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EXAMINATION THE INTERACTION BETWEEN THE COMPOSITION OF A THEORETICAL ECOSYSTEM AND THE INCREASE IN THE ATMOSPHERICAL CO_2 LEVEL

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The development of automotive industries and energetics has a large impact on the carbon-dioxide level in the atmosphere and therefore on the climate change process. There is a continuous cycle and flow of inorganic compounds between the atmosphere and the ecosystems, therefore the anthropogenic affects (such as CO_2 emission) strongly modify the activities of ecosystems. The modified activities are as follows: fluxes of the photosynthesis, CO_2 emission of the soil or the quantity of dissolved organic compounds in the ocean. These activities could have a feedback on the climate controlling the compounds of the atmosphere and therefore on the temperature of the Earth.

The most important anthropogenic green-house gas (GHG) is the carbon-dioxide. The global CO_2-level has an increase from 280 ppm (before industrial era) to 380 ppm (by 2008). The annual fossil CO_2-emission was 6.0–6.8 Pg C in the 1990s, and 6.9–7.5 Pg C in 2000–2005. There is positive correlation between the amount of green house gases in the atmosphere and the temperature, so the larger the increase in the GHG-level the higher the global temperature in the Earth.

The ecosystems could control the climate (precipitation, temperature) in a way that an increase in the atmosphere component (e.g. CO_2 concentration) induces the processes in biosphere to decrease the amount of that component through biogeochemical cycles. These feedbacks could affect the climate either on positive or negative ways.

In our research the answers of a theoretical freshwater ecosystem are examined on the change in the value and the fluctuation of the temperature. Our aim is to show a simple ecological model related to this feedback mechanism, and to examine the feedback ability of the theoretical ecosystem to the temperature of the atmosphere.

Keywords: theoretical ecosystem, feedback, climate modelling, climate change, control

Introduction and aims

The latest IPCC report [8] points out that a rise of 1.5–2.5 °C in global average temperature makes important changes in the structure and the working of ecosystems, primarily with negative consequences towards the biodiversity and goods and services of the ecological systems (e.g. [1, 3, 13, 17]).

The ecosystems could control the climate (precipitation, temperature) in a way that an increase in the atmosphere component (e.g. CO_2 concentration) induces the processes in biosphere to decrease the amount of that component through biogeochemical cycles. Paleoclimate researches have proved this control-mechanism for more than 100,000 years. The surplus CO_2 content has most likely been absorbed by the ocean, thus controlling the temperature of the Earth through the green house effect. This feedback is negative therefore the equilibrium is stable.

During the climate control there may be not only negative but positive feedbacks. One of the most important factors affected the temperature of the Earth is the albedo of the poles. While the average temperature on the Earth is increasing the amount of the arctic ice is decreasing. Therefore the amount of the sunlight reflected back decreases, which warms the surface of the Earth with increasing intensity. This is not the only positive feedback during the control, another good example is the melting of frozen methane hydrate in the tundra.

The environment, the local and the global climate are affected by the ecosystems through the climate-ecosystem feedbacks. There is a great amount of carbon in the living vegetation and the soil like organic substance which could be formed to atmospheric CO_2 or methane hereby affecting the climate. CO_2 is taken up by terrestrial ecosystems during the photosynthesis and is lost during the respiration process, but carbon could be emitted like methane, volatile organic compound and solved carbon. The feedback of the climate-carbon cycle is hard to determine because of the difficulties of the biological processes [4, 9].

The biological simplification is essential during the modelling of vegetation processes [14, 18, 20]. It is important to consider more feedbacks to the climate system to decrease the uncertainty of the estimations.

Materials and methods

An algae community consisting of 33 species in a freshwater ecosystem is modelled [5, 6, 11, 19]. During the examinations the behaviour of a theoretical ecosystem is studied by changing the temperature systematically. The conceptual diagram of the TEGM model summarizes the build-up of the model *(Fig. 1)*. Theoretical algae species are characterized by the temperature interval in which they are able to reproduce. The daily reproductive rate of the species can be seen on the vertical axis, which means by how many times the number of specimens can increase at a given temperature. This corresponds to the reproductive ability of freshwater algae in the temperate zone [7]. Since the reproductive ability is given, the daily number of specimens related to the daily average temperature is definitely determinable.

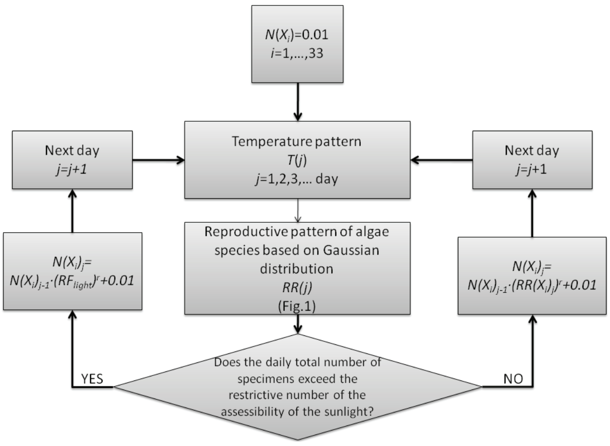

Figure 1: Conceptual diagram of the TEGM model (RR: reproduction rate, RF: restriction function related to the accessibility of the sunlight, $N(X_i)$: the number of the i^{th} algae species, r: the velocity parameter)

The theoretical ecosystem is imagined that the amount of the biomass (a part of the carbon stored by the ecosystem) participates in the build-up of the plants or affects the carbon-content of the atmosphere. It is supposed that the plants alter into atmospherical CO_2 at the moment of their ruination. The net primer production (NPP) is considered as biomass production of plants, because these data are available instead of net ecosystem production (NEP).

Let be equal the amount of the plant biomass with the production of the temperate freshwater ecosystem. The area of the freshwater lakes, rivers and wetlands is 10.3 million km^2 in the Earth [16], the average net primer production value of these ecosystems is 0.36 C/m^2/year. It is supposed, that the freshwater splits into equal parts in the surface of the Earth, so the temperate freshwater ecosystems have 5.15 million km^2 area and annual 1.854 Pg C net primer production.

Keeling et al. [12] have found from the measuring of the atmospherical CO_2-level and the global average temperature in the Earth that 6 Pg C increase in the atmosphere is analogous with 1 K increase in global average temperature.

During the simulation it is important to calculate with the anthropogenic effect. Canadell et al. [2] have found that there is 4.1 Pg C increase annually in the atmosphere, which is 0.123 Pg C related to the temperate freshwater zone (this is the 3% of the surface of the Earth). Therefore the temperature increases 0.123 Pg C/6 = 0.0205 K in every year. To take into account the anthropogenic effect there is 0.0205 K/365 = $6.616 \cdot 10^{-5}$ K increase daily from the start of the simulation study.

During this study the base temperature data series is the existing historical daily average temperature from 1960 to 1990 in Budapest. This series consist of large number of examinations: 30*365 values. In order to simplify the description of the climate and to ignore the fluctuation between years a function has been fitted to averages and dispersion of the 30 years' data according to the least squares method. This fitted curve is the base of our simulations, as later can be seen in *Fig. 2*, the T(1) data series.

Considering the historical daily temperature data series from 1960 to 1990 in Budapest it is stated that the daily average total number of specimens (productivity) is $1.17 \cdot 10^6$ in case of r = 1, and let this number of specimens be equal to the 8.924 Pg C net primer production. (Hence the specimens of the theoretical ecosystem live for one day, the daily average production is get for the production of the ecosystem.)

The control effect of the theoretical ecosystem on the climate has been modelled as can be seen in Fig. 2.

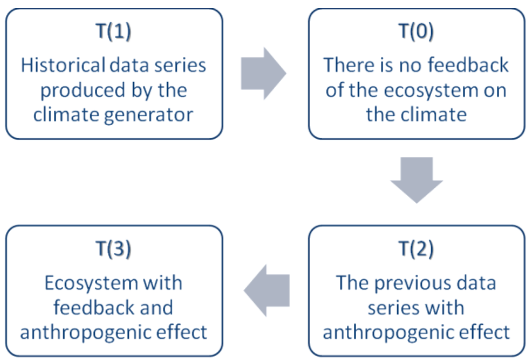

Figure 2: The block diagram of simulation study

During the simulation there are some used temperature data series. These are as follows:

T(0): the data series where there is no feedback of the ecosystem on the climate, and there is not any anthropogenic effect.

T(1): the data series where there is feedback of the ecosystem on the climate, this is related to the measured, historical temperature data.

T(2): the data series where there is no feedback between the ecosystem and the climate, but the anthropogenic effect exists.
T(3): the data series where there are both the feedback and anthropogenic effects.

The equilibrium comes into evidence while a specimen springs carbon passes out from the atmosphere in order to participate in the build-up of the plant. In the proportion of the leaving CO_2 amount the temperature of the air decreases according to the following equations:

$$T_{(0)j} = T_{(1)j} + \frac{1.854\,[\mathrm{PgC/yr}]}{1.17 \cdot 10^{6}} \cdot \frac{1}{6\,[\mathrm{PgC/K}]} \cdot N_{(0)j} \tag{1}$$

$$T_{(0)j} = T_{(1)j} + 2.641 \cdot 10^{-7} \cdot N_{(0)j} \quad [\mathrm{K}] \tag{2}$$

$$T_{(2)j} = T_{(0)j} + 6.616 \cdot 10^{-5} \cdot j \quad [\mathrm{K}] \tag{3}$$

$$T_{(3)j} = T_{(2)j} - 2.641 \cdot 10^{-7} \cdot N_{(2)j} \quad [\mathrm{K}] \tag{4}$$

where N means the number of specimens and the indexes are as follows:

0 is related to the case without the plants,
1 is related to the historical data series,
2 is related to the case with anthropogenic effect and without the plants,
3 is related to the case with anthropogenic effect and plants,
j means the number of data.

So in case of without-plants the temperature would be higher.

The simulations were run with two-type temperature inputs. In the first case the temperature input is the fitted data series of the existing daily average temperature of Budapest from 1960–1990, and the simulation was run for 120 years to answer the question, what would be if there is no anthropogenic effect. In the other case the anthropogenic effect is considered, and simulation was run from 2010 to 2130.

In every temperature interval there are dominant species which win the competition. The output parameters of the experiments are the determination of daily productivity, the diversity (Shannon diversity value) and the change in temperature caused by the ecosystem.

Results

During the simulation study the working of a theoretical algae ecosystem were examined for the future. In case of T(0), when there is no anthropogenic effect, the larger number of specimens could be found in summer and fall, in July, August and September. Considering the anthropogenic effect (T(2)) there is a decrease in the total number of specimens, the largest productivity values can be found in September and in March, sometimes in June. To compare the two case, the nearly maximum total number of specimen values do not exist in the second case as it appears in the first case.

The daily diversity values can be seen in *Fig. 3a* and *3b* for the two temperature inputs. The values change between 0 (dark colour) to 1.7 (white). It can be seen in Fig. 3a that the maximum diversity exists in May and at the beginning of November, the dispersion of the species is medium in summer and winter [10].

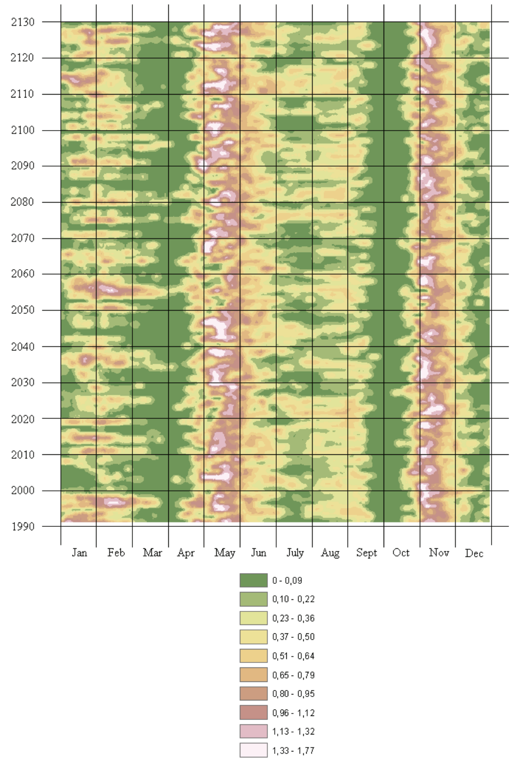

Figure 3a: The Shannon diversity values from 1990 to 2130 when there is no anthropogenic effect (T(0)-case)

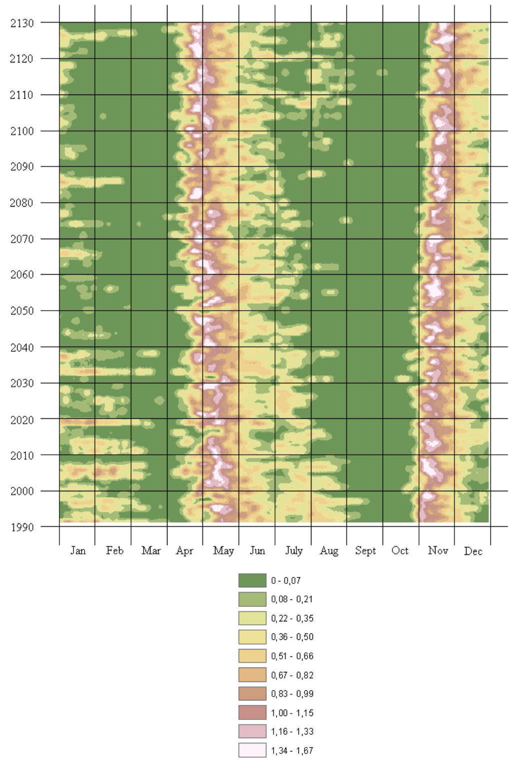

Figure 3b: The Shannon diversity values from 1990 to 2130 where there is anthropogenic effect (T(2)-case)

Considering the anthropogenic effect (T(2), Fig. 3b) the places of the diversity maximums within a year shifts during the consecutive years. At the end of the examined period the diversity maximums can be found in April and at the end of November. Because of the high summer temperature and the extinction of the species the diversity decreases in summer. To study the seasonal diversity values it is stated that there is a decrease in the diversity in summer and winter.

The composition of the ecosystem determines the feedback effect, the effect of temperature control. In the first case (T(0)) the evolving ecosystem causes 1.5–2.5 K decrease in the temperature in July, August and September *(Fig. 4a)*. So the theoretical ecosystem could have cooling effect in summer until 3 K temperature, in fall until 2 K temperature; while in winter and spring there is less amount of biotic feedback. To take into account the anthropogenic effect it can be seen in *Fig. 4b* that the feedback, the 'cooling effect' of the ecosystem is less realized, the maximum difference is (T(2)–T(3)) 1.3 K temperature difference. In fall some shifts can be seen, the temperature can decrease in February and in March.

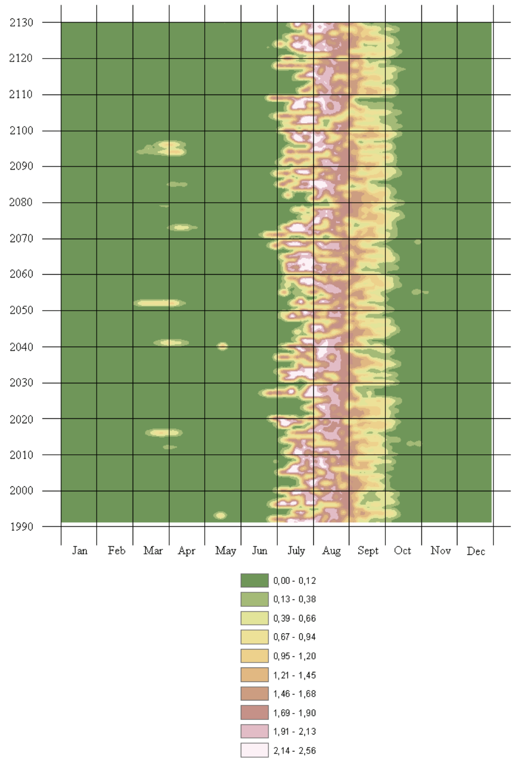

Figure 4a: The cooling effect (T(0)–T(1)) of the theoretical ecosystem 1990-2130 without anthropogenic effect

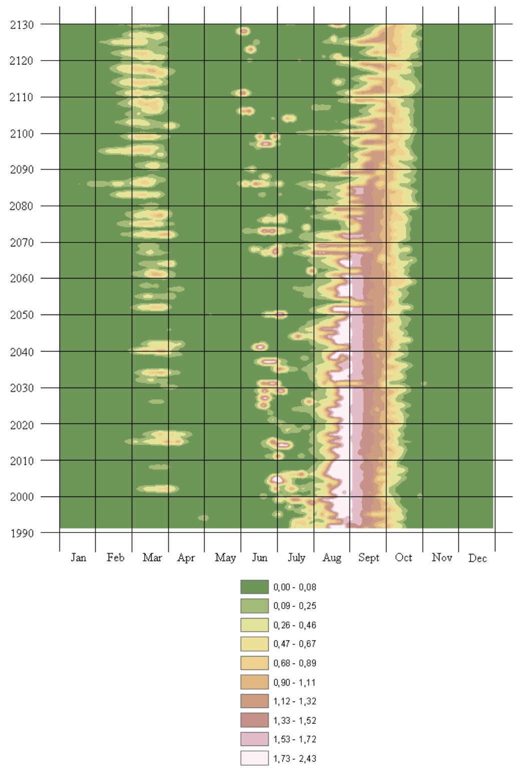

Figure 4b: The cooling effect (T(2)–T(3)) of the theoretical ecosystem from 1990 to 2130 with anthropogenic effect

Discussion

The ecosystems are important parts of the biosphere, they have an important role in the development and maintenance of the ecological equilibrium. The environment, the local and the global climate are affected by the ecosystems through the climate-ecosystem feedbacks.

During our simulation study it is investigated how the TEGM theoretical freshwater ecosystem model developed by us [5, 6] could affect the climate and the environment. It is found that the productivity of the ecosystem has changed annually and daily when the anthropogenic effect was taken into account.

The productivity correlates with the amount of the atmospherical CO_2, the growing greenery binds carbon from the air. In case where there is no anthropogenic effect the 'cooling' effect of the plants is up to 2.5 K dependent upon the seasons, months. Considering the amount of the anthropogenic carbon and the global warming it is stated that the 'cooling' effect of the living Earth, the plants decreases up to 1.3 K temperature after 100 years. This means that there will be maximum 1.2 K increase in temperature except for the anthropogenic warming due to the control ability of the plants for the climate. This result hangs together the issue investigated by Friedlingstein et al. [8]. They found that there is additional 0.1–1.5 °C warming by 2100 due to the feedback effect.

In the course of ecological modelling and biosphere research it is important to unravel much more the feedbacks and control processes to describe the function of the whole Earth.

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