The Role of Peatlands and Their Carbon Storage Function in the Context of Climate Change

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Abstract Peatlands are unique habitats that are covering around 3% of the land area and they are characterized by high sensitivity to climate. These very complex ecosystems impact both water and carbon cycle at local as well as global scale. Peatlands are also valuable ecosystems due to their mitigating features in terms of floods or soil erosion and they can store and filtrate water in the landscape as well. As a result of high moisture they can also gather a big amount of carbon and this ability makes peatlands climate coolers. On the other hand a stored carbon can be released into the atmosphere due to peat moisture decrease and it accelerate the global warming processes. Beside climate changes, peatlands are under pressure that is caused by human activities like land use changes or fires. Peatlands protection and restoration can both mitigate climate changes and water balance disturbances. A review of peatlands status and feature in the context of climate changes and human-induced disturbances are presented in this paper.

Keywords Peatlands protection and restoration · Carbon storage
Climate change

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1 Introduction

Water is the basic component of many processes on the Earth and its permanent presence in the landscape causes the emerging of many unique and valuable habitats such as peatlands. They are very sensitive ecosystems that arise due to organic matter accumulation and high water table (Kulczyński 1949; Whiting and Chanton 2001; Keddy 2002; Erwin 2009; Rydin and Jeglum 2013). The main factor is inundation, which stimulates peat forming (mainly by anaerobic processes).

Globally, peatland habitats are rare (Gorham 1991; Keddy 2002) since they cover approximately 3% of the land area on the Earth (Clymo et al. 1998; Blodau 2002; Rydin and Jeglum 2013) and store one-third of global soil carbon (Gorham 1991; Lappalainen 1996; Page et al. 2011; Rydin and Jeglum 2013). Most peatlands are located in the northern hemisphere (around 80% in the boreal and subarctic zones), 10% can be found in the tropics and Southeast Asia and another 10% are located in the temperate zone (Yu et al. 2010, Frolking et al. 2011, Tobolski 2012). Figure 1 shows peatlands distribution on the Earth (Main Report 2007).

The classification of peatlands can be very complex, yet the simplest one consists of four types of peatlands (Keddy 2002):

- Swamp—dominated by trees with roots in hydric soils (not in peat), like tropical mangrove swamps.
- Marsh—dominated by herbaceous plants emerging through the water and rooted in hydric soils (not in peat), like reed beds around the Baltic Sea.
- Bog—dominated by *Sphagnum* moss, shrubs, sedges or evergreen trees with roots in deep peat, like floating bogs covering shores of lakes in temperate and boreal regions.
- Fen—dominated by sedges and grasses rooted in the peat and considerable water movement through the peat is noticed, like the extensive peatlands in northern Canada.

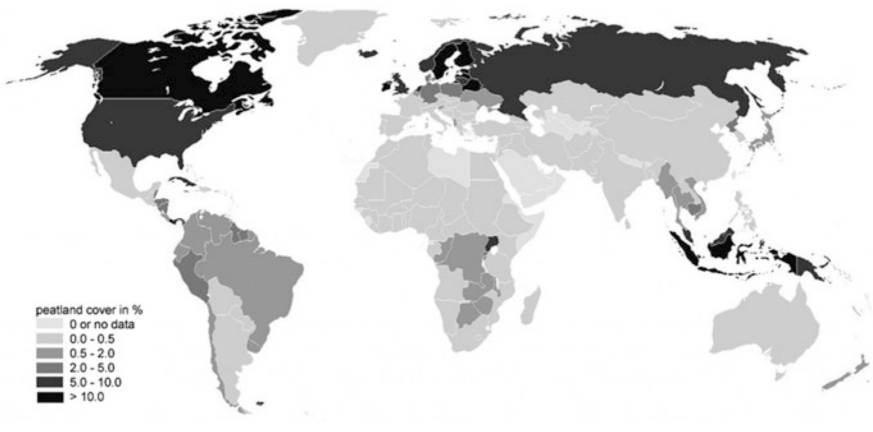

Fig. 1 Percentage peatlands distribution per country (Main Report 2007)

Peatland's ecological functions can have direct and/or indirect effects. The first group of functions is related to water, including: storage, filtration and supply. They also mitigate floods and prevent erosion. They stabilize the macroclimate and play an ecological function. Due to their ability to retain water, peatlands often prevent drought (Tobolski 2012). Indirect functions include nutrient retention, carbon storage, and sediment retention. Peatlands provide water to other ecosystems and they are rich in biological diversity (genetic reservoirs of many organisms). Their unique features create habitats suitable for many endemic and/or endangered species of plants and animals and they can form ecological corridors enabling migration (Mäkilä and Saarnisto 2008). Peatlands can be considered as sources of humus in the landscape (Keddy 2002; Mäkilä and Saarnisto 2008). Peatlands can be also considered as an archive of past climates due to their sensitivity to weather and capability of long term conservation of produced biomass (Clymo et al. 1998). The carbon accumulation process in the peat appears when the rate of organic matter decomposition is lower than the amount of primary production of the ecosystem. In their natural state, peatlands are usually carbon sinks (Turunen et al. 2002; Mäkilä and Saarnisto 2008) and this feature makes these ecosystems very important elements of the environment in the context of climate change, since the absorbed CO_2 is one of the major greenhouse gases. Furthemore, peatlands possess unexplored diversity of protists playing important role in this ecosystem (Marcisz et al. 2014; Geisen et al. 2017; Mulot et al. 2017) They contribute to carbon fixing, however this issue still needs scientific investigation (Jassey et al. 2015, 2016).

Analyses of modern and palaeoenvironmental data identify peatlands as an element of nature that is predicted to affect future climate. Therefore, further research, protection and restoration of these vulnerable ecosystems should be a priority in the context of global warming (Dise 2010; De Jong et al. 2010; Lamentowicz et al. 2016). The maintenance of those peatlands' functions requires the appropriate management and conservation. This paper contains the overview of peatland's function in the context of future environmental changes and the interactions between the climate and these valuable ecosystems.

2 Carbon Dynamics in Peatlands

Despite the fact that peatlands cover relatively small area of the land, their role in the global carbon cycle is not insignificant (Frolking et al. 1998; Moore et al. 1998; Yu et al. 2011; Charman et al. 2013; Loisel et al. 2014). There are several processes in the peatlands where carbon is involved, such as CO_2 the exchange with the atmosphere, the emission of CH_4, the production and export of dissolved organic carbon (DOC) and others (Moore et al. 1998). Furthermore, peatlands are very important stores of temporarily sequestered carbon (Clymo et al. 1998; Ilnicki and Iwaniszyniec 2002; Rydin and Jeglum 2013).

The carbon balance of peatlands is basically determined by two processes, photosynthesis and respiration. There are several factors that determine the process of photosynthesis including solar radiation, CO_2, water, air temperature and nutrients (Maćkowiak and Michalak 2008). The carbon compounds enter into peatland biomass through this process. Further transformation of this biomass is deeply dependent on hydrology. High humidity of the soil leads to anoxic conditions that slow down the decomposition processes of organic matter. The peat is formed as a result of those processes - production (photosynthesis) and decomposition (respiration) and a clear, negative correlation between those opposite processes is observed (Clymo 1984; Mäkilä and Saarnisto 2008). Decomposition is the second controlling factor of carbon accumulation. This makes the peatlands more sensitive to climatic changes than to plant composition changes (Ise et al. 2008). In general, it was found that the lowest carbon accumulation was observed at the sites with the lowest water table e.g. forested and sparsely forested mires while the highest sequestration rate was observed in young *Sphagnum* peatland in coastal regions. These costal peatlands are good examples of high carbon accumulation rate since the *Sphagnum* production is mainly controlled by the moisture that is transported from the sea (Mäkilä and Saarnisto 2008). Under the present climate conditions, differences between the carbon accumulation ability of different types of peatlands are noticeable. The boreal raised peatlands are currently a carbon sink (Turunen et al. 2002), whereas the northern circumpolar wet aapa-mires are source of greenhouse gases and their carbon accumulation rate is lower than most southern raised bogs (Mäkilä and Saarnisto 2008).

In addition, part of pristine areas, mainly tropical and permafrost, may no longer accumulate the peat because of recent climate changes (Main Report 2007).

Peatlands are second only to oceans natural stock of carbon and they can contain twice as much carbon than the entire world's biomass (Rydin and Jeglum 2013). This is the effect of high carbon concentration in the peat (approx. 50%). Peatland ecosystems are characterized by low productivity but long-term storage. However, the length of the storage time depends on the wetness of the substrate (Strack 2008).

In general, the absorption of CO_2 from the atmosphere over 12,000 years allowed for the large quantity storage of carbon in the peat (Yu et al. 2010). The global estimation of the peatland's carbon storage is problematic mainly due to the difficulties of precisely defining the area of peatlands and the assessment of the thickness of peat layer. Recently, large areas of peatlands were also discovered inter alia in Peruvian Pastaza-Marañón (Draper et al. 2014) and the Congo Basin (Dargie et al. 2017). These findings determined the increase of the estimation of tropical peatland carbon stock by 36%, to 104.7 GtC (Dargie et al. 2017). Currently the global amount of carbon that is stored in the peat is estimated to exceed 600 GtC and the sizes of northern, southern and tropical stocks are approximately 550 GtC, 15 GtC and 100 GtC, respectively (Yu et al. 2010; Köchy et al. 2015; Abrams 2016; Kleinen et al. 2016).

The amount of this resource is inter alia the result of ice ages when the peatlands' role in the global carbon cycle was clearly noticeable. The CO_2 concentration in the atmosphere during this period dropped by approx. 100 ppm and one of the explanations of this fact was high water saturation of the high-latitude soils that slowed down the rate of organic matter decomposition (Zech et al. 2011). This factor has the biggest importance in the carbon accumulation process in the soil.

When the climate was getting warmer (after the glacial period), the permafrost started to disappear and the result of this process was the emission of trapped soil carbon both in gas (CO_2 and CH_4) and dissolved in water (DOC-dissolved organic carbon and POC-particulate organic carbon) forms (Limpens et al. 2008; Billett et al. 2010). Simultaneously, higher concentrations of CO_2 in the atmosphere and higher air temperature during summer improved the effectiveness of the photosynthetic process that induced a rapid growth of vegetation. The high latitude areas that were released from the ice cover became a suitable environment for new peatlands to form. Due to continuous spatial expanding of peatlands during the early Holocene period years ago, a noticeable drop in CO_2 concentration was found (Zech et al. 2011). The linkage between thawing permafrost and expanding forest was also found. When the ice was melting down and peatlands of Arctic North America and Eurasia were releasing the greenhouse gases, the expansion of forests northward into tundra compensated for this emission (Mäkilä and Saarnisto 2008).

It was also found that local environmental factors and natural succession of peatlands may attenuate the regional relationships between climatic factors and observed stratigraphical and hydrological changes of peatlands in Finland (Mäkilä and Saarnisto 2008).

3 Hydrology

The minimum ambient temperature provides the conditions for peatland growth if the proper amount of water is available (Yu et al. 2009). Therefore, water, in the context of peatlands, is considered a first-order factor determining their occurrence, growth and development (Keddy 2002). The water balance of peatland basically consists of precipitation, evapotranspiration, runoff and retention and the climate solely regulates all presented elements (Charman and Mäkilä 2003; Mäkilä and Saarnisto 2008). In the temperate climate conditions, water is the most important ecological factor that determines two types of peatlands: rheotrophic mires (fens) that are fed directly by both rain- and ground-water flow, and ombrotrophic mires (raised bogs) that rely on water input only in the form of rainfall (Moore et al. 1998; Tobolski 2012). In the case of ombrotrophic raised bogs it is impossible to detect the impact of surface runoff and groundwater so the only reasonable components of the water balance are precipitation and evapotranspiration (Charman and Mäkilä 2003).

Peat growth is related to the amount of precipitation and temperature, thus the changes in the hydrology can be studied by analyzing the changes of the peat accumulation rate in the peat profile (Yu et al. 2009). Paleoecological studies show that more peat was accumulated during wet periods in Holocene and it had an effect of the higher growth of existing peatlands as well as their proliferation in the landscape (Yu et al. 2003). Conversely, during the Holocene's dry periods the rate of carbon accumulation dropped to about half of the present level. These changes caused by the precipitation reduction were found at both the northern and tropical peatlands (Strack 2008). These findings make the peatlands very large natural carbon stock highly vulnerable and susceptible to any changes of hydrological cycles (Erwin 2009; Belyea and Malmer 2004; Clymo et al. 1998; Dise et al. 2011).

The complexity of peatland's functions and its high vulnerability to many factors impede the detailed assessment of the future dynamics of these ecosystems. Nowadays, palaeoecological and observational studies strongly suggest that peatlands will be affected mainly by climate change and human determined disturbances (Turetsky et al. 2002; Mauquoy and Yeloff 2007; Yu 2007; Lamentowicz et al. 2008).

4 Climate Change

Climate change can be considered as both natural (Erwin 2009) and anthropogenic (IPCC 2013) and it has been associated with a range of weather-related disasters, including droughts, windstorms, ice storms and wildfires (Canadian University of Waterloo report). Moreover, some climate changes will certainly have impact on peatlands' hydrology but other changes may cause an increase in local and regional temperature, alter evapotranspiration, biogeochemistry, amounts of suspended sediment loadings, fire, oxidation of organic sediments and the physical effects of wave energy (Erwin 2009; Burkett and Kusler 2002). Global air temperatures increased by about 0.7 °C during the period of 1906–2005 (IPCC 2013). Furthermore, on the basis of general climate models scientists predict that the temperature will increase by additional 2–8 °C by the end of the 21st century, depending on the region (Christensen et al. 2007; IPCC 2013; Erwin 2009). IPCC also predicts changes in precipitation that consider both extreme rainfall periods and periods of drought (IPCC 2013).

Recently, global estimation of carbon loss from the upper soil horizon due to 1 °C increase varies from 30 to 203 GtC by 2050 (Crowther et al. 2016). This temperature could induce a global increase in heterotrophic respiration of 0.038–0.100 GtC per year (Dorrepaal et al. 2009). Moreover, the amount of global CH_4 emission from the peatlands is estimated at approximately 0.123 GtC per year. Due to the fact that at high latitudes the air temperature will increase to a greater extent in the next century, the emissions of CH_4 from the northern areas can increase disproportionately (Bridgham et al. 2013). It is believed we can expect even bigger loss of carbon in the form of methane in the future.

5 Fires

The role of peatland fires in the carbon cycle deserves increased scientific attention (Gorham 1991; Strack 2008). Recently, scientists have observed the climate warming causing longer and more severe drought periods that in the near future may result in higher fire activity (Higuera 2015; Kettridge et al. 2015). These heat waves may amplify the fire activity in peatlands and lead to a release of huge amounts of carbon dioxide into the atmosphere (Turetsky et al. 2011, 2015). The enormous load of carbon that has remained in peat over millennia will be converted into the atmospheric part of the global carbon cycle. The peat fires can be also the source of non-CO_2 greenhouse gases in the atmosphere. For instance, anoxic conditions present at peatlands result from the fact that fires of these ecosystems can emit around ten times more CH_4 per unit of combusted biomass than fires of savannas (Yokelson et al. 1997; Andreae and Merlet 2001; Christian et al. 2003). These increased GHG emissions may cause the intensification of the greenhouse effect and lead to rising temperatures which intensify the frequency of climate determined fires. This positive feedback is amplified by more frequent boreal forests fires (Randerson et al. 2006; Flanningan et al. 2001). Moreover, peatland fires can smolder for months due to the thick peat layer and pose a threat of further fires in the vicinity of peatlands (Benscoter et al. 2015). These conditions can be observed, especially in autumn when the peat moisture is relatively low (The Guardian 2016). The peat destroyed by the fire is the source of mineral compounds in the environment (Strack 2008). Thus, this temporary heavy fertilization results in the withdrawal of plants not adapted to such conditions (Kuhry 1994; Sillasoo et al. 2011). The presence of permafrost in the peat profiles of the northern peatlands effectively limits the depth of peat burning but the projections of its thawing reduces the fire resistance of these ecosystems (Natural Resources Canada 2016).

Recently, the tropical peatlands destruction became an important environmental issue. These usually pristine ecosystems were systematically destroyed by drainage and burning and these activities altered their water and carbon retention capabilities. As a result, the peatlands' carbon balance was shifting from a sink to a source (Wösten et al. 1997; Page et al. 2002; Canadell et al. 2007; Rieley et al. 1996). Page et al. 2002 estimate that due to big fires in 1997 the dried peatlands of Indonesia released 0.8–2.6 GtC both from peat and vegetation, which represents around 13–40% of the mean annual global carbon emissions from burning of fossil fuels in the world. As a result, in 1997–2009 the contribution of peatland fires to total global emissions increased from 4% to 5% (Werf et al. 2010). Tropical peatlands fire with vegetation changes have a meaningful impact on the carbon cycle, the atmosphere, the ecosystem services and they cause wide-ranging social and economic impacts too. Recently, fires at extensive tropical peatlands have become more regular and the biggest ones were linked with the El Niño phase of ENSO that causes long drought periods (Page et al. 2009a). Rapid land use changes and climatic variability led to an increase of fire frequency in recent decades. In addition, highly variable, from year to year, carbon emission from this source will not be balanced by peatland's regrowth that follow the fire (Werf et al. 2010).

Peatlands and their carbon stock can be also affected by fires of the vegetation in the surrounding areas. Fires causing local or regional deforestation affect hydrology of peatlands of different size—from small kettle-hole peatlands to extensive raised bogs. It was shown for example that large fires of the Noteć forest in W Poland caused not only hydrological changes (wet shift/aqualysis) but also triggered floating mats development in some wetlands (Lamentowicz et al. 2015). Furthermore, a high-resolution study by Marcisz et al. (2015) revealed how important might be an indirect impact of fires in a peatland catchment that was also inferred recently from a peat core in S Poland (Kajukalo et al. 2016).

6 Peatlands Reduction

The disappearance of peatlands from the landscape had various spatial and temporal intensity but it was always caused by the economic and/or vital needs of human. Peatlands are potential farming areas thus they have been disturbed or completely degraded by human activities over the last two centuries. Those transformations were initially realized in Europe. For instance, 90% of peatlands in Switzerland disappeared mainly due to conversion to agricultural, garden and vegetable crops (Tobolski 2012; Lamentowicz et al. 2007).

This land-use change was mainly done by drainage that causes water table level instabilities. This factor led to deeper aeration of acrotelm that resulted in abrupt change - the replacement of plant communities and substantial transformation of the peatland ecosystem (Milecka et al. 2016). The peat extraction for fuel and industrial purposes is the second reason of peatland reduction (Strack 2008). There are large quantities of peat harvested for electricity production in Finland, Ireland and Sweden (World Energy Council 2013). Peatlands also disappear from the landscape due to transformation in order to change the landscape retention e.g. river valley flooding purposes or by irresponsible destruction e.g. the solid minerals, petroleum and natural gas mining (Tobolski 2012). A good example of the negative impact of mining activity was recently observed in the destruction of peatlands in Canada. The preparation of these areas for bituminous sand mines caused the release of around 11.4–4.73 million tons of stored carbon (Rooney et al. 2011).

Recently, socio-economic changes in Southern Asia caused enormous damage of tropical peatlands (Page et al. 2009b). The average peat thickness of tropical peatlands is around 5 m (maximum depths are over 20 m) while the mean thickness of peat observed at higher latitudes is lower than in Finland which is around 1.2 m (Page et al. 2011, Tropical peatlands-University of Helsinki). A place of special importance in the context of climate protection is South-eastern Asia. Peatlands in this region are significant terrestrial carbon storage, both in aboveground biomass and thick deposits of peat (Page et al. 2009a; Hamada et al. 2013).

In addition, tropical peatlands have far greater ability to accumulate carbon. Although they represent only 10% of the world's peatlands, they are responsible for up to 37% of this potential. Tropical peatlands also contain 10 times more carbon per hectare than ecosystem on mineral soils, whereas subpolar and boreal zone peatlands contain 3.5 and 7 times more carbon, respectively (Strack 2008).Tropical peatlands are an important component of the global terrestrial carbon resource because they store around 20% of carbon of all peatlands in the world in both their aboveground biomass and underlying thick deposits of peat (Page et al. 2011, Tropical peatlands-University of Helsinki).

Nowadays most of these ecosystems are systematically destroyed mainly by preparing the soil for palm oil plantations. These land use changes are realized by deforestation, fire and drainage because dry peat is much more prone to wildfires (Werf et al. 2010). This unprecedented scale of destruction converts the peatlands into a big source of atmospheric CO_2 (Moore et al. 2013; Page et al. 2011; Hooijer et al. 2010; Yale Environment 2017). Due to land use changes in 1990–2015, the carbon reservoir in tropical southeastern peatlands has decreased by about 2.5 GtC which corresponds to several hundred or even several thousand years of carbon accumulation in peatlands (Miettinen et al. 2017).

Moreover, the rate of peat exploitation is more than twice as fast as in its formation and it causes the decrease of peat by approximately 20 km^3 (Main Report 2007). These disturbances also modify the peat carbon dynamics due to the fact that since 1990, southeast Asian disturbed peatlands caused a 32% increase in fluvial organic carbon flux. This increase is more than half of the entire annual fluvial organic carbon flux from all European peatlands. Moreover, altering the structure of peatlands causes higher DOC release from deep peat layers that were formed thousands of years ago (Moore et al. 2013).

Total peat destruction would be equivalent to 100 years of coal burning at current rates. Additionally, the part of peatlands (including tropical and northern permafrost ones) doesn't accumulate peat anymore due to global warming. Consequently, the actual rate of carbon accumulation by all peatlands over the world does not exceed 0.1 GtC per year (Main Report 2007).

7 Peatlands Protection and Restoration

The enormous scale of destruction of these ecologically valuable elements of nature raised concerns and questions about the fate of these carbon depots and the interaction between the climate and peatlands in the future (Joosten et al. 2017; Bonn et al. 2016).

There are two modes of peatland's protection, passive and active (Tobolski 2012). The passive protection consists of total or maximum exclusion of human activities with the exception of preventing adverse changes introduced into the ecosystems by human activity. Usually it is realized by the introduction of different conservation strategies. The active protection is applied at the objects where human intervention is necessary. It leads to the preservation of peatlands along with rare and peat-forming peatland species. For example, mowing is introduced in order to stop vegetation succession on meadows (Hedberg et al. 2013; Kotowski et al. 2016) or even removal of the humified peat from degraded fens (Klimkowska et al. 2010). Moreover, large scale, long-term projects were utilized to restore raised bogs in N Poland (Herbichowa 2007).

Peatland protection is also carried out on different spatial scales. For example, the Ramsar convention that is the global intergovernmental treaty (adopted in 1971) provided the framework for conservation and wise use of peatlands (Erwin 2009; Matthews 1993). It was one of the first modern legal instruments to conserve natural resources on a global scale. It links the countries and restrains from unreasonable exploitation of natural ecosystems. This convention's standards of wise use principles of management and protection were adopted in the international arrangements and the national laws (Matthews 1993). The Natura 2000 was a network of nature protection areas that was adopted in 1992 for the protection of the most seriously threatened habitats in the European Union territory. Peatlands are on the list of the habitats that are protected by this form of conservation (Natura 2000). Special attention to peatlands is also espoused by various countries. For example, the Swiss federal constitution expressly states the importance of peatland protection (Tobolski 2012), while in Poland the statutory form of peatlands protection is peatland reserve and they are also protected in the framework of national parks, ecological grasslands or documentation sites (Nature protection).

The peatlands that are already disturbed or destroyed can be reestablished with restoration processes. Due to the fact that water is the most important factor determining of the existence of peatlands, rewetting is most often the solution for restoration of perturbed objects (Tuittila et al. 2000; Zerbe et al. 2013). However, increased water level does not ensure successful restoration since high ground moisture of can be insufficient for the restoration of peatlands.

Regardless of doubts about its effectiveness, rewetting can be accomplished in many practical ways, e.g. construction of small retention devices to stop the water outflow with ditch drainage system (Glińska-Lewczuk et al. 2014; Bonn et al. 2016). Raising water levels to the soil surface or even above to maintain anaerobic soil conditions results in environments that are good enough for rapid succession towards closed peatland vegetation (Tuittila et al. 2000; Zerbe et al. 2013). Water management gives promising results at many locations. Zerbe et al. (2013) found that ten years after rewetting, manipulated peatlands in North East Germany formed mosaic of vegetation types with the highest potential for peat formation. The interesting case of positive impact of human activity that positively influences the peatlands can be found in maritime areas of Canada. The stretches of dikes that protect agricultural land, infrastructure, homes and communities additionally inhibit salt marshes from naturally shifting with the level of the sea and reducing destructive wave action (Erwin 2009).

8 Discussion and Summary

Peatlands are very important terrestrial ecosystems due to their uniqueness, vulnerability and importance in the global water and carbon cycles as well as climate forming. The arising and development of these ecosystems was always determined by complex of thermal and hydrological conditions and due to long-term influence these factors peatlands are the second, after the ocean, stock of carbon in the world.

Peatlands interacted with atmosphere and cooling climate during the ice age by storing greenhouse gases (GHG) related carbon. Some Holocene climate studies suggest that peatlands are supposed to have cooled down the climate recently and only anthropogenic emissions have prevented the initiation of the Ice Age (Rudimann 2003).

Nowadays, the human activity and climate changes are expected to be the most important factors determining the peatland's carbon sequestration (Charman et al. 2013; Loisel et al. 2014). Additionally, the fires induced by both mentioned above factors will become the serious threat for these ecosystems. This set of simultaneously acting factors affect both the hydrology, land use, temperature (direct and indirect way) (Ferretti et al. 2005) and the intensification of extreme weather events that also will have a destructive impact on every kind of ecosystem in the world. There are accompanying effects that usually play role at local scale such as altered hydrology, base flow shifts, decreased water resource, increased heat stress, soil erosion, increased flood and risk of fires etc. (Erwin 2009). All the factors described above affect the stability of peatlands carbon stocks and finally lead to bigger emission of carbon and warming up the atmosphere. These changes in the functioning of peatlands transform many of them from climate 'coolers' (carbon net sinks) to the 'heaters' (carbon net sources) and it can be considered as very serious threat due to their possible positive feedback with climate. Additionally, the CO_2 uptake ability of peatlands will not be able even to compensate the anthropogenic GHG emissions (Mäkilä and Saarnisto 2008; Petrescu et al. 2015).

The study of carbon exchange between the peatlands and the atmosphere is necessary also because of high uncertainty of the estimation of CO_2 concentration rise as a result of climate warming. The recent projections of CO_2 increase as an effect of 1 °C temperature increase ranges from 1.7 to 60 ppm CO_2 (Frank et al. 2010; Cox and Jones 2008) and many climate change models do not include peatlands or coral reefs ($CaCO_3$) in the estimation of the future CO_2 concentration in the atmosphere.

Peatlands' function as landscape water buffer that through the quick absorption of precipitation can reduce the effects of floods are sometime neglected in the short-term economy. Values of these ecosystems can be described by the following example. The Canadian peatlands help to save around 3 million at rural site and even 50 million at urban site and it was also estimated that dehydration of peatlands under Canadian conditions will increase the cost of floods damages by 29% and 38% in rural and urban areas, respectively (Canadian University of Waterloo report). The forest succession in the context of peatlands was also found and it is an element that mitigated the emission from the peatlands during the Holocene melting period however recently this shift of plant cover can be limited by the wood harvesting within the regular forest management. The forest surrounding the peatland can be an effective barrier that prevents peatlands of fertile water impact from the surrounding fertilized fields; therefore, the forests (especially dominated by Pinus sylvestris) might affect peatlands' trophic state in long-term context (Lamentowicz et al. 2007; Milecka et al. 2016).

There is no doubt that the global changes are unavoidable and because of that fact the suitable management and protection strategy need to be implemented to ensure the future peatlands sustainability. Since, mentioned before, the important role of these ecosystems in the global carbon cycle the comprehensive understanding of the functioning of peatlands under climate change as well as human impact that is critical for adequate protection's strategy of peatlands. Additionally, the protection of each object requires the basic knowledge about the local history, ecology and specific character of the habitat which requires its precise analysis (Erwin 2009; Page et al. 2011; Tobolski 2012). Moreover, the choice of protection method is critical because of complex character of the influence of each implemented change.

Activities that will allow the effective protection of peatlands should include good protection policy of peatlands that roots from general approaches expressed in global/continental scale conventions and ends up with locally related protection goals and tasks. Additional efforts necessary for successful protection are to increase the public knowledge related to protected objects. The education is fundamental to gain the success in peatland protection, especially on local scale. The effectiveness of maintaining the peatlands as the carbon sinks is directly related to the ecological awareness of the local communities. Another tool that will support the introduction of reasonable protection management is the appropriate monitoring program (Słowińska et al. 2010) that provides the information both long and short-term changes of these vulnerable ecosystems. Such system provides insights to the potential ecological consequences of the changes, supporting the decision makers to determine the management practices that should be implemented. It helps also the understanding the range of current variability in some parameters and detecting desirable and undesirable changes in time within peatland areas and adjacent ecosystems (Erwin 2009). These activities will allow to introduce adequate solutions to mitigate the effects of climate change and reduce or eliminate the human impact on these valuable ecosystems.

Recently, beside protection, people have tried also to restore disturbed or completely destroyed areas of the peatlands in the world (e.g. Werf et al. 2010). Appropriate techniques are selected on the basis of local conditions and they are related to water since this factor determines the existence of peatlands (Erwin 2009). Such actions have been taken inter alia in Germany and Canada and in these cases it was successful (Zerbe et al. 2013). However, one must be aware that restoration might not always be effective because past disturbances were too extensive.

Techniques that are often used concern rewetting and building the small retention devices in order to water retention in the peatlands or rising the water level. This promotes the biological diversity and strongly moistened conditions cause also the spreading of peatland vegetation that definitely has a positive effect on the peatlands regeneration. A certain threat to the peatlands restoration may be a fact of increased global water demand since it increased more than triple since 1950 and in the future it is going to be doubled again by 2035 (Postel 1997). But, on the other hand, peatlands as a store of water in the context of floods can offset the increasing water demand. Summarizing this study, peatlands need to be protected and restored as an element of sustainable development of global civilization since it is very important in the context of mitigating the global warming effect.

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