Greenhouse Gas Emissions from Reservoirs

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Reservoirs are manmade lakes created by building dams on rivers for various purposes: flood control, electricity generation, irrigation, water supply, aquaculture, environmental services, recreational activities, navigation etc. In freshwater ecosystems, several mechanisms are involved in the natural carbon cycle. They receive carbon from terrestrial ecosystems through drainage, capture the carbon through primary production, bury the carbon in sediments, emit GHG through biomass degradation and respiration, and transport the carbon downstream to the seas or oceans. GHG emissions can be increased by human activities around the ecosystem through sewage and agricultural pollution.

greenhouse gas multipurpose reservoirs sustainability

1. Introduction

Dams affect the natural carbon cycle in freshwater ecosystems through floods of terrestrial vegetation and soils. The flooded organic matter decomposes causing additional GHG emissions, especially in the first years after the reservoir creation. Flooding can also increase sedimentation and decomposition in the reservoir, due to longer water residence times, which can lead to higher GHG emissions [1]. In addition, reservoirs can have large fluctuations in the water level, especially hydroelectric reservoirs that store large volumes of water to be used during drought. It can, therefore, be said that artificial reservoirs differ from natural lakes by riverine nutrient inputs, the flooding of terrestrial organic carbon, and water-level fluctuations; they also may have different GHG emissions. Reservoirs present, from a social, economic and environmental point of view, not only advantages, but also disadvantages.

2. The Use of Reservoir

Reservoir use can serve single or multiple purposes. According to the International Commission on Large Dams (ICOLD), 70% of large reservoirs are designed for single-purpose usage. Around 11% of large reservoirs have been built only for hydropower generation and 14% for hydropower generation plus other uses. These high figures show why GHG emissions from reservoirs should be accounted for. In addition, the study of these emissions indicates ways to reduce them.

3. Greenhouse Gases

The main greenhouse gases emitted by a reservoir are CO_2, CH_4 and N_2O. They have a different global warming potential (GWP). For the time period of 100 years, GWP for CO_2 is 1; for CH_4, it is 34 times higher than that of CO_2, and for N_2O, it is 298 times that of CO_2 [2].

The CO_2 is generated by the decomposition of organic material and nutrients transported in the reservoir by affluent or by rainfall and overland flow, by the decomposition of dead organic matter stored in the soil of the reservoir, by the respiration of vegetation present in the reservoir, from CO_2 dissolved in water and from the oxidation of CH_4. The sediments in drawdown areas are also a source of CO_2 emission, due to their exposure to air during water level fluctuations.

The emission of CH_4 comes from the decomposition of organic matter and vegetation under anaerobic conditions in the soil or sediment layer of the reservoir.

Nitrous oxide (N_2O) arises as a by-product of the aerobic nitrification reaction or of the anaerobic denitrification that occurs in lake riparian areas. The few measurements of N_2O emission from reservoirs showed a variation similar to that of CH_4 in terms of generation. The contribution of N_2O to the total GHG emission expressed as an CO_2 equivalent is low, compared to CH_4 și CO_2 (N_2O—17 mg $CO_{2eq}/m^2/d$; CH_4—275 mg $CO_{2eq}/m^2/d$ and CO_2—1585 mg $CO_2/m^2/d$) [3].

GHG (CO_2 and CH_4) reaches the atmosphere through the following channels: diffusive flow from the reservoir surface, through degassing when passing through the hydraulic turbine and spillway (due to pressure drop), through diffusive flow at the downstream river surface. Methane can also reach the surface of the reservoir through bubbling in shallow areas of reservoir.

The main factors influencing GHG emissions are the carbon stock in soil and flooded biomass or that transported by the upstream rivers in reservoirs; the concentration of dissolved oxygen in the reservoir; water quality and nutrient content; the inflow and shape of the reservoir; the water depth and extension of the littoral zone; the wind speed at the reservoir surface; and the water temperature and configuration of dam intake and outlets [3]. These factors influence the biochemical processes of organic matter formation, respiration, methanogenesis, CH_4 oxidation, gas exchange between the reservoir and the atmosphere. The GHG measurements showed a variation in time and space within a reservoir and also a seasonal variation and a decrease in general with the age of the reservoir.

There are many studies on the evaluation of GHG emissions from reservoirs, which differ by the methodologies used, the lifespan considered, and the size and type of reservoir [1][4][5][6][7][8][9][10][11][12][13][14][15][16][17][18][19][20][21][22][23][24][25][26][27][28][29][30][31][32][33][34][35][36][37][38][39].

Most studies have analyzed GHG emissions from hydropower reservoirs. The few studies performed on natural lakes have shown that there are no significant differences between reservoir surface emissions from hydropower reservoirs, compared to non-hydropower reservoirs [10]. At hydropower reservoirs, there are also degassing emissions, downstream emissions and emissions from drawdown zones.

From the analysis of GHG emissions from 85 different hydroelectric reservoirs with a global distribution, it was observed that all the reservoirs are sources of CH_4 to the atmosphere, the majority (88%) are also a source of CO_2 (only 12% of reservoirs are net sinks of CO_2) and that there is a large variation in emissions [5].

Knowing the GHG emissions generated by reservoirs is an important factor in making decisions to finance future projects and discerning how environmentally friendly they are.

4. Conclusions

Built to meet human needs, multipurpose reservoirs increase human well-being, but they cause changes in the water quality, ecosystem and flow regime of river networks. They are considered neutral in terms of GHG emissions, but they may become considerable sources of GHG depending, especially, on the climatic zone in which they are located and their uses. The creation of a water reservoir on a river leads to the generation of GHG, due to biogeochemical processes in the reservoir. The calculation of GHG emissions of the studied reservoir, which is placed in a temperate zone and has multiple uses of water, shows that they are lower than those of a lake (306.85 g CO_{2eq}/m^2/yr versus 953.73 g CO_{2eq}/m^2/yr).

Knowing the GHG emissions from the reservoir is useful to accurately report the greenhouse gas (GHG) emissions. To calculate the CO_2 emission, four models were used; to calculate the CH_4 emission, six models were used. If the difference between the highest (520 mg CO_2/m^2/d) and the lowest CO_2 emission value (205.48 mg CO_2/m^2/d) is more than two-fold, the difference between the highest CH_4 emission (76.52 mg CH_4/m^2/d) and the lowest emission value (1.16 CH_4 mg CH_4/m^2/d) is much larger, by about 65 times.

Because not all the methodologies reviewed make an overall assessment of GHG emissions and because some are used only for hydropower reservoirs—except the G-res tool, which estimates the GHG emissions from the reservoir surface, drawdown, turbines and spillway—it is difficult to compare the results obtained by applying the methodologies to the multipurpose reservoir, Stânca-Costești.

In the absence of a standardized methodology for calculating GHG emissions from the reservoirs, the reviewed models can be used in correlation with the available data on reservoirs.

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