CALCULATION OF THE ROLE OF INDOCHINA COUNTRIES IN GLOBAL WARMING AND ITS CONSEQUENCES IN THE WORLD

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Received: 11 June 2012, Accepted for publication: 8 November 2012

ABSTRACT

This paper presents the calculation of the change cycle Carbon dioxide (CO_2) in the global biosphere with the aid of spatial mathematical models. The absorption of CO_2 emissions from burning fossil fuels, deforestation, and soil erosion by terrestrial ecosystems have been calculated for all countries in the world, especially the countries of Indochina. The paper also provides several experiments to evaluate simulation results based on different scenarios of implementing the Kyoto Protocol. Thereby showing the Indochinese countries have a significant role in the absorption of CO_2 into the atmosphere, affecting ugly the Kyoto Protocol. The deforestation and soil erosion are the main causes..

Keywords: global warming, mathematical model, Kyoto protocol.

1. INTRODUCTION

The aim of this work is the mathematical modeling of the global carbon dioxide cycle and investigation of the role of the biosphere in the compensation impact of anthropogenic emissions of CO_2 to the global climate and calculation of the effects of warming in the countries of Indochina.

Calculations of dynamics of the biosphere processes taking into account the impact of economic activities of the world, countries and regions were performed with the aid of spatial mathematical model of the global carbon cycle in the system atmosphere - terrestrial ecosystems – ocean. This model was developed by A. M. Tarko and first published in 1982 in [1]; the results of modeling of the global CO_2 cycle then were published in the books [2 - 4].

In the model the land territory of the planet is divided into the cell size 0.5x0.5^o degrees of geographical grid. The model describes the processes of growth and decay of vegetation, accumulation and decomposition of humus in terms of exchange of carbon between the atmosphere, plants and soil humus in each cell. Anthropogenic emissions of CO_2 to the atmosphere from fossil fuels burning, deforestation (mainly tropical) and soil erosion, related to incorrect use of land are taken into consideration. An average annual temperature of the air at the earth's surface and the annual precipitation characterizes the climate in each cell.

To calculate CO_2 effects for given country or region makes necessity to take into account the total emissions of all countries over the world during long period and we must use a global spatial model for the whole planet.

The rest of paper includes the following sections; the second section presents mathematical model of problem. In the third section, the experimental results and conclusions were given.

2. DESCRIPTION OF THE MODEL

The spatial model of the global carbon cycle in the "Atmosphere – Plants – Soil" system (APS) was elaborated in [1, 2, 4]. In the model the land territory is partitioned into cells of size 0.5 × 0.5°. In each cell there is vegetation of one of the types corresponding to a given classification [5, 6]. The flow diagram of the model is shown in Fig. 1.

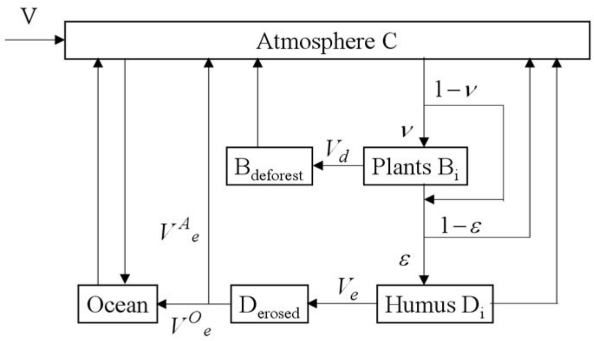

Figure 1. The flow diagram of the model.

The model is described by a system of ordinary nonlinear differential equations. In each cell of land, numbered i ($i = 1,..., I$), the ecosystem is characterized by the quantity of carbon per unit area in the phytomass of living plants B_i, and in soil humus D_i. The area of cell i is denoted by σ_i. The time unit in the model is one year. The total quantity of carbon in the atmosphere is denoted by C. The climate in cell i is characterized by annual surface temperature T_i, and annual precipitation P_i. The values of T_i and P_i depend on C (a greenhouse effect) and are calculated using a general circulation model [9].

It is assumed that annual production of vegetation in each cell i depends on C, as well as on the temperature T_i and precipitation P_i and does not depend on the ecosystem type in this cell. The rate of humus decomposition h is represented as a given function of T_i and P_i: $h = h(T_i,P_i)$.

The model takes into account three anthropogenic factors that affect the biosphere and result in the growth of CO_2. The first is fossil fuels burning or industrial emissions; we denote by V. The second factor is cutting down of the forests. The phytomass of the utilized forest biomass is decomposed with a certain delay; we denote by B_d the amount of carbon in the utilized forest biomass. The third factor is soil erosion resulting from the inappropriate land use. The dead organic matter is decomposed with a certain delay and goes to the atmosphere into the ocean; we denote by D_e the amount of carbon carried out due to the soil erosion.

The dynamics of carbon in APS is described by the following system of equations:

$$\begin{aligned}
&\frac{dB_i}{dt} = v_i Q_i - m_i B_i - k_d^i B_i, \forall i = 1,..., I \\
&\frac{dD_i}{dt} = \varepsilon(m_i B_i + (1-v_i)\, Q_i) - h(T_i, P_i)\, D_i - k_e^i D_i, \forall i = 1,..., I \\
&\frac{dB_d}{dt} = \sum_{i=1}^{I} (k_d^i B_i \sigma_i) - q_d B_d, \\
&\frac{dD_e}{dt} = \sum_{i=1}^{I} (k_e^i D_i \sigma_i) - q_e D_e - q_m D_e, \\
&\frac{dC}{dt} = -\sum_{i=1}^{I} ((1-\varepsilon_i)(m_i B_i + (1-v_i) Q_i) - h(T_i, P_i) D_i)\sigma_i + q_d B_d + q_e D_e + V, \\
&\sum_{i=1}^{I} \left(\frac{dB_i}{dt} + \frac{dD_i}{dt} \right)\sigma_i + C + \frac{dB_d}{dt} + \frac{dD_e}{dt} = V
\end{aligned} \qquad (1)$$

here $Q_i = Q(C, T_i, P_i, B_i), \forall i = 1,..., I$ is annual production of the plants per unit area in cell number *i*, and $m_i, \varepsilon_i, k_e^i, k_d^i, q_d, q_e, q_m$ are coefficients.

There are two expressions for dependence of annual net primary production. The first was suggested by Keeling C. D. (see [7]). In this case annual production depends on the concentration of CO_2 in the atmosphere and on the vegetation phytomass:

$$Q = F_o(1 + \beta \ln(C/C^o))(B/B^o)^{2/3} \qquad (2)$$

here F_o is annual production for the initial state, *B* is the vegetation phytomass, expressed in carbon units C^0, B^0 are initial values of the corresponding variables, and β is a coefficient.

The second dependence was developed by Tarko A. M. (see [8]). Here annual production depends on the concentration of the atmospheric CO_2 and does not depend on the phytomass:

$$Q = F(T, P)(1 + \frac{\delta}{10}(C / C^o - 1)) \qquad (3)$$

The function $F(T,P)$ expresses a nonlinear dependence of annual production on the temperature and precipitation. This dependence was received by statistical data processing [4].

The model has been complemented by the model of the carbon cycle in the ocean - atmosphere system [10]. It is supposed, that in the absence of anthropogenic emissions of CO_2 into the atmosphere the amount of carbon in the system atmosphere - plants - soil - ocean is constant and that prior to the beginning of anthropogenic influences the system was in a steady state.

A computer program was developed to simulate the model. For the 0.5×0.5^o resolution the model involves around 80,000 terrestrial cells and around 160,000 equations. For simulations, the initial values for the phytomass in the cells were taken from [6].

3. EXPERIMENTAL RESULTS AND CONCLUTIONS

3.1. Biosphere dynamics under the impact of industrial CO_2 emissions, deforestation, and soil erosion

The above model was used to simulate the dynamics of the “Atmosphere − Terrestrial Ecosystems − Ocean” system in 1860 − 2100 under industrial releases, deforestation and soil erosion. Deforestation and subsequent destruction of tropical forest phytomass takes place in 1950 − 2100. The rate of reduction of tropical forests equals to 0.6 % per year. Soil erosion begins in 1860 and increases with the rate of 0.2 % per year. Annual industrial releases in 1860 − 2008 are simulated using data [11]. In the period following 2008 the industrial emissions are set as to average over ten pervious years (1.68 % per year).

Calculations show that during 1860 - 2100 the atmospheric CO_2 increases 2.2 times. Increase of CO_2 in the atmosphere contributed to the increase in productivity of vegetation and growth of plants. Terrestrial ecosystems and the ocean, absorbed part of the surplus of CO_2 and generally slow down atmospheric growth, showing a compensatory properties of the biosphere.

3.2. Carbon dioxide budget of countries in 2008

Carbon budget is defined as annual production minus industrial emissions, minus humus decomposition, minus deforestation, and minus soil erosion. Fig. 2 shows carbon budget of 21 countries, which are the greatest “producers” of industrial CO_2 releases in 2008. The greatest industrial emissions in 2008 went from the China, USA, India and Russia. In the majority of the countries industrial emissions exceed the ecosystems’ absorption. This year ecosystems of Russia absorbed CO_2 more than any other countries.

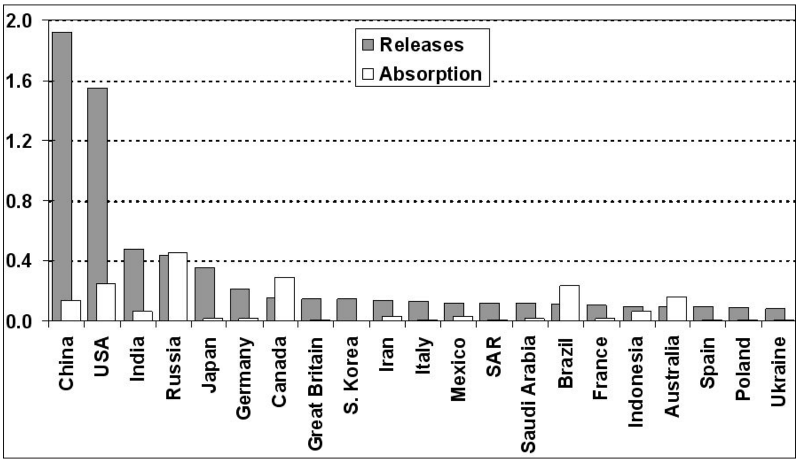

Figure 2. Industrial emissions of countries, which are its major CO_2 producers, and carbon absorption by ecosystems in 2008 (Gt C/ year).

Thus we can conclude that the greatest CO_2 releasers come from two of the most industrialized countries (USA, Japan) and two countries with the largest population (China, India). In 2008 these countries have allocated 52 % of the total CO_2 emissions. Therefore, these countries, and not Russia, which CO_2 balance is positive, are mostly responsible for the fast CO_2 growth in the atmosphere.

Let us look at carbon budget of seven Indochina countries - Bangladesh, Cambodia, Laos, Malaysia, Myanmar, Thailand, and Vietnam in 2008 (Fig. 3). We see that CO_2 emissions of these countries are about 10 % of the above-mentioned largest releasers. The greatest industrial emissions go from the Thailand, Malaysia, and Vietnam. In the majority of the countries industrial emissions exceed the ecosystems' absorption. Other countries of region were CO_2 absorbers.

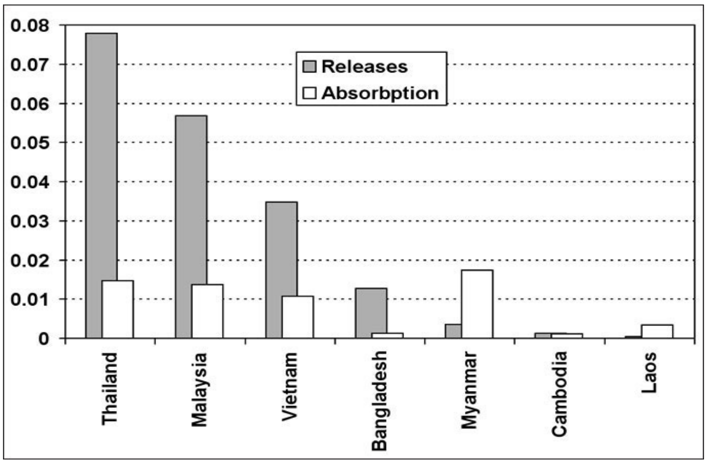

Figure 3. Comparison of industrial CO_2 emissions and carbon absorption by ecosystems in countries of Indochina in 2008(Gt C/ year).

3.3. Estimation the variants of implementation of the Kyoto Protocol to the UN framework convention on climate change

According to the Kyoto protocol to UN Framework Convention on Climate Change countries by 2010 were to reduce emissions of greenhouse gases in the atmosphere to a level of 5 % below the industrial CO_2 emissions in 1990. Not all countries participate in the implementation of the protocol.

We calculated, what effect could give different restrictions, leading to a reduction of CO_2 emissions. In Fig. 4 presents the results of calculations of dynamics of carbon dioxide in the 1860-2060. The following scenarios were considered:

1. above the baseline scenario of anthropogenic impacts ("Main scenario"),
2. scenario 1, after 2010 deforestation and soil erosion shall be terminated ("Deforestation and erosion finished"),
3. scenario 1, after 2010 the Kyoto protocol except the USA is fulfilled by all countries ("Nonparticipation of USA"),
4. scenario 1, after 2010 Kyoto protocol is performed by all the participating countries ("Kyoto protocol 1997"),
5. scenario 1, after 2010 all countries of the world are performed the UN Framework Convention on Climate Change, i.e. every country of the world reduces CO_2 emissions to the values at the 5 % less than the level of 1990 ("Framework convention 1992"),
6. scenario 1, after 2010 all the countries except countries of Indochina perform the Kyoto protocol. Values of CO_2 releases in Indochina countries are equal to simple exponential forecast, which is based on real growth of emissions ("Realistic releases of Indochina countries").

It should be noted that seven countries of Indochina have large growth of CO_2 emissions to the atmosphere and relatively large values of industrial emissions. Also these countries have high values of growth of Gross Domestic Product (GDP) and large level and rate of growth of population. Exponential estimation of forthcoming level of CO_2 emissions to the atmosphere shows that these emissions in several decades will become very large. To implement CO_2 emissions of Indochina countries in scenario 6 results there were used results of mentioned estimation.

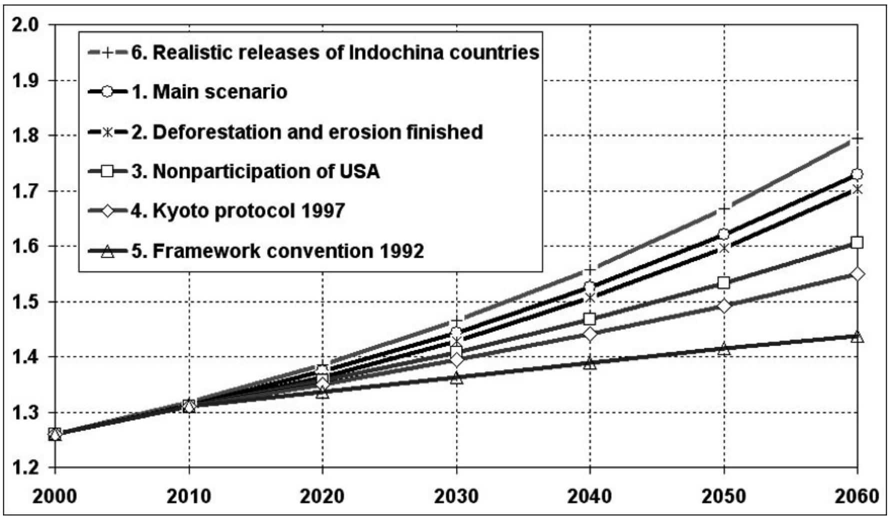

Figure 4. Simulation results of the variants of Kyoto Protocol scenarios. The dynamics of the values of carbon in the atmosphere are shown relative to 1860 from 2000 till 2060. In the legend, the figures designate number of scenarios.

Model calculations show the following effects. In accordance with scenario 1 the concentration of CO_2 in the atmosphere will rise to 2060 by 1.73 times, compared to the year 1860. The impact of the cessation of deforestation and erosion gives the weakest effect. Implementation of Kyoto protocol leads to the fact that the concentration of CO_2 in the atmosphere will rise up to the value of 1.55. Decreasing effect in relation to the baseline scenario will be 0.18, which is not very great. The effect of the refusal of the USA to participate in the implementation of the Protocol would result in to the value of 1.61. The most significant impact in slowing down the growth of CO_2 would implement the Framework Convention: the CO_2 concentration would increase by 1.44, that is to 0.49 less than in the baseline scenario. However, this scenario the world community is not still taken.

In scenario 6, when there is a fast increase of CO_2 emissions in Indochina countries (1.79), it will be highest CO_2 growth, even by 0.06 more than the baseline scenario.

Therefore, we see that the effect of the implementation of the Kyoto protocol will give small limiting of CO_2 growth and taking into account the scenario 6 we can expect the opposite effect - even greater growth of concentration in the atmosphere, which negates the purpose of the implementation of the Protocol. Nevertheless, there is no doubt that the role of the accepted limitations will be especially important for the transformation of the economy in the world and for increasing the efficiency of energy resources. The only reliable way for restriction of forthcoming significant increase of CO_2 emissions is free distribution of advanced energetic technologies for countries of Indochina and other countries.

3.4. Regional consequences in Indochina

On the study the regional impacts of global warming and land use in the countries of Indochina it was carried out the analysis of changes of phytomass and humus and changes in the amount of carbon under the influence of industrial CO_2 emissions, deforestation (tropical forests) and humus. Quantity of humus was changed because of soil erosion, related to incorrect use of land, and in the result of regional climate change.

The calculations were carried out during the above-mentioned simulating experiment at and there were chosen countries of Indochina - Bangladesh, Cambodia, Laos, Malaysia, Myanmar, Thailand, and Vietnam. Carbon changes in phytomass and humus in these countries during 2000 - 2060 were under investigation. The results of calculations from 2000 to 2060 are presented in Figs. 5 - 7.

Figure 5 shows change of phytomass of countries as a percentage of the value of 2000. We see a growth of phytomass in all countries. Despite significant tropical deforestation in these countries, the growth of CO_2 concentration and temperature leads to an increase in annual production and phytomass. The greatest increase in the phytomass is happening in Malaysia.

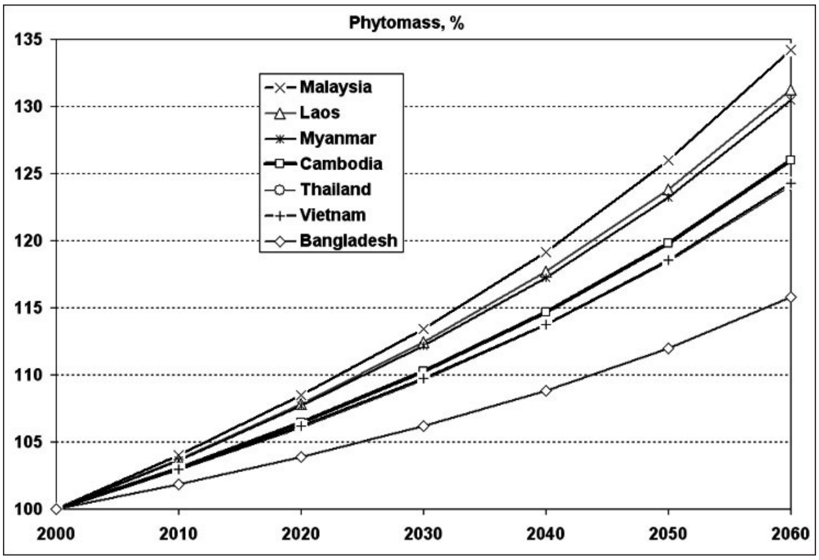

Figure 5. The change of carbon in phytomass (%) in the countries of Indochina during 2000 - 2060. Here 100 % relates to 2000. Thailand and Vietnam give practically one curve. Their difference in 2060 is no more than 0.2 %.

Figure 6 shows the changes of the amount of soil humus in 2000 - 2060. We see the decrease of humus in all considered countries in the beginning of 2000th However, in Malaysia, after 2040 - 2050 we see the increase of quantity of humus up to values more that was in 2000. Quantities of humus in Bangladesh, Myanmar, and Vietnam by 2050 - 2060 are slightly being increased. In Laos and Cambodia decreasing does not stop by 2060.

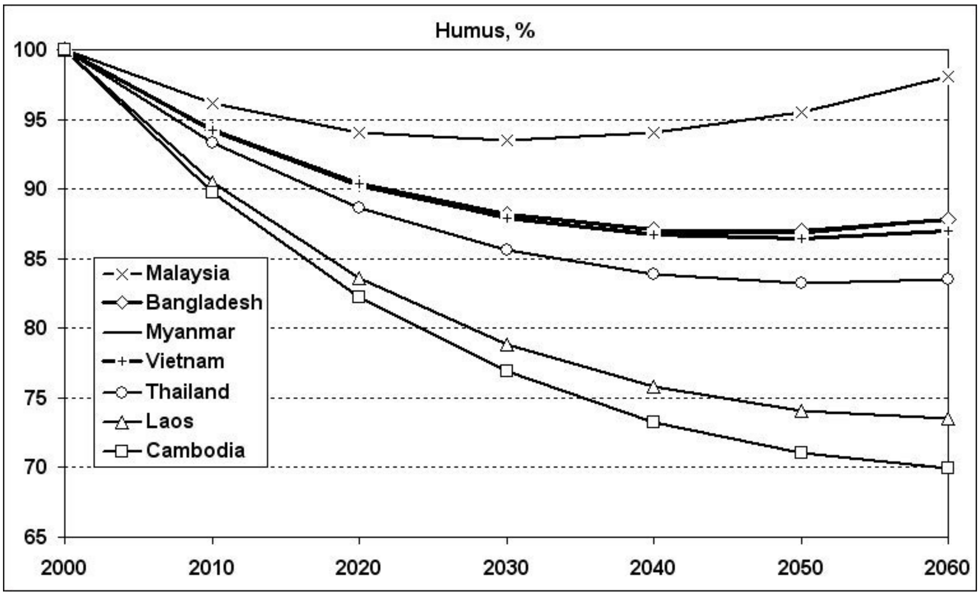

Figure 6. The change of carbon in humus (%) in the countries of Indochina during 2000 - 2060. Here 100 % relates to 2000. Bangladesh and Myanmar give practically one curve. Their difference in 2060 is no more than 0.1 %.

The change of total quantity of carbon in phytomass and humus in 2000-2060 in the countries is presented in Fig. 7. In all countries after several years of decrease of the quantity we see that values are being increased. The greatest growth of carbon in 2060 is happening in Malaysia, the lowest - in Cambodia. Vietnam occupies the 3rd place.

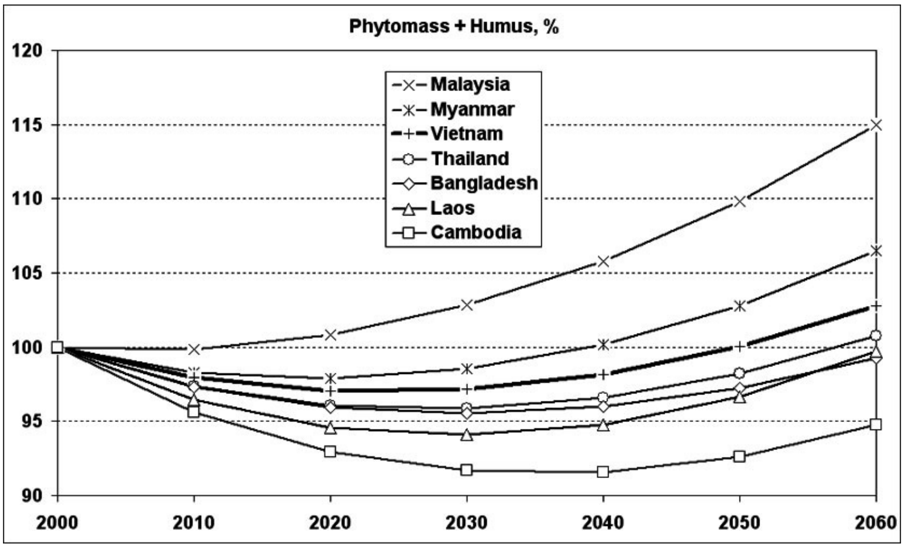

Figure 7. The change of sum of phytomass and humus carbon (%) in the countries of Indochina during 2000-2060. Here 100% relates to 2000.

Acknowledgment. This work was supported by Russian Foundation for Basic Research (RFBR), Projects 11-01-93003-Viet_a and 11-01-00575-a; and by a funding of Vietnam Academy of Science and Technology, Project No.5, VAST_RFBR 2011/2012.

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TÓM TẮT

TÍNH TOÁN ĐỂ ĐÁNH GIÁ VAI TRÒ CỦA CÁC NƯỚC ĐÔNG DƯƠNG TRONG BIẾN ĐỔI KHÍ HẬU TOÀN CẦU VÀ HẬU QUẢ CỦA NÓ TRÊN THẾ GIỚI

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Bài báo trình bày những tính toán về chu kì biến đổi carbon dioxide (CO_2) toàn cầu trong sinh quyển với sự trợ giúp của các mô hình toán học. Sự hấp thu khí thải CO_2 do đốt nhiên liệu hóa thạch, nạn phá rừng, xói mòn đất bởi các hệ sinh thái trên cạn đã được tính toán cho tất cả các nước trên thế giới, đặc biệt là các nước Đông Dương. Bài báo cũng đưa ra một số thí nghiệm mô phỏng để đánh giá hậu quả dựa trên các kịch bản khác nhau của việc thực hiện Nghị định thư Kyoto. Qua đó cho thấy các nước Đông Dương có vai trò đáng kể trong việc hấp thụ khí thải CO_2 vào bầu khí quyển, làm ảnh hưởng đến Nghị định thư Kyoto. Trong đó nguyên nhân chủ yếu làm ảnh hưởng đó là nạn phá rừng và sự xói mòn đất.

Từ khoá: ấm lên của khí hậu, mô hình toán học, Nghị định thư Kyoto.