Mitigation of greenhouse gases emissions impact and their influence on terrestrial ecosystem.

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Abstract. Nowadays, one of the most important challenges faced by the humanity in the current century is the increasing temperature on Earth, caused by a growing emission of greenhouse gases into the atmosphere. Terrestrial ecosystems, as an important component of the carbon cycle, play an important role in the sequestration of carbon, which is a chance to improve the balance of greenhouse gases. Increasing CO₂ absorption by terrestrial ecosystems is one way to reduce the atmospheric CO₂ emissions. Sequestration of CO₂ by terrestrial ecosystems is not yet fully utilized method of mitigating CO₂ emission to the atmosphere. Terrestrial ecosystems, especially forests, are essential for the regulation of CO₂ content in the atmosphere and more attention should be paid to seeking the natural processes of CO₂ sequestration.

1. Introduction
Increasing temperature on Earth, caused by a growing emission of greenhouse gases into the atmosphere, constitutes one of the most important challenges faced by the humanity in the current century [1]-[3]. Although the global warming is a natural phenomenon, the anthropogenic activity contributed to its aggravation, mainly due to an increase in the amount of combusted fossil fuels [1], as well as cement production, and changes in land use, which lead to a further increase of temperature on Earth [4]. In 2005, the total global CO₂ emission resulting from this process amounted to 26.4 billion tons [5]. Starting from the year 1750, the CO₂ emission is constantly on the rise, mainly due to the combustion processes of carbon-containing fuel, as well as due to the mining activity [6], [7]. Carbon sequestration is a growing research topic that addresses an important aspect of the overall strategy for carbon management to help mitigate the increasing emissions of CO₂ into the atmosphere. Terrestrial ecosystems, being recognized as an important component of the carbon cycle, have gained importance owing to its potential to sequester carbon [8].

Apart from the obvious emission reduction, sequestration of carbon dioxide is a chance to improve the balance of greenhouse gases. This term denotes a number of actions aimed at mitigating the emission of carbon dioxide into the atmosphere. This process, in great simplification, consists of consecutive actions: capturing and separating carbon dioxide from exhaust fumes and storing CO₂ in a particular location [5]. According to Raj and Venkata [9], carbon sequestration is the process of capture and long-term storage of atmospheric carbon dioxide (CO₂). We can distinguish between storing the carbon dioxide
in plants and soil (Terrestrial Sequestration), underground (Geological Sequestration) and deep in Ocean (Ocean Sequestration).

Sequestration by terrestrial ecosystems remains one of the under-appreciated methods of CO$_2$ sequestration. According to the data from IPCC reports, the annual emission of CO$_2$ from the anthropogenic sources approximates 9.8 billion tons, in C equivalent, or 35.9 Mg tons in CO$_2$ equivalent. On the other hand, the annual absorption by terrestrial plants in the course of photosynthesis roughly amounts to 123 billion tons, in C equivalent or 451 billion tons in CO$_2$ equivalent. This indicates that an increasing CO$_2$ absorption in the course of photosynthesis by 12.5% would neutralize the emission of CO$_2$ from the anthropogenic sources [4].

2. Flux of CO$_2$ in the ecosystems of Earth

According to the literature [10] (published by Le Quéré et al. in 2015) the mean emission of CO$_2$ into the atmosphere constantly increases by 3.1 in 1960 to 9.8 GtC/year in 2014. Two sources are mainly responsible for this phenomenon: combustion of fossil fuels (see Table 1) and cement production.

| Years  | 1960-69 | 1970-79 | 1980-89 | 1990-99 | 2000-09 | 2005-14 | 2014 |
|--------|---------|---------|---------|---------|---------|---------|------|
| Emission [GtC/year] | 3.1±0.2 | 4.7±0.2 | 5.5±0.3 | 6.4±0.3 | 7.8±0.4 | 9.0±0.5 | 9.8±0.5 |
| Emission [GtCO$_2$/year] | 11.4±0.7 | 17.2±0.7 | 20.2±1.1 | 23.5±1.1 | 28.6±1.5 | 33±1.8 | 35.9±1.8 |

Table 2. CO$_2$ emissions caused by changes in land use, mainly including deforestation and drying of marshes [10].

| Years  | 1960-69 | 1970-79 | 1980-89 | 1990-99 | 2000-2009 | 2005-2014 | 2014 |
|--------|---------|---------|---------|---------|-----------|-----------|------|
| Emission [GtC/year] | 1.5±0.5 | 1.3±0.5 | 1.4±0.5 | 1.6±0.5 | 1.0±0.5 | 0.9±0.5 | 1.1±0.5 |
| Emission [GtCO$_2$/year] | 5.5±1.8 | 4.8±1.8 | 5.1±1.8 | 5.9±1.8 | 3.7±1.8 | 3.3±1.8 | 4.0±1.8 |

Apart from the industrial emissions, the changes in land use are another important source of CO$_2$ emissions. These include drying of marshes, deforestation and volcanic eruptions (Table 2).

Simultaneously, an increase in the absorption of this compound by the terrestrial ecosystems is observed, ranging from 1.7 GtC/year in 1960 to 4.1 GtC/year in 2014. The rising CO$_2$ concentration in the atmosphere, in conjunction with nitrogen oxides of anthropogenic origin precipitating onto the earth, strengthens the fertilization effect. The direct outcome of this phenomenon is an observed increase in the absorption of CO$_2$ by the terrestrial ecosystems. The ocean waters constitute another absorber of CO$_2$. Oceans absorb 92 GtC/year and release 90 GtC/year at the same time [11]. The amount of CO$_2$ that is absorbed by the oceans depends on various processes, including biological activity, ocean currents and water temperatures.
The comparison of CO$_2$ emissions into the atmosphere from the anthropogenic sources (9.8 GtTC/year in 2014) and absorption of CO$_2$ by the terrestrial ecosystems clearly indicates that an increase in the absorption of this compound by the terrestrial plants by 8.2% would inhibit its rising content in the atmosphere [12], [13]. Therefore, appropriate control of CO$_2$ by the terrestrial ecosystems is purposeful and will result in the inhibition of CO$_2$ concentration increase in the atmosphere.

3. Role of Earth ecosystems in the regulation of CO$_2$ cycle

The terrestrial ecosystems play a major role in regulating the CO$_2$ cycle [14]. According to the data published by Trumper et al., the greatest amount of CO$_2$, i.e. 547.8 GtC, was accumulated in the tropical and subtropical forests as well as peatlands [15]. Tropical rainforests constitute one of the largest ecosystems of the Earth. In total, they absorb 1.3 Gt (net) of carbon per year. This includes 0.6 Gt of carbon in the Central and South America, 0.4 Gt of carbon in Africa and 0.25 Gt of carbon in Asia [16], [17]. It is estimated that approximately 6.5 to 14.8 million ha of tropical forests is being cut down, which additionally elevates the CO$_2$ emission by 0.8-2.2 Gt of carbon [18], [19].

Peatlands play an extremely important role in the carbon absorption. The estimated data indicates that peatlands contain 550 Gt of carbon, with 1450 t of carbon per hectare [20]. A rapid degradation of peatlands and their dewatering carried out in order to expand the area of arable lands, leads to the release of CO$_2$ into the atmosphere. It is estimated, that elimination of 6 million ha of peatlands additionally releases 0.5-0.8 Gt of carbon each year [21].

It should be noted that elimination of peatlands and cultivation of coconut palms in their place – in order to obtain biodiesel fuel – does not reduce but rather increases the emission of CO$_2$ into the atmosphere by as much as 3-9-fold.

The tropical and subtropical meadows, bushes and savannah constitute another important ecosystem containing 463.6 Gt of carbon. These areas are vulnerable to fires, which contribute to an annual emission of CO$_2$ by 0.5-4.2 Gt of carbon. Nevertheless, these ecosystems still absorb 0.5 Gt of carbon per year [15].

The meadows of temperate zones also play an essential role in the regulation of CO$_2$ fluxes in the Earth ecosystem. They contain 183.1 Gt of carbon, which is mainly (1333 t) accumulated in soil [22]. Another important ecosystem includes the forests in temperate zones, containing 314.9 Gt of carbon. These forests are characterized by a high content of carbon, ranging from 150 to 320 tons/ha. The forests in Europe currently absorb 7-12% of CO$_2$ emitted from the anthropogenic sources [21]. It should be expected that a gradual increase in the area occupied by forests and appropriate silviculture will make the European forests one of the ways of conducting CO$_2$ sequestration. The northern forests found in the Scandinavian countries, Alaska and Russia, contain substantial amounts of carbon, reaching approximately 384.2Gt. The low temperature characterizing these areas slows down the decomposition of dead biomass, which contributes to a high carbon content in soil ranging from 116 to 343 t per hectare [23].

The tundra found in the arctic regions, i.e. northern Canada, Scandinavian countries, Russia, Greenland and Iceland forms yet another ecosystem, which contains 155.4 Gt of carbon. Similarly to the northern forests, the decomposition of dead biomass in it is very slow. It is estimated that the permafrost formed under a relatively thin layer of soil contains 1600 Gt of carbon [21]. Due to a constantly increasing global temperature, there are concerns that CO$_2$ and CH$_4$ contained in the permafrost will be released. It is estimated that 100 Gt of carbon in the form of CO$_2$ and CH$_4$ will be released into the atmosphere, thus raising the carbon concentration by as much as 47 ppm [24].

The performed analyses indicate that the terrestrial ecosystems constitute an enormous carbon reservoir. It contains approximately 2000 Gt of carbon and additionally absorbs 1.5 Gt of carbon (net) each year. It should be noted that the tropical forests play an extremely important role in the carbon balance. It is estimated that until 2100, carbon sequestration by the natural ecosystems will prevent an increase in the CO$_2$ concentration by 40-70 ppm.

Deforestation conducted in order to create agricultural lands leads not only to a decrease in CO$_2$ absorption by plants, but is also conducive to the emission of this compound, which results from the
oxidation of organic carbon contained in soil – the largest reservoir of carbon. The IPCC report from 2014 states that the amount of carbon in the organic compounds contained in soil approximates 1580 Gt. The above-mentioned data indicates that the terrestrial ecosystems, forests in particular, play a key role in regulating the CO₂ content in the atmosphere.

4. Conclusion

By taking various actions, e.g. accumulating carbon in terrestrial carbon sinks such as plants, plant products and soils, the emission of CO₂ into the atmosphere may be significantly reduced, and thus contribute to the mitigation of climate changes. Appropriate soil and land management practices should be applied, which will increase the carbon stocks of land ecosystems and hence reduce the losses to the atmosphere. Increasing CO₂ absorption by terrestrial ecosystems (by intensifying photosynthesis) and consequently increasing plant biomass production, is one way to reduce the atmospheric CO₂ emissions.

5. References

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