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DOI: 10.1515/frp-2017-0029
Available online: www.lesne-prace-badawcze.pl

Leśne Prace Badawcze / *Forest Research Papers*
Wrzesień / September 2017, Vol. 78 (3): 257–266

DISCUSSION ARTICLE

e-ISSN 2082-8926

Reference and control plots – a useful tool for forestry?

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Abstract. In the current age, the increased need for the restoration of forest ecosystems necessitates a better understanding of natural processes. Forest stands that are affected only by natural processes and disturbances can serve as references and controls for comparison with cut or otherwise managed forests. Such a comparison may help us determine, whether our sylvicultural practices actually pursue the goal of sustainable development. It is also important to use uniform terminology across the world to facilitate sharing of experiences and results. Creating reference and control stands in every ecoregion will provide a rich scientific basis for comparison with managed forests and allow us to design and apply restoration methods more effectively.

Keywords: control conditions, control plots, reference conditions, reference plots, restoration

1. Introduction

Forest management, in the context of planning, can be called a long-term experiment, conducted on almost every continent over several centuries, and will most likely last for many years to come (Frelich et al. 2005). The management activities that have been used for a long time were often based on certain assumptions, such as that the climate in a given area will remain unchanged throughout the life of a tree, that the trends in habitat change influenced by various factors (natural or anthropogenic) have a similar character and that the strategies that worked well in the past will be effective in the future (Bernadzki 1993; Frelich et al. 2005). In turn, all the changes occurring in tree stands, such as the species composition of the biocoenosis, have a long-term character and most often are unable to be grasped by one or two generations of foresters. This is due, amongst other things, to the life span of trees or the pace of other natural processes modifying the conditions of the stands. This is why a key issue in forestry, where the species composition of tree stands is planned and established over a long time period, is observation and developing an understanding of the processes occurring in nature, as well as predicting their direction, intensity and causes.

It is thus important to know the scale of the impact of silviculture activities on forest biodiversity. At present, in view of the generally functioning concept of sustainable development, protecting the value of natural forest ecosystems is no less important than timber production yields. Some of the treatments (e.g. monocultures and clear cuts) transform natural heterogeneous stands, so important to forest populations such as invertebrates (e.g. Niemelä et al. 1996) or birds (e.g. Freemark, Merriam 1986), into more age- and species-uniform stands, with greater fragmentation and discontinuity (e.g. Faliński 1998). Intensively managed forests are characterised by a 10–15% reduction in total carbon content compared to undeveloped stands (Krankina, Harmon 1994) as well as deficits, from a biocenotic point of view, in the amount of dead wood, which negatively affects the populations of saproxylic invertebrates (Ranius, Roberge 2011). They exhibit a lack of balance and markedly weakened stability (Bernadzki 1993). In addition, areas of intensive forest management have a much lower species richness of bryophytes, lichens and fungi than forests excluded from economic use (Paillet et al. 2009). It should also be remembered that many very rare and protected species are primarily associated with natural forest ecosystems (The Polish Red Data Book of Plants, The Polish Red Data Book of Mushrooms, The Polish Red Data Book of Animals).

In order to effectively reconcile economic requirements with the requirements of nature protection, one must not only modify forest management but also establish areas

Received: 19.04.2017, reviewed: 29.05.2017, accepted: 5.07.2017.

excluded from economic activity, to serve as benchmarks in setting goals for the future. A properly established network of excluded areas for monitoring and comparing the state of biodiversity to the conditions prevailing in managed stands will provide information on the species richness of different taxonomic groups in different types of forests, as well as fundamental knowledge on the processes that shape biodiversity in the forest (Paillet et al. 2009). It will also be a valuable tool to protect species and deter habitat degradation, threatening natural resources (Stockland 1997).

In other countries (especially in the United States, which produces most of the publications on ecosystems excluded from forest management activities), the concepts of 'reference forest stands' and 'reference conditions' have been known for many years. Sometimes the terms 'control stands' and 'control conditions' are also used to define areas with slightly different functions. Poland also uses the terms 'forests' or 'reference stands' (or 'base', 'standard', 'untouched', 'model', 'representative'), but they are defined slightly differently than in other countries, which may cause some misunderstanding, especially if trying to transfer experiences from other countries to Poland.

The aim of this paper is to present the definitions and discuss the role of different types of research plots used for comparisons with managed stands, to propose equivalents in the Polish nomenclature and ways of establishing them, to present the possibilities of using this issue in studies in Poland and to explain the causes of the controversy about this concept.

2. What functions in Poland and what functions abroad?

According to Paragraph 6.4 of the Forest Stewardship Council (FSC) standards in force in Poland, representative ecosystems (sometimes referred to as 'reference forests') should be designated within certified forests and their economic utilisation, as defined in the forest management plan, should be limited so that these ecosystems can fulfil essential natural and other non-economic functions (www.ic.fsc.org). These are most often ecosystems in a natural or close to natural state. Planned use of activities are either not carried out in representative ecosystems or conducted in a very limited scope, depending on the extent of their protection. The intent of establishing them in FSC certified areas is the passive protection of valuable natural biocoenoses. However, in justified cases, certain treatments (such as cutting, removing dead trees) are acceptable or even necessary. Such areas function in many forest districts in Poland (even up to a dozen or more within one district) (e.g. gdansk.lasy.gov.pl, poznan.lasy.gov.pl, szczecinek.lasy.gov.pl).

Other types of areas in Poland are reference areas, serving scientific purposes. An example is a forest of about 475 ha in the Pisz Forest District, which was completely excluded from forest management after a hurricane on July 4, 2002 (Rykowski 2012). At present, it is called the 'Szast' protected forest, and it is used to analyse natural (Dobrowolska, Farfał 2009) and soil habitat (Czerepko 2009) regeneration, amongst other things. Another example of areas excluded from forest management for scientific purposes are those located within twelve promotional forest complexes in different parts of the country (Borowski et al. 2016). These areas have been inventoried to describe their initial conditions. In the future, they will be the starting point for monitoring the natural processes occurring in soils, tree stands as well as the populations of plants, animals and fungi.

There are places in Poland where permanent experimental areas for monitoring forest conditions and its characteristics have been functioning for many years. For example, in 1936, in the Białowieża Primeval Forest strict reservation, five research plots were established, called 'Włoczewski's areas' (Bobiec 2016), named after their creator. They were initially intended to explain the impact of soil conditions on the spatial diversity of the tree stand and on the dynamics of its variability over time. To this day, changes in stand structure and species composition are monitored, providing invaluable knowledge about nature (e.g. Bernadzki et al. 1998, Brzeziecki 2008, Brzeziecki, Bernadzki 2008, Bolibok 2014 and Brzeziecki 2016). Thanks to this work implemented over many years, we now know that the idea of strict conservation is not a universal method of preserving the richness of natural resources and does not guarantee the maintenance of high levels of diversity in forest ecosystems (Brzeziecki 2011). Similar conclusions are drawn from studies on natural forests in other countries (e.g. Cole, Young 2010).

Even older plots are the so-called 'Schwappach's areas' established in the 19th century in Brandenburg and Prussia (Dudzinska, Bruchwald 2006, Mędrzak 2011). They were established to observe the increase in the volume and height of different types of tree stands in different phases of development and to monitor their reactions to treatments. After the border changes of 1945, seventy-three of these areas (out of about 1,000) came to be located in Poland and since then, they have been cyclically surveyed and measured. It is precisely on the basis of the data obtained from these areas more than a century ago that wood volume and increment tables were drawn up (Schwappach 1912).

Outside of the country, there are also areas that were completely excluded from forest management at a certain point in time. They are called control stands, and the conditions that exist in them are called control conditions (e.g. Frelich et al. 2005).

A different type of area is the reference area. It serves as a model containing model sets of desirable traits that should be brought into existence in a specific site over a certain period of time. This term refers to the environmental conditions that are not influenced by human activity (Stoddard et al. 2006) as well as to the scope of the natural variability of the structural and functional features of ecosystems and their living organisms (Landres et al. 1999; Moore et al. 1999). Reference conditions include information about potential vegetation, soil properties, landscape structure and composition, natural disturbances (e.g. fires, diseases and pest outbreaks), species occurrence, succession stages and biotic links (Kaufmann et al. 1994).

3. The role of reference and control areas

Both these concepts, especially reference areas, are used particularly in the context of protecting and reconstructing various types of ecosystems, including the forest ecosystem. At present, establishing reference areas is one of the standards of habitat protection in most European countries (Schuck, Rois 2004). Reference conditions serve as a benchmark for determining the extent of ecosystem degradation, setting ecosystem rehabilitation targets and assessing the effectiveness of restoration measures (Stoddard et al. 2006). They are used, for example, to assess whether the processes in degraded ecosystems will lead to the regeneration of their desired ecosystem functions or whether specific actions are needed to accelerate or change these processes (Pickett, Parker 1994; White, Walker 1997; Beauchamp, Shafroth 2011). Reference conditions are separated into the conditions at the scale of the tree stand and at the scale of the landscape (Frelich et al. 2005). At the scale of the stand, comparisons are made to the conditions in commercial forests in terms of species composition and the spatial distribution of trees in different age classes, the existence of gaps and dead trees. In terms of the landscape, the share of stands in different stages of development is compared.

Reference forests are useful, and defining reference conditions is a valuable tool for recreating degraded forest ecosystems. Reference conditions have been defined in the United States for alluvial forests (e.g. Harris 1999), fir-pine (e.g. Taylor 2004; 2012) and coniferous forests (e.g. Pollock et al. 2012), yellow pine stands (e.g. Covington et al. Fulé et al. 1997) and various types of mixed stands (e.g. Laughlin et al. 2004; Frelich et al. 2005; Margolis et al.). However, owing to the long period in which changes take place in forests and the development cycle of trees, there are no examples that clearly illustrate the reconstruction of a tree stand using previously determined reference conditions. Time is one of the main factors that make it impossible to draw simple and unequivocal conclusions based on the reference conditions. Thanks to 'Włoczewski's areas' operating now for more than eighty years, it is clear that natural forest ecosystems are unstable (Brzeziecki 2008), constantly reacting to environmental changes (Bernadzki et al. 1998). Thus, changes and trends occurring over a short time period should be interpreted with caution (Bobiec 2016).

On the other hand, the aim of establishing control areas is to assess the effects of forest management on tree stands (Frelich et al. 2005). This enables us to compare the conditions of managed forests with control conditions in the short and long terms. Some of the differences resulting from the cessation of silviculture activities are visible in a short time (e.g. the amount of light reaching the forest floor, changes in the number of naturally regenerating trees), whilst others (such as changes in the cycle of elements, organisms or successional pathways) need longer periods.

4. Determining control and reference conditions

Determining control conditions is not difficult, because, by definition, they exist in forest stands excluded from forest management. However, designating and obtaining reference conditions is problematic.

At least several aspects must be defined to determine the desired conditions of an ecosystem, for example, the volume of alive and dead trees, species composition of the tree stand and average tree height and diameter at breast height (Pollock et al. 2012). These features are essential to precisely describe the reference conditions, to determine the objectives for which these conditions will be created and to plan the appropriate management of the stand. It is important to be aware that using only one of the conditions can lead to erroneous assumptions in planning treatments, so it is important to include at least several of them.

The existence of ecosystems not affected by humans in any aspect (Kaufmann et al. 1998) and subject to naturally occurring disturbances (Frelich et al. 2005) is the optimal situation for obtaining reference conditions for their specific types. Unfortunately, human impact on the planet is so extensive that such ecosystems seem not to exist (Kaufmann et al. 1998). For this reason, attempts are being made to reproduce them using different methods, which can be divided into two main groups. The first is the analysis of historical data. The conditions in the ecosystems of the past are reproduced by means of surviving material (e.g. written records and photographs), archaeological and paleontological studies. The second group includes reconstruction models, applied with the principle in mind that the present is a product of the past. Thus, indications of changes are sought in present-day conditions that once existed in a given ecosystem. Of course, these methods can be combined. A model containing data on current conditions and supplemented with historical data allows reliable results to be developed on the reference conditions (e.g. Brown, White 2002).

However, keep in mind that every method has its limits or even erroneous assumptions. Historical data may be incomplete, they may omit very important aspects or their range does not go back far enough (White, Walker 1997). When trying to extrapolate historical data on the same type of stand in another location, there is a high risk that they will not be accurately transposed. On the other hand, analysing and modelling data from the present state may result in an erroneous evaluation of the results of some long-term processes − many years of observations are needed to precisely determine their impact on a given tree stand (Magnusson et al. 1991).

One of the most serious obstacles to determining reference conditions are the incessant changes in the climate, resulting in the transformation of vegetation in the boreal, temperate and tropical zones (Gonzalez et al. 2010, IPCC 2007a, b, Rozenzweig et al. 2008). Faced with global warming, the attempt to faithfully reproduce the conditions of several dozen or even hundreds of years ago seems unrealistic. For this reason, the objective of many researchers is not an ideal reproduction of past conditions but rather to create the conditions most closely resembling those of many decades past (e.g. with a similar stand structure and with the presence of native species) and to allow natural processes and disturbances to occur undisturbed (e.g. fires) (Fulé et al. 1997; Moore et al. 1999). These are quite bold postulates, especially the ones that suggest creating the conditions for fires, which are unlikely to be carried out in managed forest. But is it not worth considering the possibility of creating them in places where disaster will not be perceived in terms of a threat to human life and economic loss, but only as an opportunity to conduct interesting, from a scientific point of view, observations?

5. Useless?

The idea of creating and using models of tree stands untouched by humans also has a large group of adversaries. The argument against establishing reference areas is the lack of substantive arguments explaining their usefulness (Spellman 2013). This is reflected in the results of scientific research, characterising natural forests as being less multifunctional than managed forests. And yet, in principle, the multifunctional forest is the best and safest way to take full account of all the functions of a forest − productive and non-productive (Zachara 2000). Meanwhile, according to many authors (e.g. Ohlau 2010, Matuszkiewicz 2011, Walentowski 2011, Tzschupke 2012), abandoning breeding practices in tree stands leads to insignificant differences or even a decline in biodiversity, economic losses and the deterioration of forest health.

Furthermore, there is also the opinion that knowledge about the development and functioning of forests should be the result of research carried out in facilities where targeted management is conducted (Spellman 2013) and that the 'multilateral needs that we expect from the forest can be met only by targeted breeding activities' (Jaworski 2011). Establishing areas where only natural processes can occur is called 'the primeval forest game' (Encke 2012), and focusing attention and expectations on such an area means a regression in the development of forestry thought by decades (Smith et al. 1997).

Opponents of reference forests reject them, then, as an element of the multifunctional forestry, recognising them as an idea that does not serve the future of humankind and the aims of the human management of the forest, that is, to ensure the priority of certain tree species and stand structures, or for the processes of developing tree stands of desired characteristics (Smith et al. 1997). On the other hand, the natural forest, vulnerable to random natural selection processes and to strong competition with all the components of plant and animal species, does not provide the appropriate dynamics of tree stand development.

6. Suggestions for forestry in Poland

As noted, the concept of reference forests is controversial. It is, therefore, worth knowing all the consequences of their establishment or elimination before deciding whether to establish them in Polish forestry practice.

Before developing such areas, it is important to remember that there is no uniform nomenclature used everywhere. To avoid unnecessary discrepancies in sharing experiences and using models from abroad, the term 'control area' (or 'comparative' area) should be used for the tree stands in which management activities have ceased and are intended to serve scientific purposes to study natural succession processes and to assess the effects of management on the forest ecosystem. In the case of stands that are as close as possible to a natural state and are strictly or actively protected, that is, as in the case of implementing the guidelines of point 6.4 of the FSC standards, the term 'reference area' (eventually 'representative', 'model') is justified and need not be modified.

To establish a complete network of control stands, they should exist in every ecoregion for all the types of stands existing there (e.g. Frelich et al. 2005). In Poland, small areas, such as mesoregions, should be considered (Kondracki 2002). This is important from the point of view of local factors. Whilst global or regional factors (such as climate change, nitrogen deposition, acid rain, various human activities impacting a large area) generally affect managed, control and reference tree stands in the same way in a given region, the impact of local factors may differ in various areas (Frelich et al. 2005).

From a scientific point of view, control areas provide invaluable opportunities to monitor natural processes occurring without human intervention at virtually any stage, with the ability to precisely determine the initial conditions. This allows one to capture the initial state, the rate and the direction of actually any change occurring in each ecosystem.

In the context of silviculture, control stands are a valuable tool when looking for breeding solutions that are close to natural ones (e.g. Franklin et al. 2002). In addition, the long-term comparison of conditions in commercial stands where harvesting operations have been conducted continuously for centuries with conditions in control stands can, for example, show whether current treatments are providing adequate productivity (Frelich et al. 2005). Short-term control can also be conducted to verify the effectiveness of a single treatment. For this purpose, the managed stand can have a designated area serving as the control, where the treatment will not be used, and another part in which the experiment will be carried out.

Consideration should be given to establishing control areas in promotional forest complexes, thereby fulfilling the scientific role of these facilities (www.lasy.gov.pl). This allows a better understanding of the natural processes of regeneration in different types of stands in the twenty-five regions of the country to be gained, creating a solid network of test areas for research. Efforts should not stop there, of course. It is also worth setting up control areas in sites where natural disturbances occur, as was done after the hurricane in the 'Szast' protected forest of the Pisz Forest District. It would be valuable to know and compare natural regeneration processes, given various types of disturbances: after a fire, an insect infestation or the appearance of pathogenic organisms.

The most important tree stand characteristics requiring analysis in terms of change are the number and type of dead trees, number of naturally regenerating trees, phenology of leaf development, rate of organic matter decomposition in the soil, dynamics of growth in tree volume, species diversity of different groups of organisms, spatial structure of the tree stand and structural characteristics of each forest layer (Borowski et al. 2016).

It is also desirable to establish reference areas to serve as models of the natural functioning of all types of stands in Poland in each region, which at the same time can become an important element in the protection of local or regional biodiversity. The deciduous forests of central Europe deserve particular attention, as they are amongst the most vulnerable to degradation because of the loss of their naturalness (Bengtsson et al. 2000). However, finding completely unaffected forest ecosystems of each type in every mesoregion in Poland is a huge challenge, if at all possible. Therefore, reference conditions for each type of stand should be reproduced using available historical data, and models should be developed taking into account the factors mentioned earlier.

As far as the use of historical data is concerned, a significant problem may be determining the time period of the reference point required for setting the reference conditions. In the United States, where most of the research on this topic is based, the reference conditions most often acknowledged are those that existed in the tree stands during the pre-Columbian era (e.g. Wallin et al. 1996; Fulé et al. 1997; Landres et al. 1999; Fulé et al. 2002; Taylor 2004), the time before the continent was intensively settled by colonists, whose presence and activities greatly affected the forest condition. In Poland, the most intensive logging, transformation and degradation of forests occurred in the nineteenth century (Żabko-Potopowicz 1960, Szymanowska 1974). Theoretically, attempts can be made to seek out historical sources prior to this period, to determine the conditions of various types of stands at that time and to consider them as the reference conditions.

However, this is not so obvious, given the climate change that has taken place since this time. The current state of knowledge about its impact on ecosystems and their species is inadequate. Some experts predict relatively small transformations of the forest (Loehle 2000), but others believe that very serious changes may occur in the vegetation (Aber et al. 2001, Scott et al. 2002), and this depends on whether the climate will be warm or cool in the future (Kozak et al. 2017). Since the mid-twentieth century, the average annual temperature in Poland has increased by about 1ºC, the period without snow cover has increased, whilst in summer, the number of hot days has increased and the amount of rainfall has decreased (Degirmendzic et al 2004, Wibig 2014). A continued increase in temperature by another 1–3ºC is predicted by the middle of the twenty-first century and by 5ºC at its end (Anders et al. 2014 for Giorgi et al. 2004; Räisänen et al. 2004; Rowell 2005; Christensen et al. 2007; Déqué et Kjellström et al. 2007). Rainfall is expected to increase around 10% in summer and 15% in winter in 2065 (Anders et al. 2014 after Christensen and Christensen 2007; Christensen et al. 2007). In addition, human activity further complicates the response of ecosystems to changing climatic conditions and thus reduces the credibility of various forecasts. As a result of this activity, changes occurring in tree stands may occur at an even faster pace (Ledig 1992). The full return to the natural conditions of forests from several decades ago (not to mention those from few hundred years ago), which, after all, were inextricably linked with the climate at the time, seems unlikely or even impossible.

It is worthwhile, however, to try to compare the conditions currently prevailing in natural forests functioning as reference areas with those of the past. This would lend credence to the degree of naturalness of these stands. Also, during the planning stage of new reference areas, the above-described methods should be used to support the reconstruction of the conditions from many years ago. Establishing representative tree stands within old forests, long protected as natural reserves or national parks, is fully justified, as the natural processes have been continuing there for many years (e.g. Goebel et al. 2005). They also serve as local or regional sources of biodiversity.

It can, therefore, be acknowledged that a part of the network of these areas has long existed. We should consider, then, whether there are already enough of them, whether they provide the knowledge we expect from them and whether and how we should establish new ones (e.g. what should be their minimal area and whether we have adequate funds and resources to maintain and study them). Undoubtedly, the multidirectional work at the 'Włoczewski' and 'Schwappach' areas, as well as other research facilities of this type, should be continued. They provide opportunities to monitor the developmental processes of tree stands and individual trees over many decades. As history shows, maintaining similar experimental plots can bring unforeseen benefits to future generations. For example, based on data from the 'Schwappach' area, in addition to the already-mentioned stand tables, at the end of the 20th century, that is, about 100 years after their establishment, stochastic models of individual tree growth were developed for the more important forest tree species (Bruchwald 1986, 2001; Bruchwald et al. 1996, 1999, 2003; Bruchwald, Zasada 2010). Some of the algorithms of this tool have been adopted in forestry practice, enabling very accurate forecasts to be made of tree stand development, which can be used to optimise harvesting and to appraise the value of a forest (Dudzińska, Bruchwald 2006).

It should also be remembered that even though the conditions in a natural forest may seem appropriate to act as the reference conditions, they may not always provide the expected conclusions required for nature preservation or forest management. As seen in the exemplary results of research in the Białowieża Primeval Forest, the natural processes occurring there are not conducive to pine regeneration, with the expansion of fir in fresh coniferous forest habitats, or for ash regeneration in the thick undergrowth and strong pressure of game animals in alder-ash forests (Matuszkiewicz 1952). Oak tree seedlings are also suffering as a result of competition with fir regeneration in fresh mixed forests (Sokołowski 2004). The results of geobotanical work carried out in Białowieża National Park also show that in the past 50 years, natural processes have resulted in a significant decrease in the floristic diversity of various types of plant assemblages, with some assemblages almost disappearing (Matuszkiewicz 2011). Additionally, as stated in the previous section, a higher degree of a forest's naturalness very often means that the wood production is less cost-effective (e.g. Ohlau 2010).

This does not mean that forestry should abandon natural processes of stand development. On the contrary, there are national and international studies confirming the effectiveness of the semi-natural development of some stands (e.g. oak trees, where regeneration occurs spontaneously under the canopy) and the significant possibilities of its use (Pigan, Pigan 1999; Schirmer et al. 1999).

When using reference areas as a model for the functioning of protected areas or managed forests, the objectives of the project, its benefits and results should be thoroughly considered. It is also not a good idea to definitively resign from some type of management (or lack thereof) if there is a chance of achieving positive results.

7. Conclusion

In the Polish nomenclature, the notion of reference tree stands differs somewhat from the concept as understood in forestry in Western countries. Using the names 'reference areas' and 'control areas', according to the proposals suggested in this paper, will help avoid any eventual inaccuracies when exchanging knowledge and experiences.

The issue of introducing reference and control forests as tools to improve forest management and to serve as sources of scientific knowledge may be controversial. The cessation of silviculture practices in a tree stand, according to many opinions, results in limiting its multifunctional character, and thus it loses its most important features for modern forestry. Economic losses stemming from stand condition and lower biodiversity are arguments that speak against establishing these types of areas.

On the other hand, the 'Principles of Silviculture' states that 'each forest in every place and time simultaneously serves various functions in a natural way. Some functions, considered particularly important to humans, can be enhanced by forest management methods'. And 'multifunctional forest management should ensure the ability of the forest to fulfill all its natural functions in a sustainable and balanced way, and enhance those functions acknowledged as priorities for a given area' (Principles of Silviculture 2012). So it is not so obvious that 'only deliberate human action ensures the provision of the multifaceted needs that we expect from the forest'. Perhaps, at times, we can take from it what it wants to give us without our help and expectations?

Defining control and reference conditions can thus be an important tool for forestry in the context of the conservation and restoration of stands, as well as providing a better understanding of the natural processes occurring in forests and monitoring them. Control stands in which silviculture practices have ceased provide the opportunity to assess the scale and effectiveness of economic operations in the context of productivity and the ecological functions of stands. They are also very valuable experimental plots, making it possible to attain precise knowledge about the natural processes of forest regeneration. In order to understand these processes, it is worth establishing control areas not only in managed stands not affected by natural disturbances but also in stands impacted by strong disturbances, resulting in an immediate and significant transformation of their structure.

Establishing reference areas, according to the FSC standards in force, as stands that most closely reflect natural conditions and function without human intervention is desirable primarily due to their biocenotic and research values. They enable us to determine the prevailing conditions needed for a given type of tree stand and which of its elements should be reproduced. To effectively assess the degree of naturalness of reference stands, it is worth making an attempt to recreate the conditions of the past.

It is extremely important, from scientific, economic and natural points of view, that both reference and control stands (when deciding on their further establishment) exist in each type of stand in every mesoregion because of the local factors that may modify ecosystem functioning. When developed skilfully, they can become important elements in preserving the biodiversity of ecosystems, improving stand productivity and better understanding the natural processes occurring in forests.

Setting reference conditions is a very subjective issue that depends on the planning approach, its goals and the time frame in which it should be achieved. Decisions also need to be made on how to approach what is happening in the forest. For some, the conditions of natural forests are the unstable results of random, disordered and chaotic events and for others, a harmony of natural and logical processes and relationships that have always existed, some of which are still waiting to be discovered. Certainly, it is worthwhile to continually reap the benefits of good ideas and follow the example of predecessors-visionaries, whilst counting on the continuation of their work in future generations.

It is also worth asking from time to time whether what appears to be known from the experiences gathered over several hundred years of forestry practice (over two hundred in the case of Poland) is still valid in the context of the current situation and the prospects of forthcoming changes.

Conflict of interest

The author declares no potential conflicts of interest.

Acknowledgements and source of funding

No funding sources were used to write this article.

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