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**REVIEW ARTICLE**

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# Can changes in forest management contribute to the reduction of $CO_2$ in the atmosphere? Literature review, discussion and Polish example

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## Abstract

Both COP21 and COP22 stressed the role of forests in climate protection as a natural $CO_2$ sink. With this in mind, the study reviewed some literature findings related to afforestation, stand level management, forest soils, peatland management and storage yards to increase the amount of $CO_2$ absorbed by the forest ecosystem. It was shown that some of the assumptions, for example, afforestation or improved water relations in soils, may contribute to reduced $CO_2$ levels in the atmosphere. Our research was of a review nature and consisted in seeking information in various scientific publications. For a better interpretation of the results, we have divided our research into several parts. In the first part, we analysed the importance of deforestation and afforestation in the context of $CO_2$ accumulation. We discussed the results of research on these issues giving specific examples. We have analysed the possibility of afforestation of new land. Using the example of Poland, we have indicated problems related to this issue. We have analysed the possibility of afforestation of new land. On the example of Poland, we have indicated problems related to this problem. We have come to the conclusion that in today's Europe, the obstacle to such efforts is the lack of land that can be afforested and the financial incentive to abandon farming for forestry is too low. In the second part, we discussed the role of forest stands in the process of $CO_2$ accumulation and reduction. We discussed breeding treatments that can be performed on racks. We noticed their importance in the $CO_2$ reduction process. We noticed that when the density of forests increased, this has a positive effect on organic carbon storage. We presented and discussed examples of different rotation strategies in the context of their impact on $CO_2$ accumulation. We analysed issues related to obtaining wood raw material and possible further storage of coal or its release into the atmosphere. We have recognized that proper forest soil management is important for $CO_2$ accumulation. Therefore, another part of the research was devoted to the discussion on the role of soil in the process of $CO_2$ accumulation. We discussed examples of using soil for forest and non-forest purposes, looking for the answer: how does this affect $CO_2$ accumulation? In addition, we analysed the impact of soil moisture on processes related to $CO_2$ storage. In our research, we critically treated wood storage as a method of reducing $CO_2$. We also discussed the problem of treating wood as a source of bioenergy. We came to the conclusion that wood as an energy source can have a positive effect on $CO_2$ reduction. The condition is, however, that energy produced from wood replaces energy from fossil fuels. Finally, we presented and discussed financial and legal issues related to $CO_2$ reduction activities involving forests. We have found that attempts to commercialize $CO_2$ emission reduction units for emissions generated in forests should be linked to the environmental responsibility of companies, and as such, should not be included in the current



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emissions' trading policies. In the article, we also present a Polish proposal to run coal farms. We discuss their importance in the context of the issues discussed in this article.


## Key words

forestry, politics, environment, climate, protection, sustainable development, $CO_2$, carbon


## Introduction

Climate change is an unequivocal phenomenon: the atmosphere and the oceans have warmed (leading, e.g., to heatwaves); the extents of snow and ice have decreased (Greenland and Antarctic ice sheets have been losing mass); the sea level has risen (an average of 0.17 m since the beginning of the twentieth century), leading to coastal erosion, storm floods and flooding of coastal areas; rainfall patterns have changed; and greenhouse gas concentrations have increased (Rayner et al. 2003; Alexander et al. 2006; Church and White 2006; Rignot and Kanagaratnam 2006; Schwartz 2008; Rockstrom et al. 2009; Solomon et al. 2009). This phenomenon is associated with the increase of the emissions of greenhouse gases (GHGs, mainly carbon dioxide – $CO_2$) due to anthropogenic activities. Carbon dioxide emissions result primarily from combustion of fossil fuels, but forest degradation and deforestation are also the contributing sources (Houghton et al. 1992). Climate change impacts are associated with risks to the satisfaction of basic human needs (health, food security and clean water), as well as risks to development (jobs, economic growth and the cost of living) (Pires 2017). The carbon capture and storage (CCS) technology is expected to play a major role in the mitigation of global warming (Szulczewski et al. 2012; Kim et al. 2017; Minasny et al. 2017). The only options in the short run to halt emissions of $CO_2$ are the large-scale application of Carbon Capture and Storage (CCS) in combination with increased energy efficiency. In the long run, we have to radically transform our societal metabolism towards greater resource efficiency, where renewables can play a more important role (Wennersten et al. 2015). Taking into account this phenomenon, several countries participated in the recent United Nations Climate Change Conference in Paris (Minasny et al. 2017). The climate policy of individual countries is changing and the number of countries adopting or resigning from this agreement is changing. The summit of the G20 leaders in Buenos Aires (30 November to 1 December 2018) confirmed the divisions in the area of climate policy. With regard to climate policy, the differences seen at the Hamburg Summit in July 2017 persist. In Buenos Aires, all members of the group, except the U.S., recognized the irreversibility of the 2015 Paris Agreement and supported its full implementation. In turn, the U.S. confirmed its withdrawal from the accord, emphasising attachment to energy security and the use of all energy sources, while expressing concern for the environment. However, it should be emphasised that all G20 members supported efforts to implement the UN Sustainable Development Goals for 2030, including activities in the area of climate protection.

The COP21 (21st Conference of the Parties to the United Nations Framework Convention on Climate Change) in Paris (November 30 to December 11, 2015) produced the Paris Climate Agreement. This is a global agreement on the reduction of climate change, limiting global warming to less than 2 degree Celsius (°C) compared to the pre-industrial levels and to pursue efforts to limit the increase to 1.5°C (Meinshausen et al. 2016). To accomplish this, countries have submitted Intended Nationally Determined Contributions (INDCs) outlining their post-2020 climate action (Trabalka et al. 1986).

This conference (COP21) and the following one held in 2016 in Marrakesh (COP 22), both stressed on the role of forests in climate protection as the natural $CO_2$ sink. It was decided that the efforts to curb increasing $CO_2$ concentration in the atmosphere should not be limited only to reducing emissions, but also focus on strengthening these natural resources, which naturally absorb $CO_2$ from the atmosphere. The carbon balance of terrestrial ecosystems may be considerably altered by the direct anthropogenic impact, for example, deforestation, combustion of biomass, land use change and environmental pollution, all releasing trace gases, which in turn enhances the greenhouse effect (Trabalka and Reichle 1986; Houghton et al. 1990). Soil organic carbon comprises approximately two third of the terrestrial carbon storage. It has recently been suggested that soil carbon may play important roles as a source or sink of carbon in response to changing climate and atmospheric $CO_2$ (Schimel et al. 1994). The direct incorporation of land use change and forestry into the fight with global warming is a new project in the internationally adopted policy aiming at countering climate change. Forest ecosystems can be managed to assimilate $CO_2$ via photosynthesis and temporarily store C in the biomass and soils (Winjum et al. 1993; Kinsman et al. 1997). Changes in the composition and structure of ecosystems are driven by a combination of management practices (including lack of management practices) and changes in climate and atmospheric composition. For example, the biomass increases currently observed in many forested areas largely reflect successional changes due to the past changes in forest management (Walker and Steffen 1997). Forest and agroforest establishment and management practices can be grouped into two major functions: to maintain or improve existing sinks and to expand forest areas that can serve as sinks of $CO_2$ (Orellano and Isla 2004).

According to the Report on Polish Forests, in the ownership structure of forests in Poland, public forests dominate - 80.7%, including forests remaining on the board of the State Forests National Forest Holding - 76.9%. The company is implementing a project called Forest Carbon Farms (FCF). A pilot scale project termed FCF was initiated in 2017. The project implements the concept for an increased absorption of $CO_2$ and other greenhouse gases thanks to the additional measures introduced in forestry. The activities implemented within the framework of the project are to increase the forests' capacity for coal absorption, increase existing carbon resources in the ecosystem, reduce carbon emissions from soils, and reduce the risk of uncontrolled $CO_2$ emissions caused by disaster. Within the project, the introduction of fast-growing species trees, growth of forest area through afforestation, as well as the simplification, enlarging areas of the natural regeneration. Currently in Poland, during the period 2017–2026, the main additional activities in forest was and will be underplanting (4,328.66 ha), natural renewals (611.60 ha) and artificial regeneration conducted Sobański's method (1,368.60 ha). This method tries to imitate nature - it uses sowing seeds of various species as a semi-natural way of renewing the forest. In the optimal variant of its use, oak seeds (usually *Quercus petraea* [Matt.] Liebl.) are sown in autumn, and with them also other species (rowan, hornbeam, pear, apple tree and others), whose task is to cultivate the habitat. In the spring of the next year, pine cuttings are introduced, according to the species composition of the forest defined in the Forest Management Plan. The remaining part of additional activities are afforestation, introduction of fast-growing species, use of shelterwood method, change in the age of final cutting and renewal on open areas. The advantage of the shelterwood cut is that a vigorous new stand occupies the site before the final harvest (Clark and Watt 1971). In 2018, activities were carried out on the area of nearly 800 ha. Of this, 65% was underplanting and renewals of the so-called Sobański's method accounting for 29% of this area. In this document, a decision was made to discuss, based on the literature review, the suitability for $CO_2$ reduction of selected activities carried out in the forests covered by FCF program. It was decided to review the scientific articles on the possibility of using new afforestation and existing forests, forest soil and timber storage in order to increase the amount of $CO_2$ absorbed by the forest ecosystem and wood.

## Forestation

The deforestation of tropical forests and creation of croplands has identified as one of the main causes of the increase in the atmospheric greenhouse gas $CO_2$ (Johnson 2009). Stabilisation of atmospheric $CO_2$ concentrations might be partially achieved by limiting forest cutting and burning (thus reducing the C source), and replacing millions of hectares of forest that have been destroyed (thus expanding the $CO_2$ sink). Up to $2 \times 10^9$ ha of deforested or degraded land are technically suitable worldwide for forestation (expansion of forest area) or other improved land management techniques using tree cover (Kinsman et al. 1997). One of the FCF assumptions is connected with afforestation. Clearly, the C sequestration function of forests is closely related to the production function of forests (i.e., the growth rate of trees). In the simplest case, if non-forested lands such as agricultural fields are reforested, it is clear that there is a large accumulation of C in the aboveground tree biomass (Johnson 1992; Richter et al. 1999). Minasny et al. (2017) summarize SOC accumulation rates for various countries and climatic conditions as: afforestation (~0.6 t C/ha/yr), conversion to pasture (~0.5 t C/ha/yr), organic amendments (~0.5 t C/ha/yr), residue incorporation (~0.35 t C/ha/yr), no or reduced till (~0.3 t C/ha/yr), and crop rotation (~0.2 t C/ha/yr). While the soil organic carbon (SOC) rates for organic amendments, residue incorporation, no or reduced till and crop rotation may be considered disputable, as it was indicated by White et al. (2017) that the figures for afforestation and conversion to pasture are fully justified. For this reason, these measures may contribute to increased SOC and in turn promote the realisation of the COP 21 guidelines. This was confirmed by Kinsman et al. (1997) who stated that there is a considerable potential for forestation, reforestation and improvement of degraded land to remove $CO_2$ from the atmosphere and that the socio-economic benefits for developing national forest C offset programs may be great (Dixon et al. 1993).

In Poland, the potential for afforestation of new areas, particularly former farmland, is limited. While the National Programme for the Augmentation of Forest Cover was accepted for implementation by the Council of Ministers of the Republic of Poland on 23 June 1995, it has not been adopted as a government programme and no funds have been allocated for its execution over a long-term perspective. The only decisions were to identify specific tasks aiming at increasing forest cover of Poland from 28% to 30% by 2020 and 33% after 2050, expecting target forest cover by 2050 to reach 1.5 million ha of arable land. The program stipulates afforestation of both state and privately-owned land. However, it does not introduce long-term funding instruments or any system of incentives for afforestation of land owned by farmers. This is a serious obstacle for the execution of afforestation measures stipulated by the program.

At present, the rural development program can be the source of afforestation financing in Poland. Rates for afforestation for farmers in 2018 were set at the following amounts (it concerns the costs of establishing a crop): (i) support for afforestation - one-time payment for afforestation in the amount of PLN 4984 (ca 1250 EUR) /ha to PLN 7385 (ca 1700 EUR)/ha, (ii) depending on the type of land, slope of the forested area and species composition of the afforestation carried out, (iii) additionally, the fence is entitled to a payment of 8.82 (ca 2 EUR) PLN/running meter. Additionally, the farmer is entitled care premium (paid for maintenance and care of crops) in the amount of 794 PLN (ca 183 EUR) /ha/yr to 1628 PLN (ca 370 EUR) ha/yr and possible protection against animals through the use of repellents – in the amount of 424 PLN (ca. 98 EUR) /ha/yr. The last element of support for afforestation of fields by farmers is afforestation premium – is compensation for lost income from agricultural activity – 1215 PLN (ca 280 EUR) /ha/yr.

Support for afforestation shall be granted to the beneficiary for land of at least 0.1 ha up to a maximum of 20 ha. Afforestation may be carried out only on land that is included in the land and building register as arable land or orchards or land with natural succession (Regulation of the MRiRW z dnia 23 maja 2019 r.).

However, at present, another obstacle for such efforts is connected with a lack of land, which may be afforested, while direct payments for agricultural activity contribute to increased attractiveness of agricultural crops in comparison to forest culture, particularly since income from forestry may be obtained only after a longer time period. For this reason, potential permanent elimination of $CO_2$ due to afforestation in Poland, similar to the case in other European countries, is considerably limited. Currently, another obstacle to this type of activity is the lack of areas that may be afforested, while direct payments for agricultural activities contribute to increasing the attractiveness of agricultural crops compared to forestry culture, all the more so that the income from forestry can only be obtained after a longer period of time. For this reason, the potential permanent elimination of $CO_2$ through afforestation in Poland is significantly reduced. In the author's opinion, the permanent afforestation of new soils can significantly contribute to the accumulation of organic carbon. However, this limitation will not be continuous. This is best illustrated by the example presented by Haberla et al. (2012). Imagine a hectare of arable land abandoned and allowing reforestation. These growing plants would absorb carbon from the atmosphere, creating a plant tissue, that is, biomass.

Part of this biomass will be used, and the carbon will be released by animals, fungi or micro-organisms and will return to the atmosphere. Another portion of coal would be stored in vegetation and soil as the forest grows, and the absorption of carbon would compensate for some of the carbon dioxide emissions resulting from the combustion of fossil fuels, and thus stop global warming (Baldocchi 2008; Le Quere et al. 2009; Richter et al. 2011). If, instead, land was used to grow energy crops to be burned in a power plant, emissions from fossil fuels would decrease, but not the emission of coal by the power plant chimneys. For a unit of energy, CO2 emissions would normally be higher than for a fossil-fuel power plant because: (i) biomass contains less energy per unit of carbon than petroleum products or natural gas, and (ii) biomass is usually burned with lower efficiency than fossil fuels (Bird et al. 2011). Although the increase in bioenergy production is absorbed by coal, the use of land for the cultivation of bioenergy plants devotes carbon sequestration to the forest. This persistent sequestration of carbon dioxide, which is not included in current GHG accounting related to bioenergy, can be significant. For example, in western Ukraine, the growth of forests after the abandonment of agricultural land caused a decrease in the coal content by almost a ton of coal per hectare of forest and year (Kuemmerle et al. 2011). We can hypothetically assume that the use of forests is zero. In this situation, atmospheric $CO_2$ will decrease. The level of this reduction will increase in proportion to the growth of trees; however, this trend will not last. After some time, the stand will become old and as a result of degradation processes, part of the coal will be released into the atmosphere. However, this does not change the fact that in this situation, the balance of coal circulation will be beneficial for the climate. For global equilibrium, we must assume that such a forest would reduce the amount of $CO_2$ required for its development until it dies. We cannot assume that a new generation would reduce the equivalent amount of $CO_2$. Just the opposite - we have to assume that this reduction will only be a difference in the amount of C absorbed by the new generation of the forest and released in the process of dead wood degradation from dead trees. However, bearing in mind that trees live for a long time, thanks to afforestation, we will get time to look for new solutions that allow for permanent reduction of $CO_2$.

## The tree stand

Apart from afforestation within the FCF system, measures will be taken in relation to stand breeding, such as: (i) changes in forest tending methods and its advance felling, (ii) changes in cutting age, changes in final cutting methods, (iii) introduction of the underbrush, (iv) stand conversion, (v) introduction of nurse crops. Previous studies have shown that changes in forest management may reduce the warming impact of forest bioenergy on the climate (Cherubini et al. 2011b; Routa et al. 2012; Sathre and Gustavsson 2012). The influence of changes in energy demand on climate has been described in many literature items, for example, Taseska-Gjorgievska (2012) and Dedinec (2016).

Modelling studies indicate that an increase in forest density compared to the current recommendations or intensive fertilisation decrease life cycle $CO_2$ emissions (Alam et al. 2012; Routa et al. 2012) and improve the climate impact (Sathre and Gustavsson 2012). Studies concerning the effect of the relationship of forest site and species protection and climate change have been presented, for example, by Peters 1990, Halpin 1997, Noss 2001, Spittlehouse and Stewart 2003, Drever et al. 2006, Millar et al. 2007. Examples of strategies to increase forest carbon stocks include extending rotation lengths (Cooper 1983; Kaipainen et al. 2004; Liski et al. 2001), changes in initial stand density and thinning strategies (e.g., Niinimäki et al. 2013; Pihlainen et al. 2014) and forest fertilization (Boyland 2006). In Poland, in view of the adopted model of forest management, an extension of an already long rotation period seems unlikely, while forest fertilisation is prohibited, in contrast to other countries; as, for example, in Sweden, it is applied to intensify timber production. Markiewitz (2006) demonstrates that the C storage in wood products due to accelerated growth of trees to a sawn log category might exceed the incurred C emissions 3-fold (i.e., 35 Mg $ha^{-1}$). If the combined C sequestration benefits from soil C accumulation, increased C storage in paper products and storage in sawn timber products would outweigh the fossil fuel C emissions due to increased silvicultural activities.

Nevertheless, it seems that the measures proposed within the FCF system aim first of all at increased organic carbon storage rather than its permanent elimination. We need to ask here if storing anything is equivalent to its elimination or rather only a temporary exclusion of that substance. It would be a rational approach to undertake measures aiming not at carbon storage in the forest, but at the efficient and permanent absorption of carbon from the atmosphere. For this reason the role of forests in the execution of COP21 recommendations should be associated not with carbon storage in forests, but with its absorption. It seems that over a longer period, there is no simple equivalence between increased timber biomass per 1 ha and reduction of $CO_2$ from the atmosphere. While during the tree growth, also that of the trees planted under in the understorey, more $CO_2$ will be absorbed; at the moment of timber harvesting sooner (e.g., energy timber) or later (e.g., wooden houses), the contained C will again be released to the atmosphere. This results from the fact that the C stocks in the ecosystem aim at an equilibrium between the amount of C reaching the biomass and soil and its release, first of all through the degradation of organic matter to $CO_2$ and $H_2O$ (as well as $CH_4$ under anaerobic conditions).

It needs to be stressed that timber is first of all the C stock and its role in the permanent reduction of organic C may not be underestimated. In view of the demand on the timber market or in the case of its discontinued use in the process of tree ageing and death, carbon stored in timber will be released. Moreover, the capacity of forests to absorb $CO_2$ also changes. For example, a more recent study by Wear and Coulston (2015) showed a decline in annual net sequestration in the U.S. by approximately 45% over the next 25 years. This includes some regions (such as the Southeastern U.S.) that transition from the net sink to the source status (Latta et al. 2018). Intensifying biomass removal from forests reduces forest carbon stocks and carbon sink capacity, and thus, may partly offset the climate benefits of forest bioenergy (Haberl et al. 2012; Holtsmark 2012a; Repo et al. 2011, 2012; Schlamadinger et al. 1995; Schulze et al. 2012; Walker et al. 2010; Zanchi et al. 2011). Does it mean that forests may not be realistically used to execute the COP21 guidelines? In the opinion of the author, it is possible to utilise forests in the process of reducing the amounts of $CO_2$ currently found in the atmosphere. In this respect, a considerable role is played not only by trees, which in the production process will be felled and sooner or later will release the accumulated carbon, but first of all by the forest soil. Obviously, timber at the practical application of principles of bioeconomics will also play an important role on condition that at the withdrawal of spent wood-based products, they will be disposed of by permanent storage, for example, in empty former workings in coal mines. Hypothetically, carbon contained in unprocessed wood may also be disposed of, for example, as chips. However, this would require more extensive economic and legal analyses in terms of the value of the raw material itself and changes in the added value of wood in the course of processing operations, and thus, the considerable importance for economies in individual countries. Under the current economic conditions, storage of timber biomass generated from wood recycling is not realistic and storage of timber biomass constituting a raw material for the timber industry is simply impossible. Availability of the raw material is a basic requisite for the development of the timber industry (Adamowicz 2010; Adamowicz and Noga 2014; Adamowicz et al. 2016), while in Poland, the demand for this material is systematically increasing.

An important element to be considered is connected with the adequate management of felling residue. In Poland, felling residue is not utilised on the commercial scale. Forest harvest residues, such as branches, unmerchantable tops and stumps are an important source of bioenergy from the northern temperate and boreal forests, and the use of these residues is expected to grow in future (Díaz-Yáñez et al. 2013; Mantau et al. 2010; Scarlat et al. 2013). Increased harvesting of forest residues decreases carbon input to the carbon pools of dead wood, litter and soil, and consequently results in forest carbon losses (Mäkipää et al. 2014; Schlamadinger et al. 1995; Schulze et al. 2012; Zanchi et al. 2011). The costs of carbon loss compensation varied widely from 5 to 4000 € $ha^{-1}$ between the management options. The lowest costs resulted from harvesting quickly decomposing branches combined with low levels of fertilization (Repo et al. 2015). Bioenergy production immediately releases the carbon stored in the harvested residues into the atmosphere. If left on the forest ground, the decomposition of the residues would still release the carbon, but the process would take years or decades (Repo et al. 2011). Consequently, the use of forest harvest residues to energy decreases forest carbon stocks and increases the atmospheric concentration of $CO_2$ compared to a situation, in which the residues are left to decompose in forests. These emissions that result from a decrease in the forest carbon stocks are similar to those occurring with land-use change (Fargione et al. 2008; Melillo et al. 2009; Searchinger et al. 2008, 2009). In Polish forestry, in view of the current practice not to utilise forest harvest residue and to leave it in the forest, it is impossible in this respect to introduce changes, for example, consisting of a reduction of the share of this biomass in the generation of energy, which may contribute to increased accumulation of $CO_2$.

A dubious direction is also connected with the establishment of an increasing number of unused forest reserves. Interesting results were also presented by Degórski (2005), who reported the effect of the forest utilisation method on the stocks of organic carbon in the soil. The author stated that in the ecosystems with stands aged several hundred years, which for almost 100 years have been covered by legal protection, specific stocks of organic carbon mainly in lessive and rusty soils were by almost 50% lower in comparison to the same soil types, found in forests that were historically being managed commercially.

We need to agree here with Wójcik (2013) that timber harvesting is in itself a crucial aspect. An economic activity having a particularly important effect on the volume of carbon sequestration is connected with timber harvesting technology. Following the felling operation, many inevitable disturbances take place in the ecosystem (Bekele et al. 2007). However, a decrease in SOC stocks occurring after felling is primarily an effect of soil structure destruction as a result of mixing its upper horizons rich in organic matter with layers located deeper (10–30 cm). This leads to increased microbial respiration, which in the case of particularly inappropriate harvesting methods may lead to losses of 20 Mg C per hectare, that is, equivalent to approx. 25% total SOC pool (Zummo and Friedland 2011). If the timber harvesting operation is performed with due diligence, it does not destroy the upper soil layer and if some timber harvesting residue is left on the site, its effect on carbon stocks in soil is negligible (Post 2003; Yanai et al. 2003). An interesting proposal seems to be the change in the principles of forest cultivation, which consists of growing classic tree species together with fast-growing species. In the author's opinion, forest crops can produce much higher yields, economic effects and ecological benefits if, at the same time, fast-drying trees such as poplar, willow and so on are planted alternately with noble species such as spruce, pine, oak or beech. This is expected to make more efficient use of the forest area, and at the same time, increase the $CO_2$ accumulation capacity of the forest. However, this claim requires detailed research in order to confirm it. Unfortunately, as mentioned earlier, the FCF will carry out actions consisting of: underplanting, artificial regeneration conducted Sobański's method (broadcast seeding) and natural renewals. Activities aimed at the use of stands as a $CO_2$ sink are therefore limited to underplanting only.

## Forest soil

In view of the above, it seems that soil may play a markedly greater role in permanent storage rather than only accumulating organic carbon. It needs to be remembered that in terms of various land use systems, it is estimated that the amount of carbon in the soil is 2 to 3-fold greater than that in the aboveground plant mass and it may amount to approx. 1500 Pg (Dixon et al. 1994). Carbon stocks in the ectohumus may range from 1.3 to 70.8 tons of carbon per hectare, while in the surface 20-cm layer of mineral soil, it was from 11.3 to 126.3 tons of carbon per hectare (Baritz et al. 2010). Considerable differences in carbon concentration were observed between farmed and forest soils to the advantage of the latter. In order to fulfil the FCF assumptions, forests may be used, but in such cases, the function of timber production may not or should not be executed or prioritised. Additionally, it may be stated that the model of Polish forestry is based on the commonly accepted concept of forest management, that is, sustainable forest management (SFM). Multifunctional forest management in Poland is implemented based on the principle of a lack of priority functions in individual forest sites. Nevertheless, it seems that in the Regulation (Zarządzenie… 2017) concerning the FCF system, such functions, although not sanctioned, are still present.

The said Regulation specified that the primary characteristics qualifying forests to the FCF management system include: (i) inaccessibility to felling, extraction and hauling of timber, (ii) poor quality timber found in the stands, (iii) absence of woody vegetation and the presence of marshy soils. The FCF management system should be practiced first of all on land suitable for afforestation and currently unforested. This is a rational approach, since afforested areas are characterised by a relatively high SOC. This problem has already been discussed above. In the opinion of the author, soil provides the greatest potential for the implementation of FCF principles. This results from the fact that under optimal conditions, which need to be created within the FCF operations, readily degradable substances are completely mineralised, while the others, as a result of humification consisting in a series of complicated reactions of hydrolysis, oxidation, enzymatic synthesis and polymerisation, are converted to dark-coloured, cyclic colloid compounds, referred to as humus substances. Although researches have been investigating soil organic matter since the second half of the 18th century, the mechanism of humification have not been fully clarified to date. It is known that the resulting humus substances are sparsely degradable, and as such, they bind carbon in the most stable manner. This refers particularly to that portion of humus, which binds to the mineral fraction of soil, especially silt minerals (Richardson and Edmonds 1987; Theng et al. 1989).

We need to stress here the importance of biomass pyrolysis and the application of thus produced charcoal (biochar) in soil fertilisation. The application of charcoal in the reclamation of soils deficient in organic matter is not a new concept. Already in 1541, a Spanish conquistador Francis de Orellana discovered large cities in the Amazon Basin. Those cities were supplied with food from areas of fertile, dark coloured soil, distributed in patches among shallow, infertile rainforest soils, and called 'terra preta' (black soil) in Portuguese. Present-day analyses have shown that terra preta is a manmade (anthropogenic) soil. To produce it, the pre-Columbian farmers used animal waste, plant origin waste, animal bones and first of all charcoal. Thanks to the exceptional stability of contained charcoal, anthropogenic soils have recently become the object of intensive studies, resulting in the concept for fertilisation of contemporary soils using pyrolyzed biomass. Research results in this respect are highly promising: charcoal may be produced both on a single farm and on the commercial scale. By-products of pyrolysis include heat as well as synthetic gas and oil, which may be used in the energy sector replacing fossil fuels (Woolf et al., 2010). An additional advantage is connected with the reduction of SOC oxidation and soil enrichment progressing for centuries. It is estimated that if 10% global net primary production were pyrolyzed, for millennia 4.8 Gt C/year would be bound in the produced charcoal, that is, approx. 20% more than the current annual increment in atmospheric $CO_2$ level, at the same time, enhancing soil fertility for several centuries (Matovic 2011), which would additionally affect timber growth rate.

The second basic category of land used for FCF management comprises marshes, including peatlands in forest areas. When using these areas for those purposes, a pre-requisite was imposed that the FCF principles have to be implemented without compromising the biological diversity of these areas. This approach needs to be considered justified, since appropriate management of peatlands is essential for the carbon cycle. A significant role is played here by the peatland flora. In this respect, we need to stress that it is crucial to apply the results of research (Goud et al. 2017) showing that the plant traits that best predict carbon (C) storage are increasingly important, as global change drivers will affect plant species composition and ecosystem C cycling. The above-mentioned research shows that the predictions of peatland carbon fluxes showed a positive relationship with leaf area and leaf persistence, and a negative relationship with the proportion of woody species. This is confirmed by a study by Bubier et al. (1998), indicating that plant communities in poor to intermediate fens had higher maximum $CO_2$ fixation rates than the deciduous shrub-dominated (*Salix* spp. and *Betula* spp.) rich fens. Additionally, water relations in those soils are of paramount importance. Carbon enters peatlands in groundwater, precipitation and primary productivity. Carbon leaves peatlands by groundwater and surface water outflow and by the outgassing of methane. Results of simulations of the carbon budget show that the peatland is now probably a sink for carbon, a finding supported by field data showing that peat is, in fact, accumulating at the rate of about 1 mm/yr (Rivers et al. 1998).

As it results from a study by Goodrich et al. (2017), dry conditions lead to significant reductions in the annual carbon storage, which results nearly equally from enhanced ecosystem respiration due to the lowered water tables and increased temperatures, and from reduced gross primary production due to vapor pressure deficit-related stresses to the vegetation (Goodrich et al. 2017). This shows that appropriate management of these areas within forest farms is of importance for the implementation of the COP21 guidelines. Potential directions of changes in peatland management and their consequences for the accumulation of $CO_2$ were presented, for example, by Young et al. (2017), who simulated the long-term impacts of drainage and restoration on the ecohydrology of peatlands.

Soil is the largest carbon (C) pool, containing approximately 2400 Pg C in the upper 2-m layer (Batjes 1996). Soil-surface carbon dioxide ($CO_2$) efflux is one of the largest C fluxes (Schimel 1995) that yields a net loss of C to the atmosphere, mainly through soil respiration and a combination of root and heterotrophic respiration (Hanson et al. 2000). This loss might increase with raising temperatures through the stimulation of biological activity in the soil (Gaumont-Guay et al. 2006), while $CO_2$ emissions might form part of a positive feedback by contributing to climate warming. Soil temperature and moisture are major abiotic factors controlling soil respiration through their effects on soil biological activity and the decomposition of soil organic matter (Gaumont-Guay et al. 2006; Koncz et al. 2015).

A chance for FCF is provided by management operations aiming at improving water relations. We need to recreate forest water bodies and watercourses, and first of all, strive to preserve the existing marshes and peatland. Organic carbon stocks in soils of lowland moist and marshy habitats exceed C stocks in soils of fresh sites by 24–80% and as much as 675–1220%, respectively (Wójcik 2013). In Poland, natural and drained wetlands cover approx. 4.4 million ha, accounting for approx. 14.2% area of the country. These wetlands also include over 50 thousand peatlands (both natural and drained) of min. 1 ha in area, jointly covering approx. 1.3 million ha, which accounts for almost 30% wetland area and 4% area of the country, of which only 18.5 thousand ha are protected as nature reserves, including 111 thousand in forest areas (GUS 2017). The number of smaller peatlands, many found, for example, in lake districts, is unknown. In view of the above, it needs to be stated that this is the area, where changes may be introduced in the economic management of forest areas following the FCF principles in order to activate peatlands for permanent carbon capture from the atmosphere.

## Yards storing fuel wood

Within the framework of the FCF project, it is planned to organise multifunction yards, for example, to capture organic carbon by accumulating and long-term storage of fuel wood. This action has not been taken and it seems that it will not be taken in the future. In the opinion of the author, the storage of timber in yards may never contribute to the reduction of atmospheric $CO_2$ levels. In this respect, we need to agree with Repo et al. (2015) that in order to mitigate climate change efficiently with forests, it is crucial to understand both the temporal dynamics of emissions and carbon sequestration, and those of atmospheric concentrations of GHGs. Previous studies have paved the way for this understanding, but have mainly focused either on forest carbon balances (Schlamadinger et al. 1995; Palosuo et al. 2001; Melin et al. 2010), or the radiative forcing resulting from the timing of the emissions (Zetterberg et al. 2004; Cherubini et al. 2011a; Guest et al. 2012). Lumber yards are to be used primarily to store timber, which will ultimately be used for energy generation purposes. This might have been the rationale for the policy-makers to consider them as a possibility to reduce $CO_2$.

Haberl et al. (2012) claimed that it is critical to correctly address the carbon implications of bioenergy, as a variety of studies and policies contemplate the use of very large quantities of biomass in the belief that bioenergy is almost a GHG-neutral replacement for fossil fuels. Many projections imply at least doubling the total human harvest of world plant material. For example, the International Energy Agency has predicted that bioenergy could supply over 20% of the world's primary energy by 2050 (IEA 2008). A report by the Secretariat of the UNFCCC has claimed that bioenergy can supply 800 EJ/yr (UNFCC 2008), which is far more than the total world energy used today. The IPCC Special Report on Renewable Energy (SRREN) suggests that the global bioenergy potential could be as high as 500 EJ/yr (Chum et al. 2012), comparable to the current fossil energy use. In contrast, the total global biomass harvested for food, feed, fibre, wood products and traditional wood use for cooking and heating amounts to approximately 12 billion tonnes of dry matter of plant material per year (Krausmann et al. 2008) with a chemical energy value of 230 EJ.

An increase of this magnitude in the use of bioenergy could create substantial adverse impacts on natural ecosystems, compete with food production and undermine other goals to reduce the present impacts of agricultural production on the environment and improve the welfare of farm animals (Haberl et al. 2011; Lambin and Meyfroidt 2011; Smith et al. 2010).

Forest biomass has been considered a carbon neutral energy source on the assumption that $CO_2$ emissions from biomass combustion are offset by the growth of the next tree generation (Stupak et al. 2007; EC 2009). This assumption has been questioned, first because there is a delay between biomass combustion and tree growth, and second because the intensifying forest biomass removal reduces the carbon stocks or the carbon sink capacity of forests (Schlamadinger et al. 1995; Holtsmark 2012b; Repo et al. 2011; Zanchi et al. 2011; Haberl et al. 2012; Schulze et al. 2012; Timmons et al. 2016). In the past, all biomass energy was considered to be carbon neutral as long as it was based on sustainable yields: while burning biomass releases carbon, but assuming land use and productivity do not change, plants later reabsorb this carbon in new growth. In the case of short-rotation biomass crops such as switchgrass, this reabsorption of the emitted carbon dioxide can take place in less than a year. However, for woody biomass carbon dioxide released in combustion may not be completely reabsorbed by new tree growth for decades or even centuries (depending on the region and forest type) (Timmons et al. 2016). Many studies have now demonstrated that this time interval between carbon release and reabsorption can be a source of temporary greenhouse gas increases, and thus, that biomass is not necessarily carbon neutral or may only be carbon neutral over longer timeframes (Marland and Schlamadinger 1997; Pearson and Palmer 2000; Zachos et al. 2008; Johnson 2009; Cherubini et al. 2011b; Hudiburg et al. 2011; McKechnie et al. 2011; Holtsmark 2012a; Schulze et al. 2012; Lamers and Junginger 2013; Mika and Keeton 2015). The state of Massachusetts, USA, commissioned the Manomet Center for Conservation Sciences to conduct a study on forest biomass energy carbon dynamics (Walker et al. 2010, 2013). The Manomet report quantified carbon emissions from forest biomass energy used in different applications and estimated carbon reabsorption times for the Massachusetts forests. For most uses of biomass energy, more carbon is released initially than when using fossil fuels to produce the same quantity of energy, so an initial 'carbon debt' is incurred (Fargione et al. 2008). Growing forests gradually reabsorb or pay back this carbon debt. The number of years until forests absorb more carbon than would have been released by fossil fuel use is called the 'carbon payback'. After payback, continued forest carbon sequestration generates a 'carbon dividend' (Walker et al. 2010). Depending on the energy application, reference fossil fuel and the assumed forest management strategy, forest biomass carbon payback periods can range from less than a decade to many decades. In view of the above, it needs to be stated here that biomass may play a role in the reduction of atmospheric $CO_2$; however, its role may not be overestimated in this respect. Moreover, substitutivity of biomass is of critical importance. We may stress a positive effect of biomass on the level of $CO_2$ only when it replaces fossil fuels and not other green energy sources.

In Poland, the storage and use of energy wood as an element of $CO_2$ accumulation was initially adopted. At present, however, there are no activities carried out in this respect. It seems that this concept will not be implemented in the future either.

## Legal and economic conditions

The FCF pilot project will be conducted until the end of 2026 in several dozen forest districts in Poland (Fig. 1). The Polish concept for the utilisation of natural resources to increase $CO_2$ absorption is based primarily on two measures. Firstly, actions will be taken to store additional amounts of organic carbon in geographically specified parts of forests. Secondly, $CO_2$ will be stored in timber kept in energy timber yards. The forecasted amounts of additionally absorbed carbon within the FCF system in the period of the forecast will be estimated using appropriate tools, mainly the Carbon Budget Model (CBM). By using this model, it is possible to analyse the changes in the amount of accumulated carbon in all forest layers, including the often neglected layers of undergrowth, understorey, litter or soil. The CBM program was created in Canada and it serves to estimate changes of the amount of carbon in the forest ecosystem. It is obvious that the coal balance model created for forests located so far from Poland requires adjustment to the conditions prevailing in Polish forests. In order to adapt CBM to Polish's conditions, the variables in the existing model are replaced with local parameters, which reflect the characteristics of forests growing in Poland. Research is currently being carried out for this purpose.

According to the information obtained from the directorate of State Forests in Poland in 2018, the estimation of the anticipated effect of the project for the next 30 years was conducted. According to the preliminary results, the forests within the FCF will additionally absorb about 1 million tonnes of $CO_2$. The estimation was made with the aid of the Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3).

Implementation of changes in forest management has to be consistent with the assumed paradigm of forestry and the forestry policy adopted in a given country. This problem has been indicated, for example, by Lindahl et al. (2017) who stressed that the forest policy formulation closes down the range of alternative outputs, a shortcoming that hampers its capacity to respond to the current sustainability challenges. Consequently, there is a need for an extensive public debate regarding not only the role of forests in the future society, but also the operationalisation of sustainable development.

In Poland, according to Central Statistical Office information, harvesting timber has been systematically increasing from less than 30 million $m^3$ timber in the early 2000's to over 40 million $m^3$ timber at present. The European Commission proposed new principles for offsetting the EU accounts related with forests using the 'forest reference levels' based on the practices and intensity of management in the past (1990–2009). The ENVI Committee decided to continue this approach, voting for the compromise in order to compare the intensity of forest management in the years 2020–2030 in relation to 2000–2012. This solution may be a problem for Finland, Sweden and Poland, as in these countries, in the nearest future, timber harvesting will increase, which results from the growing timber volume in forests of those countries. It can be expected that the implementation of the FCF concept will avoid a situation in which forest management will contribute to more emissions than $CO_2$ accumulation. This is due to the fact that additional measures (underlining, artificial regeneration conducted by Sobański's method and natural renewals) can contribute to increasing $CO_2$ accumulation. We also need to consider a situation when forest farms, through increased timber harvesting, as a result become $CO_2$ emitters. Thus, actions taken by the administrator of the Polish forests within the FCF system aiming at reducing $CO_2$ need to be considered justified.

Proposals for regulations, addressed by the environmental commission, also stipulate that products from felled trees, such as construction materials or furniture, will also be considered as removing $CO_2$, as they isolate this gas absorbed during tree growth. Such regulations aim at encouraging the EU member states to use wooden products and $CO_2$ absorption by dead trees. In view of the presented examples, it seems that the actual effect on climate in the longer timeframe, this action may have a positive effect, but it is necessary to apply the principles of bioeconomics.

In Poland, the implementation of the FCF concept will require adaptation of national legislative solutions related with forest management. At present, the polish Act on forests (Dz. U. 1991 No. 101 item 444 Act of 28 September 1991 on forests) indicates five objectives for forest management, that is, preservation of forests, their protection, protection of the beneficial effect of forests on water and soil, and timber production. The effect of forests on climate or air has not been mentioned. There is no legal framework for the functioning of the financial and legal system related with the trade of $CO_2$ units by forest districts implementing the FCF project. In view of the national character of these changes in the opinion of the author, the implementation of the FCF concept will be fully possible after the adaptation of the Act on forests and introduction of immediate corrections to Forest Management Plans.

In view of the examples of literature on the subject, it needs to be stated that the utilisation of wood or the use of old wooden products as biomass for energy purposes will be beneficial for the atmosphere only when the biomass will replace fossil fuels. Another problem may be connected with the discrepancy between the protection of air and the protection of climate (Adamowicz, 2018). What is important, according to Sala (2017), in the case of practical biomass burning, the $CO_2$ balance is much less favourable than the theoretical calculation, due to emissions during production (e.g., pelleting) and biomass transport. According to a research by Princeton University, the use of biomass for energy purposes will only balance $CO_2$ emissions to zero after about 100 years.

It is costly, particularly in countries such as Poland, in which industry, especially energy and heat generation, is dependent on fossil fuels. For this reason, adequate economic instruments introduced to the EU policy are required. Trade in $CO_2$ emissions may be considered such an instrument. This is the case in the countries, which signed and ratified the Kyoto Protocol. It stipulates that specially appointed institutions allocate allowances to emit $CO_2$ to production plants. The unit of emission is 1 EUA (European Union Allowance) authorising the emission of 1 ton $CO_2$. At present, in the EU, the following are in circulation: Assigned Amount Units (AAU), Removal Units (RMU), Emission Reduction Units (ERU) and Certified Reduction Units (CER), including Temporary CER (tCER) and long-term CER (lCER). The plants that do not fully utilise their allocated allowances (e.g., thanks to plant modernisation) may sell it to those plants, which have already used their allowances. In the EU countries, plants and enterprises with the capacities exceeding 20 MW as well as some other production plants have been obliged to participate in the emission trade. In the entire European Union, there are approx. 12,000 such enterprises. The number of allowances has been decreasing from year to year; thus, their market value is increasing, which provides incentives for the producers to modernise their factories. It needs to be remembered that the Kyoto Protocol allows for the mechanism, on the basis of which enterprises are obliged to reduce emissions – not necessarily in their own plants. They may participate in projects, which are implemented, registered and monitored by the UNFCCC environmental protection bureau in developing countries. Investors participating in those projects issue special certificates, the so-called Certified Emission Reductions (CER). Enterprises may return to the state a specific portion of exchanged or purchased certificates (e.g., in Germany, it is 22%, in Poland 10% share of allowances allocated to the 2nd accounting period), as emission reductions (CERs), and in this way, fulfil the legally imposed obligation. Certificates may also be remitted, for example, ERU from Joint-Implementation (JI) projects. They are projects concerning energy efficiency in countries of Eastern Europe. The FCF concept assumes that the product, which may be subject to legal turnover, that is, the carbon dioxide unit (CDU), will be the difference between the amount of deposited organic carbon in the situation when additional actions are undertaken, and in the case when they are not implemented. CDU is the amount of organic carbon corresponding to 1 tonne of $CO_2$, which – as a consequence of additional activities – will be accumulated in tree stands and in soil. The entire income from the sale of CDUs will be designated by the State Forests for new undertakings indicated by the buyers. These are activities related to the protection of nature and biodiversity, forest and historical education, tourism, for example, construction or modernisation of bicycle trails, rest areas, parking spaces.

It needs to be decided whether the said units (CDU) would be an elements of trade within the EUA system. Assuming the principles for the introduction of additional allowances, resulting from forestry operations consisting of the increase in storage and not the elimination of $CO_2$ following the principle of supply and demand, it may be expected that the price for the allowances, together with the increase in supply will be decreasing. As a consequence, this will cause changes in the relationship between the cost of utilisation of new energy-efficient and low emission technologies and costs of traditional technologies emitting large amounts of $CO_2$ supplemented with the costs of purchase of allowances for their emissions. Unfortunately, profitability of the former is lower than that of the latter and the primary economic factor providing equality of the compared technologies is connected with the supervision system and potential financial consequences for excessive use of the environment. In the opinion of the author, low emission technologies with no additional burdens imposed as limitations on $CO_2$ emissions are less profitable in terms of unit economic benefits for the enterprise in relation to high emission technologies. Otherwise, economic principles would replace high emission technologies with low emission technologies, as it is the case when high cost technologies are replaced with low cost technologies. Summing up, it should be stated that when accepting the introduction of market turnover for the so-called CDU units, their volume should be correlated with the global information on the increase or decrease in $CO_2$ emissions in a given country. This will prevent a situation when, as a result of additional $CO_2$ allowances placed on the market following the principles of economics, it would reduce the utilisation of energy generated by zero-emission sources, leading to a greater use of energy derived from fossil fuels. This also concerns biomass used as a renewable source for the generation of energy. The significant role of biomass in the reduction of atmospheric $CO_2$ levels will be observed when biomass replaces fossil fuels rather than, for example, solar energy. At present, the FCF project assumes that companies purchasing the so-called CDU units may present themselves as being environmentally friendly and involved in pro-ecological activities. In this way, companies may work on their corporate image. It seems, therefore, that trade in CDU units will primarily have a character related to shaping the company's image and may involve environmental responsibility. In this case, these activities should be considered appropriate and beneficial. However, obviously specific actions concerning the role of forests in the reduction of $CO_2$ emissions have to be outlined in detail. It results from the information provided by the State Forests National Forest Holding (PGL LP), which in Poland implements the FCF assumptions in practice that this organisation undertakes efforts aiming at the future introduction of CDU units on the emission unit market. This market is currently being transformed, particularly in terms of LULUCF and potential offsetting schemes. Gaj (2012) estimates that in Poland, forests absorb annually approx. 80 million tons of $CO_2$, which corresponds to over 1.3 billion Euro in terms of emission allowances. According to that author, introduction of the CDU units in trade will provide new opportunities for the Polish economy. Even disregarding the methodological assumptions for the presented calculations, it seems that from the point of view of climate protection, it is more advantageous to leave the CDU units in the area of corporate image.

## Conclusions

Based on the literature review and own observations, it was found that well-managed forest management can support activities aimed at reducing $CO_2$ in the atmosphere. The paper analyses the role of forestation of the tree stand, forest soil and yards storing fuel wood (wood storage). I agree with the statements of Minasny et al. (2017) and White et al. (2018) that 'only radical land use change coupled with enhanced C sequestration technology has the potential to mitigate climate change'. On the basis of the collected materials, it was found that the most important role in this process can be forest soil. As presented in this article, forest management can be carried out in a way that limits the release of $CO_2$ from the soil. An important issue is also to support the processes of humification, because in this process, coal can be eliminated from the atmosphere. Regulation of water conditions in soil is another very important element of additional activities that can be undertaken in forestry as part of increasing the $CO_2$ storage capacity. In Poland, activities in this field are limited solely to forest renewals using the Sobański method. In the author's opinion, the attempts to combine seed sowing in the autumn with artificial planting of pine saplings in spring should be positively evaluated. Based on the review of opinions of various authors in this article, it is known that the possibilities of utilizing forest soil in the $CO_2$ accumulation process are different. Therefore, in the future, within the FCF, activities in this area should be expanded. In the opinion of the author, it may be particularly important to implement small retention to forest areas. The article proves, based on a review of many scientific articles, that the regulation of water relations is of great importance in the process of $CO_2$ accumulation.

The article showed that afforestation of new lands could be of great importance in the process of taking additional measures in forest management aimed at withdrawing $CO_2$ from the atmosphere. In Poland, however, there is a problem related to the lack of new areas for afforestation by PGL LP. It seems that a good solution would be to promote afforestation in the private sector. However, this action would require better financial support from the state. In the author's opinion, the current financial support program addressed to farmers under the rural development program is insufficient. It is not related to the amount of finances envisaged for the establishment and care of the forest, but with too short a period financed by forestry activities on agricultural land.

In the author's opinion, activities related to the change in the rules of tree stand breeding are of limited importance. Forests in Poland have been carried out for years on the basis of the complexity of the vertical structure of forest stands (several forest stratum). According to the author, the concept of increasing the amount of wood from dead trees is not a breakthrough idea. Wood from dead trees left in the forest sooner or later in the decomposition process releases organic carbon into the atmosphere. We should remember that soil respiration is also strongly associated with the biomass of plants, affecting the translocation of photosynthesis during rhizospheric respiration (Ding et al. 2010; Koncz et al. 2015).

The composition of thermal coal is a concept that appears in the Order No. 2 of 2017 Director General of State Forests stated that the subject of FCF is to be, among others, keeping organic carbon in wood raw material accumulated in energetic coal storage. The author criticizes the idea of storing firewood. The mere keeping of the raw material for a year or two will not have a significant impact on the $CO_2$ cycle. The use of wood as energy biomass seems to be a more important element. We may stress a positive effect of biomass on the level of $CO_2$ only when it replaces fossil fuels and not other green energy sources. The author states that the concept of building special timber depots is unlikely to be implemented. In the author's opinion, the significance of this measure for the reduction of $CO_2$ from the atmosphere would be small. It seems that the proper course of action would be storage of wood waste underground, for example, in old coal mines. However, this opinion requires a deep ecological and economic analysis.

In Poland, an attempt was made to commercialize the effects of $CO_2$ accumulation through forests. The first CDU auction was carried out in 2018 on the auction platform www.e-klimat.lasy.gov.pl. Out of over a dozen companies that have signed letters of intent regarding cooperation with State Forests under FCF, the most units – 10,000 – they bought ex aequo of the following companies: KGHM - Polska Miedź and Jastrzębska Spółka Węglowa. About 2 thousand less JDW bought Budimex, 4.3 thousand units were purchased by Grupa Lotos and 2 thousand company Energa S.A. According to the author, CDU trade should be treated as an element of ecological business responsibility. It looks like it is happening. It looks like it is happening. Companies that purchased at the CDU auction received certificates of 'Partner for climate', and what is important, PGL LP declared that the revenues from the auction will be entirely allocated for the purposes indicated by individual buyers. The buyer may finance, through the purchase of CDU, activities related to the protection of selected species, enriching biodiversity, forestry or tourism in the forests. In conclusion, it should be stated that Polish attempts to counteract climate change through changes in forest management should be positively assessed. Based on a subjective review of the literature, the author believes that this is just the beginning of the implementation of various concepts related to forest management. Certainly, these concepts require a broad scientific discussion on this topic in the international scientific community. The author hopes that this article will be a valuable voice and a contribution to further discussion in this matter.

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