forests). In natural forests, often occurring in difficult mountain conditions, to a large extent this phenomenon determines their ability to self-regulate and sustainability of existence .

For example, the soil and climatic conditions of the Carpathians create a favorable environment for the formation of natural regeneration. It is precisely the issue of contemporary renewal that concerns, among others, beech and spruce, which will be analyzed in detail in this paper.

The abundance status of natural regeneration in beech largely depends on the wide variability of habitat conditions, and above all on light and weather conditions, as well as many other environmental factors affecting the abundance of trees in the seed year and the survival of the young generation of the forest. Jaworski and Korpel report a widely varying range of regeneration abundance depending on the developmental stages of primary forests, and associate its appearance with a particular stage in the life of the type of stand under study, referred to as a certain stage of regeneration.

Beech is a shade species and, like most such species, regenerates well by self-sowing, especially in the optimal parts of the country for its development. Regeneration of a natural character leads to the situation that it is among the somewhat "more difficult" species in the management of modern forests. This is because years of seed character are extremely rare in beech. An additional complication in the process of renewing a natural stand of beech is weather disturbances in the climate characteristic of Poland. Beech very often forms solid stands, but it shows its full breeding qualities in multi-species complexes with, among others, oak, ash, linden, sycamore, elm, fir, spruce, larch, and sycamore. Single-species beech forests are considered the result of erroneous management by man. As a result, at present, man must take measures to diversify the species composition of beech forests by introducing admixture species.

Human efforts to achieve natural regeneration must be synchronized with seed years. Beech trees harvest infrequently; abundant seed years occur in beech every six to ten years. Between seed years there are medium and poor births. For natural regeneration, full and medium birth years are important. The setting of flower buds takes place in the year before fruiting, so the expected seed year can already be determined in the autumn or winter preceding the year of flowering. Spherical flower buds can then be observed on beech trees, clearly distinguished from the usual pointed shoot buds. As indicated by various observations, high temperatures in June and July in the year of flower bud formation, i.e. in the year preceding fruiting, have a beneficial effect on the fertility of beech stands .

Increased fertility can be influenced by screening the stand by strengthening the tree crowns and by mineral fertilization, especially nitrogen and phosphorus fertilization. For various economic activities related to beech natural regeneration, it is important to know the course of beech rainfall in the year of fertility. Precipitation begins as early as late September or early October and can last until December. The greatest intensity occurs in the first three weeks (at 70% to 80%). Forecasting beech fertility is very important, as preparation for seed years must be extremely careful. Associated with seed years is the proper preparation of the soil and the carrying out of cuts of a planting nature .

In fact, it is recommended in this case to use the following methods of soil preparation for natural regeneration of beech stand :

- Soil preparation by exposing the mineral soil in the area. The simplest as well as the most common way to expose 30% to 40% of the area to mineral soil is to plow strips with a forest plow. The beechwood that has fallen to the mineral soil will overwinter best, and gives in practice far better emergence and less emergence excursions. A light mixing of buckthorn after falling with mineral soil gives even more favorable results.
- Soil preparation by discing treatment. The best results are obtained by discing with the so-called "cross" method. However, this is a much less favorable way of preparing the soil for further work, as the negative effect of mixing humus and mulch into the soil becomes apparent. In the period of light and wet winters, this method of soil preparation affects a higher percentage of buckthorn mold.
- Soil preparation with a soil tiller. This action gives, in practice, similar results to soil preparation with a disc machine. In addition, it is possible in this case to deal with very frequent situations of damage to the roots and relatively more frequent damage to the tools used in these types of work.
- Soil preparation with cultivators. This activity is by far the least favorable way to prepare the soil for the renewal of the described type of stand. It affects a higher level of weed

infestation in the soil, while there is a thick layer of humus and litter, which gives very poor results. In addition, the cultivator is a tool that gets damaged very often during this type.

During natural regeneration of beechwood, the quality of beechwood management in the period preceding natural regeneration is very important. Tending cuts play a very important role. The selective nature of tending cuts improves the quality of stands, and thus the genetic value of the resulting natural regeneration under the canopy. Cultivation cuts, through the appropriate regulation of the compactness of the crowns, allow light to enter the forest floor, which has a positive effect on the process of decomposition of litter and the quality of the humus formed. The natural preparation of the soil to a suitable state through properly carried out thinning should be carried out gradually through moderate pruning over a period of twenty years before the natural regeneration process begins. Properly carried out maintenance cuts (so-called thinning) in beech stands replace preparatory cuts .

Before the very beginning of natural regeneration in beech stands, the work should be properly planned, which should take into account the following issues :

- division of the beech stand into appropriate zones of manipulative character,
- designation of so-called skid trails,
- possible artificial introduction of admixture species in nesting cuts, which will precede the natural regeneration of the beech stand,
- carrying out appropriate preparatory cuts in beech stands, but neglected in terms of care,
- depending on the condition of the soil, preparing it in the seed year for natural regeneration,
- to perform in the seed year cuts of a sowing character and thus obtain the so-called self-sowing,
- making cuts of a revealing nature, as well as cleaning cuts.

The scope of work depends on the initial condition of the stand. When carrying out natural regeneration of beech trees, particularly serious problems are damage to harvesting and skidding. The damage that occurs in this situation can actually be minimized by proper planning of the work to be done, that is, the establishment of export routes, as well as the designation of skidding routes. Order of a spatial nature must be established before the start of cutting in beech stands, as it determines the reduction of harvesting losses. The share of admixture species should be properly planned to a basic extent. The target species composition should be determined and pursued. Sometimes, striving to achieve an appropriate species composition, there is a need to perform anticipatory nest pruning and introduce appropriate admixture species on the nests, before the natural regeneration of beech. Preparatory cuts (repeating them every two-three years) should be carried out in stands that are carelessly neglected.

Preparatory cuts accelerate the decomposition of litter and humus to a state that allows natural regeneration. The fully optimal state is when the roots of the sprouting beechwood penetrate the mineral soil already in the first year. In case of insufficient soil preparation, or the existence of weeds, in the seed year in late summer or early autumn, the soil is prepared for natural regeneration before the fall of buckthorn .

The next phase is the planting cut, which must be associated with a strictly defined good seed year. The above cutting is definitely best done in the winter months after the fall of the so-called buckwheat. Possible felling and ripping to a certain extent prepare the soil by moving it, and also lead partially to the covering of seeds. Cuts of a sowing nature should be moderate cuts as a precaution against the failure to sow the beech stand .

It should be emphasized that throughout the initial period of preparation of the stand for restoration with sowing cuts together with the applicable rules of very careful interference through pruning. When carrying out sowing cuts, it should be remembered that it is better to initially maintain a compactness slightly "too dark" than "too light". This is because beech infestations are content with much less light in the first years than the undergrowth occurring later. On soils prone to weed infestation, in many cases it is possible to dispense with cuts of a planting nature and wait for an abundant seed year after making only preparatory cuts. A beech canopy of 0.9 provides the raid with enough light for life in the first two years. Seed cuts allow the raid to access the necessary amount of light for the first three years or so .

The first revealing cut over the beech raid is made during the second winter after sowing, when the seedlings are two years old. Subsequent cuts should be repeated as needed every three to four years. Cuts of a revealing nature, especially the first, should be skillfully applied keeping in mind the high sensitivity of young regenerations to late frosts. Beech reacts very unfavorably to too rapid exposure of the overstory. With the use of exposing cuts, uniform thinning of the stand is not applied, however, care is carried out for the resulting overstory. Thus, it is necessary to thin the stand with certain clusters to help the resulting regeneration groups. The period of regeneration and the associated exposing cuts should be properly used to obtain the very important growth in beech from the so-called clearance. The above period lasts practically up to twenty years .

In this case, it is necessary to observe the principle that in preparatory cuts, sowing cuts and the first recurrence of exposure cuts, the most valuable trees should not be removed. Leaving these trees affects the genetic value of the resulting self-sown trees and increases the economic effects obtained from these stands. When the youngest undergrowth reaches the level of 60 centimeters, clean-up cuts, i.e. the complete removal of the rest of the old-growth forest, are carried out. In practice, this is the last cut of a revealing nature .

After the cleaning cut, the restoration area must be cleaned up. During such tidying up, excess overgrowth of various light-seeded species (primarily birch and aspen) is removed, and the structure of the resulting overgrowth is cleaned up. After tidying up the area, the unplanted gaps are raked, the distribution of appropriate species is planned, and the artificial afforestation of the existing gaps is started .

. The frequent occurrence of spruce self-sowing may indicate that it is a relatively easy species for natural regeneration, if its natural characteristics are taken into account. Good natural regeneration of spruce is obtained from top and side seeding. Spruce can be naturally regenerated using clear cuts, partial cuts, edge cuts or clear cuts. Clear-cutting allows the use of lateral self-seeding. The above-mentioned cutting is characterized by use, as a result of which the stand is cleared from a certain area with a single clear cut, and the regeneration grows without cover or only with lateral cover of the stand in question. Strip clear-cutting (class Ib) is used in the lowlands for the regeneration of solid spruce and spruce stands with co-dominant pine. In areas with more varied terrain, spruce stands are renewed naturally using streak clear-cutting (class Ic). For the acquisition of such self-sowing, it is necessary to synchronize the cuts with the so-called seed years .

In spruce trees, the factors that determine the proper conduct of clear cuts are determined by the threat of wind. Due to the direction of prevailing winds, cuts should be advanced from east to west or northwest. The exposed wall of the spruce stand is then on the leeward side. Clearcuts should not form large combined areas. The maximum area of a clearcut in a Class Ib clearcut should not exceed 4 hectares, while in a Class Ic clearcut - 2 hectares. In this situation, the walls of spruce stands that are not immune to wind exposure must not be exposed. It is also forbidden to establish a completely new cut when the stand cultivation on the previous neighboring cut is completely unsuccessful .

In order to apply natural regeneration of spruce in mountain forests as a rule, a streaky partial cutting (class IIc) with a streak width of up to 30 meters is used. Four basic types of cuts are used in partial-streak felling, namely: preparatory, sowing, uncovering and cleaning cuts. They will be briefly characterized :

- Cuts of a preparatory nature - the root system of spruce is superficial, which results in relatively low wind resistance of spruce trees. Spruce needs to be made more wind-resistant by developing appropriately long crowns and a low center of gravity. The above goal is served by maintenance pruning of appropriate intensity. Sometimes, however, such cuts do not, in practice, sufficiently prepare the stand for natural regeneration. It is then necessary to carry out preparatory cuts. In heavily dense stands, it is recommended to carry them out twice with a recurrence of four to five years, removing up to about 10% of the stock of the stand in each of these types of cuts. The trees to be removed here are primarily those that are diseased, misshapen, and with small crowns. Cuts of this type are carried out in such a way that the stand is evenly thinned. Thicker trees are not removed, as they are a very important component in shaping the resilience of a spruce stand. Trees left must be characterized primarily by good trunk quality, as well as properly shaped and developed crown.
- Crop character cuts - these cuts are made to create favorable conditions up to the emergence of spruce seeds. In planting cuts about 20% of the existing stock of the stand is removed. Cuts of this type are carried out during the winter months in the year of good fertility of these seeds. If there is insufficient soil fitness, the soil should be properly prepared in advance for sowing in either the summer or autumn months before the sowing cut itself. If the above soil is covered by a thick layer of mulch or is weedy, then soil preparation is carried out either manually or mechanically.

- Exposing pruning - this process begins in the period of two - three years after sowing in three - four turns every two - three years. The main task is to improve suitable growth conditions for the young generation of the stand.
- Cuts of a tidying-up nature - it is carried out in the period from 10 to 15 years after the sowing of spruce seeds.

Already after cleaning up the young forest thus formed, well-grown saplings of such tree species as larch, lilac, sycamore or maple should be introduced in groups into individual unplanted gaps. If there is a 10 to 30% admixture of either fir or beech within the stand, the partial streak cutting is subject to modification to include specific regenerated tree species. In this case, differentiation of renewal expression is required. The advance for fir should be no less than ten years. About five years after the renewal of fir, the renewal of beech is initiated. Before the renewal of fir and beech, the soil should be prepared. If there is no natural renewal of fir or beech, it becomes necessary to renew them by planting. The renewal of spruce is initiated about five years after the renewal of beech. Already during the ordering of the renewal, the fir and beech clumps should be given very great care.

Natural regeneration from top and side sowing is used in so-called step cuts. Positive results in stands consisting of spruce trees are given, among other things, by the gradual edge-cutting (class IVc).

During the so-called edge-cutting, one proceeds from one wall of the stand toward its interior, using in this case differentiated crown clearance, the strongest at the edge and decreasing directly into the spruce stand. The first streak (this is the area running along the wall of the spruce stand, with a width of 20 to 30 meters), where the stand is slightly thinning, is established on the northern side. Gradually, as the described regeneration of the forest develops, it is exposed and systematically entered with appropriate cuts in successive streaks deep into the stand. A whole sequence of streaks is created in this case, which differ in the stage of development of the regeneration.

Natural spruce regeneration can be achieved by conducting various types of pruning. When planning individual treatments in the vast majority of habitats, it is necessary to bear in mind, in particular, the need to ensure an adequate proportion of admixture species in spruce stands and the high vulnerability of spruce to wind damage. The described natural regeneration of spruce must be widely used in practice, because it is justified from the point of view of genetics and breeding of the above species, as well as from the point of view of an economic nature

Conclusion

Forests are critical for biodiversity, as they are home to countless species of animals and plants. Around the world, forests absorb and store several billion tons of CO_2, so they play a key role in maintaining climate stability. They also store and distribute vast amounts of fresh water, playing an important role in flood control, as well as preventing soil erosion and desertification. Forests in the EU make an important contribution to the processes of climate protection and biodiversity. Unfortunately, forests are also heavily exploited and sometimes destroyed, and thus their potential is diminishing. One of the reasons for this state of affairs is intensive forest management forestry: by cutting down the vast majority of timber growth, the timber industry is damaging fragile ecosystems and preventing them from rebuild. Planted forests - usually with a small number of generally fast-growing species and with trees of the same age – are displacing diverse and ecologically valuable natural forests. To This is compounded by extreme weather events, such as among others, droughts, storms, heat waves or fires caused by the climate crisis climate, which exposes EU forests to additional risks

Summarizing the considerations carried out, it should be clearly mentioned that the research objective set in the title was fully realized. It read as follows: To compare the natural regeneration of beech and spruce in the mountain zone of national parks and nature reserves in Europe. These issues were discussed on the example of three locations of the conducted analyses, namely: Sudetes, Carpathian Mountains and Alps. The literature on the subject provides a number of research results that thoroughly address the issue of natural regeneration of beech and spruce forests. This has made it possible to draw relevant insights that show which factors most strongly affect the regeneration capabilities of selected tree species.

Based on the critical analysis of the literature undertaken in the study, it should be pointed out that:

- both in the Sudetenland, as well as in the Carpathian Mountains and the Alps, the conditions for natural regeneration of stands are similar, so that the mere difference in the geographical location of individual stands does not affect the fact that regeneration is weaker or stronger,

- nevertheless, spruce as well as beech forests, which are located in the three analyzed mountain ranges, are influenced by similar external factors that can potentially limit or enhance regeneration processes,

- in all three study locations, strong correlations have been shown between the level of insolation of the plot or gap where new tree specimens grow and the regeneration rate - it has been shown that the higher the level of insolation, the higher the rate of beech and spruce stand regeneration can reach,

- in all three analyzed mountain ranges, it has also been shown that human activity manifested, among other things, by environmental pollution, can negatively translate into natural regeneration of spruce and beech,

- both in the Alps, the Sudetes and the Carpathians there are animals that bite the young specimens of trees (spruce and beech), and this in turn may translate into issues related to weakening the possibility of natural regeneration of such stands,
- In addition, insect pests were observed in each study area, which have a negative impact on forest regeneration

In conclusion, it should be pointed out that natural regeneration of forests is not such a simple matter as it might seem. Most of the representatives of the scientific doctrine believe that having a seed / sapling, there will be little problem with growing a plant, but the reality is quite different. As shown in the cases presented, natural regeneration is affected by many factors (height, size of available space, availability of light, air, water and soil pollution) and sources (abiotic, biotic). The biggest antagonist is man, who with his behavior and inconsistency in what he does, negatively affects many of the above-mentioned factors, increasing their toxicity to the environment. Deforestation, air pollution, inadequate afforestation (ill-suited vegetation to the characteristics of climate, terrain, temperature, precipitation) has a major impact on what kind and how many seedlings nature is able to produce. Unfortunately, it can't be relied on, and in the current situation, appropriate conclusions should be drawn from available research. Among other things, it is necessary to fight to reduce pollution, as well as for additional afforestation of new and old land. When conducting artificial afforestation, it is necessary to take into account all factors that may affect the species and its survival and subsequent regeneration. Particular attention should be paid to ensure that afforestation in mountainous areas is carried out in the form of cluster afforestation, which will reduce competition while strengthening and protecting plants from factors that negatively affect their development.

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What we are doing to the forests of the world is but a mirror reflection of what we are doing to ourselves and to one another.

(Mahatma Gandhi)

Reading about nature is fine, but if a person walks in the woods and listens carefully, he can learn more than what is in books, for they speak with the voice of God.

(George Washington Carver)