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WHAT IS NEGATIVE ENTROPY AND HOW DOES IT AFFECT THE SUSTAINABILITY OF REGIONS DURING THE WARFARE.

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The impact of warfare in one region on other regions is shown using the base fundamental thermodynamics laws and trends of decreasing entropy. The physical sense of the negentropy is described use of the principles of chemical thermodynamics. A phenomenological model for the description impact of warfare on the ecological part of the region is proposed. According to this model, a system without plants, with destroyed soils, can't be alive without external factors. Based on thermodynamic differences between turbulent and laminar flows, the capability of the zones formation with an absence of the ability to any own functioning outside zone with military actions is shown. With the rising number of influencing factors, especially in large areas, the probability of narrowing and loss of zones with a stable state as in the region with military action but in neighboring regions increases.

Keywords: negentropy, warfare, sustainability, thermodynamics, open system, environment.

INTRODUCTION. The concept of sustainable development has prevailed in modern society since 1992, which was declared in Rio as «Rio declaration on Environment and Development∫, (Rio declaration) of the United Nations Conference on Environment and Development (UNCED) in June 1992. The Principles of the Rio conference were made concrete in Agenda 21, the comprehensive plan of action for the 21st century which was adopted by more than 170 governments [1,2]. Such principles are 27 (Table 1).

Table 1. Principles of sustainable development and their background [3]

N⁰	Principle	Background
1	Human beings are at the center of concerns for sustainable development	They are entitled to a healthy and productive life in harmony with **Nature**
2	States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental and developmental	Do not cause damage to the **environment** of other States or of areas beyond the limits of national jurisdiction.

	policies, and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction.	
3	The right to development must be fulfilled so as to equitably meet developmental and environmental needs of present and future generations.	**Environmental** needs of present and future generations
4	In order to achieve sustainable development, environmental protection shall constitute an integral part of the development process and cannot be considered in isolation from it.	**Environmental protection** shall constitute an integral part of the development process and cannot be considered in isolation from it
5	All States and all people shall cooperate in the essential task of eradicating poverty as an indispensable requirement for sustainable development, in order to decrease the disparities in standards of living and better meet the needs of the majority of the people of the world.	Eradicating **poverty** is an indispensable requirement for sustainable development, in order to decrease the **disparities in standards of living** and better meet the needs of the majority of the people of the world.
6	The special situation and needs of developing countries, particularly the least developed and those most environmentally vulnerable, shall be given special priority.	International actions in the field of **environment** and development should also address the interests and needs of all countries.
7	States shall cooperate in a spirit of global partnership to conserve, protect, and restore the health and integrity of the Earth's ecosystem. In view of the different contributions to global environmental degradation, States have common but differentiated responsibilities. The developed countries acknowledge the responsibility that they bear in the international pursuit of sustainable development in view of the pressures their societies place on the global environment and of the technologies and financial resources they command.	States shall cooperate in a spirit of global partnership to conserve, protect, and restore the health and integrity of the **Earth's ecosystem**.
8	To achieve sustainable development and a higher quality of life for all people, States should reduce and eliminate unsustainable patterns of production and consumption and promote appropriate demographic policies.	States should reduce and **eliminate unsustainable** patterns of production and consumption and promote appropriate **demographic policies**.
9	States should cooperate to strengthen endogenous capacity building for sustainable development by improving scientific understanding through exchanges of scientific and technological knowledge, and by enhancing the development, adaptation, diffusion, and transfer of technologies, including new and innovative technologies.	Common building for sustainable development by improving **scientific** understanding through exchanges of scientific and technological knowledge

10	Environmental issues are best handled with the participation of all concerned citizens, at the relevant level. At the national level, each individual shall have appropriate access to information concerning the environment that is held by public authorities, including information on hazardous materials and activities in their communities, and the opportunity to participate in decision-making processes. States shall facilitate and encourage public awareness and participation by making information widely available. Effective access to judicial and administrative proceedings, including redress and remedy, shall be provided.	At the national level, each individual shall have appropriate access to information concerning the **environment** that is held by public authorities, including information on hazardous materials and activities in their communities, and the opportunity to participate in decision-making processes
11	States shall enact effective environmental legislation. Environmental standards, management objectives, and priorities should reflect the environmental and developmental context to which they apply. Standards applied by some countries may be inappropriate and of unwarranted economic and social cost to other countries, in particular developing countries	**Environmental** standards, management objectives, and priorities should reflect the environmental and developmental context to which they apply.
12	States should cooperate to promote a supportive and open international economic system that would lead to economic growth and sustainable development in all countries, to better address the problems of environmental degradation. Trade policy measures for environmental purposes should not constitute a means of arbitrary or unjustifiable discrimination or a disguised restriction on international trade. Unilateral actions to deal with environmental challenges outside the jurisdiction of the importing country should be avoided. Environmental measures addressing transboundary or global environmental problems should, as far as possible, be based on an international consensus.	To promote a supportive and open international **economic** system that would lead to economic growth and sustainable development in all countries, to better address the problems of **environmental** degradation.
13	States shall develop national law regarding liability and compensation for the victims of pollution and other environmental damage. States shall also cooperate in an expeditious and more determined manner to develop further international law regarding liability and compensation for adverse effects of environmental damage caused by activities within their jurisdiction or control to areas beyond their jurisdiction.	To develop national and international law regarding liability and compensation for the victims of pollution and other **environmental** damage.

14	States should effectively cooperate to discourage or prevent the relocation and transfer to other States of any activities and substances that cause severe environmental degradation or are found to be harmful to human health.	Cooperation to discourage or prevent the relocation and transfer to other States of any activities and substances that cause severe **environmental** degradation or are found to be **harmful to human health**.
15	In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation	To protect the **environment** and to prevent **environmental** degradation
16	National authorities should endeavor to promote the internalization of environmental costs and the use of economic instruments, taking into account the approach that the polluter should, in principle, bear the cost of pollution, with due regard to the public interest and without distorting international trade and investment.	To promote the internalization of **environmental costs** and the use of economic instruments
17	Environmental impact assessment, as a national instrument, shall be undertaken for proposed activities that are likely to have a significant adverse impact on the environment and are subject to a decision of a competent national authority	**Environmental** impact assessment
18	States shall immediately notify other States of any natural disasters or other emergencies that are likely to produce sudden harmful effects on the environment of those States. Every effort shall be made by the international community to help States so afflicted.	**Environmental** security
19	States shall provide prior and timely notification and relevant information to potentially affected States on activities that may have a significant adverse transboundary environmental effect and shall consult with those States at an early stage and in good faith.	Transboundary **environmental** effect and **environmental** security
20	Women have a vital role in environmental management and development. Their full participation is therefore essential to achieve sustainable development.	Gender **policy**
21	The creativity, ideals and courage of the youth of the world should be mobilized to forge a global partnership in order to achieve sustainable development and ensure a better future for all.	The place of youth in sustainable development, youth **policy**

22	Indigenous people and their communities and other local communities have a vital role in environmental management and development because of their knowledge and traditional practices. States should recognize and duly support their identity, culture and interests and enable their effective participation in the achievement of sustainable development.	
23	The environment and natural resources of people under oppression, domination and occupation shall be protected	Indigenous people **policy**
24	Warfare is inherently destructive of sustainable development. States shall therefore respect international law providing protection for the environment in times of armed conflict and cooperate in its further development, as necessary.	To protect **environment** in times of warfare
25	Peace, development and environmental protection are interdependent and indivisible.	**Peace**, development, and **environmental** protection are interdependent and indivisible.
26	States shall resolve all their environmental disputes peacefully and by appropriate means in accordance with the Charter of the United Nations.	To resolve **environmental** disputes peacefully
27	States and people shall cooperate in good faith and in a spirit of partnership in the fulfilment of the principles embodied in this Declaration and in the further development of international law in the field of sustainable development.	To further development of international **law** in the field of sustainable development.

If you look at these principles, there are only seven from twenty-seven, which would not mention the environment. Moreover, the twenty-four principles are like a non-understanding declaration. There are no differences between international warfare, military action, and national military conflicts. And, from my point of view, such a definition creates some difficulties to resolved environmental problems and problems of region's sustainability. The question arises why? The answer to these questions is the purpose of my work.

SUSTAINABLE DEVELOPMENT AND NEGENTROPY IN OPEN NONEQUILIBRIUM SYSTEMS. Let's start from the basic principles of thermodynamics for open nonequilibrium systems (including all ecological systems). It is nessesary to understand thier ability to sustanable development. At the beginning of the 20th century, V.I. Vernadsky introduced a term named negative entropy [4], the physical meaning of which was improved in the works of E. Schrödinger [5,6], I.R. Prigogine [7], Klimontovich [8,9] and others [10,11]. Such

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works were based exclusively on classical physical parameters: temperature, pressure, energy, and such a statistically distributed parameter as entropy. But to consider macroscopic phenomena, only entropy allows us to statistically describe the degree of chaos and ability of the closed system for independent existence.

The classical form of the second law of thermodynamics connects entropy with the measure of heat transferred to the system.

$$dQ = TdS \quad (1)$$

According to this law, heat tends to dissipate spontaneously. Dissipation of heat is the base of entropy changes [12].

Boltzmann gave the following formulation of entropy:

$$S = k \cdot lnW, \quad (2)$$

$k=R/N_A = 1.38 \cdot 10^{-23}$ J / K – the Boltzmann constant, W – the number of microstates that realize the macrostate, R – the universal gas constant.

This equation is the base for such allegations: 1 – the most probable state of the least probable state of an isolated system is spontaneously realized, 2 – the most uniform distribution leads to the maximum values of entropy, 3 – the entropy of a fully ordered system is zero. However, Boltzmann equation (2) can't answer the questions: why entropy must be negative? What does it mean? There are two answers to these questions: first, in all chemical and biochemical transformations in the global planetary ecosystem, heat is transferred primarily from the hot sun to the cold Earth, in which case the negative sign reflects the direction of the process [10–11]. Secondly, there is a conclusion from the second law of thermodynamics, which regulates the spontaneous realization of any chemical reaction under constant temperature and pressure and, at the same time, reflects the influence of enthalpy and entropy on the direction of chemical processes. This factor is the change in the Gibbs free energy ΔG:

$$\Delta G = \Delta H - T\Delta S. \quad (3)$$

The Gibbs energy is attributed to 1 mol of substance and is expressed in kJ / mol. For isobaric-isothermal processes, ΔH – is an enthalpy factor; TΔS is an entropic factor.

The ΔG of the most stable modification of the formation of a simple substance is taken equal to zero. At constant temperature and pressure, chemical reactions can proceed spontaneously only in the direction in which the Gibbs energy of the system decreases (ΔG < 0).

Thus, if ΔH <0 (exothermic reaction) and S>0 (entropy increases), it follows from equation (3) that at all temperatures – ΔG <0. It means that the reaction can proceed spontaneously at any temperature. Such reactions include almost all oxidation and respiration reactions.

If ΔH <0 and ΔS <O, the reaction is possible provided when the absolute value of negative ΔH in the equation for the Gibbs energy is greater than the entropy factor TΔS. Such conditions are realized either at sufficiently low temperatures or under the influence of other factors that significantly increase the system's entropy and are closely connected to the presence of any radiation, including the solar radiation or catalytic reactions involving enzymes.

If ΔH> 0 and ΔS> 0, the reaction is possible provided that TΔS is greater in absolute value than ΔH, and this is realized at sufficiently high temperatures. At high temperatures, the reactions often are to be accompanied by

an increase in entropy. The values of ΔH, ΔS, and ΔG depend on the nature of substances, their physical state, and concentrations.

Thus, the negative value of entropy is a more formalized name for the system's state, which indicates an exaggeration of the entropy factor over the enthalpy. The same exaggeration lies in the base of existing of life. In a global sense, it allows us to talk about the extraordinary impact of living matter on planetary processes, their development, and the stability of existence and development of the biosphere [4]. Especially, to the part of the biosphere that is associated with the production of organic matter using carbon dioxide. Let's consider terrestrial ecosystems. These ecosystems are the largest significant global sinkers of carbon dioxide, besides the oceans [13]. About 120 Pg C · a^{-1} (Pg = 10^{15}g) CO_2 is absorbed annually on our planet due to the terrestrial part of plants, but since 1999 there has been a significant loss of biologically fixed carbon against the background of increasing CO_2 emissions [13]. However, the global carbon cycle and the environmental processes that contribute to it are not sustainable but rather highly dynamic. This dynamic realizes due to many factors, which makes it difficult to model the distribution and binding of CO_2 [14]. Moreover, some factors are completely unpredictable – it is a criminal human activity aimed at destroying ecosystems, especially large ecosystems (forests and steppes) with large amounts of plant biomass, which is involved in the fixation of atmospheric carbon dioxide. The most unpredictable and dangerous factors are military action, which leads not only to the physical destruction of sustainable ecosystems, which can take decades to recover but also a local increase in combustion products containing large amounts of CO_2, nitrogen compounds that destroy the ionosphere, namely planetary Ozone Layer [15]. It should be noted, that soil destruction due to fires lead to increased dissipation of CO_2, CH_4 and N_2O through microbial activity between the atmosphere and soils. The maximum increase in these flows is observed in the burned soils of spruce. Thus, in burned forests, microbial respiration can supply additional carbon dioxide of approximately 14.7 t C / ha, which in terms of CO_2 is 44.1 t / ha and can last for at least ten years [16]. Therefore, warfare, even in a small area, can not only simultaneously increase greenhouse gas emissions by hundred times and remains a source of additional CO_2 emissions into the atmosphere for decades. A simple calculation of such emission in an area of 100 km^2 for ten years has additional $4.41 \cdot 10^6$ tons of carbon dioxide without other sources of its incoming. Thus, a system that has not any plants and destroyed soils already enters a state where it is impossible to implement oxidation or respiration reactions $\Delta H < 0$. Under destruction of the balance of CO_2 binding (photosynthesis reaction) with its reverse emission during respiration, the ΔS of such a system becomes state with $\Delta S < 0$. Such system begins to be in the state, where it cannot exist on its own (lost ability to spontaneous chemical reactions) without additional factors.

THE ECOLOGICAL OPEN SYSTEM IN LAMINAR AND TURBULENT STATE. Now, look at such an ecosystem in terms of the thermodynamics of open systems, in which the changing of entropy is the main parameter. In open systems, the changing of entropy (ΔS) is a measure of chaos. They do have not a concept of energy, but there is a concept of effective energy (E_{eff}), which is a function of the distri-

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bution of physical chaos. Analytically, this is an effective Hamiltonian (H_{eff}):

$$H_{eff} = -lnf_0 \ . \quad (4)$$

However, when changing the control parameter of the system, this function is not preserved in most cases [9, 12]. Therefore, to use the entropy difference $\Delta S = S_0\text{-}S_1$ to estimate the degree of the chaos at the system, it is necessary to replace the functions f_0, S_0 with normalized or renormalized functions [8, 9]. Consider a simple two-component system in which the state of complete physical chaos coincides with the equilibrium state (in the thermodynamics of ecological systems, this state considered as the death of such a system). Then in a two-component system (temperature and concentration of CO_2 (vapor pressure)) renormalization is carried out exclusively by changing the temperature:

$$\int H_{eff}\overrightarrow{f_0}(X, a = a_0)dx = \\ = \int H_{eff}f_1(X, a = a_1)dx. \quad (5)$$

In the case of the correct choice of equilibrium, $\vec{T}(a) \geq T$, that is, to maintain states in which $a = a_0$, the system needs additional heat. When using the Gibbs distribution for the renormalized function $\overrightarrow{f_0}$ for the Boltzmann equation transforms to:

$$\overrightarrow{f_0}(x) = exp\frac{F_{eff}(\vec{T}) - H_{eff}(x)}{k\vec{T}} \quad (6)$$

the Boltzmann – Gibbs – Shannon entropy equation [8, 9] already includes two renormalizable functions ie this state is non-equilibrium:

$$\overrightarrow{S_0} = -\int ln\left(\bar{f}_0(X)\right)\bar{f}_0(X)dx. \quad (7)$$

As the number of variable parameters increases, the deviation from this state should increase, but only under conditions if H_{eff} is constant. It is the case when dynamic instability and exponential trajectory divergence under conditions of uncontrolled external influences allow trajectories to mix in phase space. It means the formation of the conditions for a "continuous medium". Such media is the background for aligning parameters at infinitesimal scales. So, ΔS will be defined as:

$$\overrightarrow{S_0} - S_1 = -\int \left(ln\frac{f_1(x)}{\bar{f}_0}\right)f_1(x)dx \geq 0 \ , \quad (8)$$

$$\vec{T}(a) \geq 1.$$

It is a formal description of the effect of temperature on the increase in the entropy of the system and testifies the low informativeness of the Boltzmann H-theorem [17] without taking into account the direction of components' movement of the system and its ability to create of certain internal structures [10]. To describe these phenomena, concepts of the degradation and self-organization are used. They based on the possibility of normalizing chaos with the S-theorem [8, 9]. In many cases, the degree of the chaos of the ecological system does not provide an answer about its state (degradation or self-organization). Because the capability to live in ecological systems does not base on the thermal equilibrium. It bases on the ability to fluctuate near a state with a certain degree of chaos. Therefore, the degree of chaos is a necessary factor, but not sufficient [8–12, 18]. In this case, it proposes to use additional parameters, namely the direction of movement and the type of movement The paper [8] presents rather interesting calculations of the degree of chaos in water under turbulent and

laminar flow conditions. Calculations indicate the appearance of the new structures of water (Bernall – Fowler cells) in the turbulent flow [19]. Such structures significantly decrease the entropy in turbulent flow relatively to laminar flow. It means, that turbulence is a factor that forms new structures in the "continuous media' and decreases the full entropy of system. Why? If the laminar flow is selected as a level of physical chaos, the role of effective Hamiltonian plays the middle kinetic energy of the laminar flow. According to Boltzmann law, to fulfilling the equilibrium between kinetic energies of laminar and turbulence flows, the laminar flow must be "heated", i.o. that flow needs an energy dotation.

$$k_B T_{lam} = k_B T_{turb} + \frac{m}{3}\langle(\delta u)^2\rangle \gg k_B T_{turb} \,. \quad (9)$$

In this case, the temperature difference determined as a sum of squared diagonals of the Reynolds stress tensor. However, the Reynolds stresses have collective degrees of freedom, and part of the laminar flow is replaced by collective degrees of freedom in the transition to turbulent:

$$T(S_{lam} - S_{turb})\frac{mn}{2}\langle(\delta u)^2\rangle \geq 0. \quad (10)$$

So, by increasing the degree of the turbulence system loses entropy and changes the degree of chaos.

From another hand, changing the properties of one "continuous media" forms the new "continuous media" with lower entropy as in the nonequilibrium second genus phase transformation. It means that such a system generates gradients of energy and mass transfers (fig. 1). In this case, we can't use only thermodynamics parameters due to the formation of kinetics components. That is why, for saving the thermodynamics conditions, it is necessary to change the gradients into tensors for a linear multicomponent algebraic object in a vector space of finite dimension.

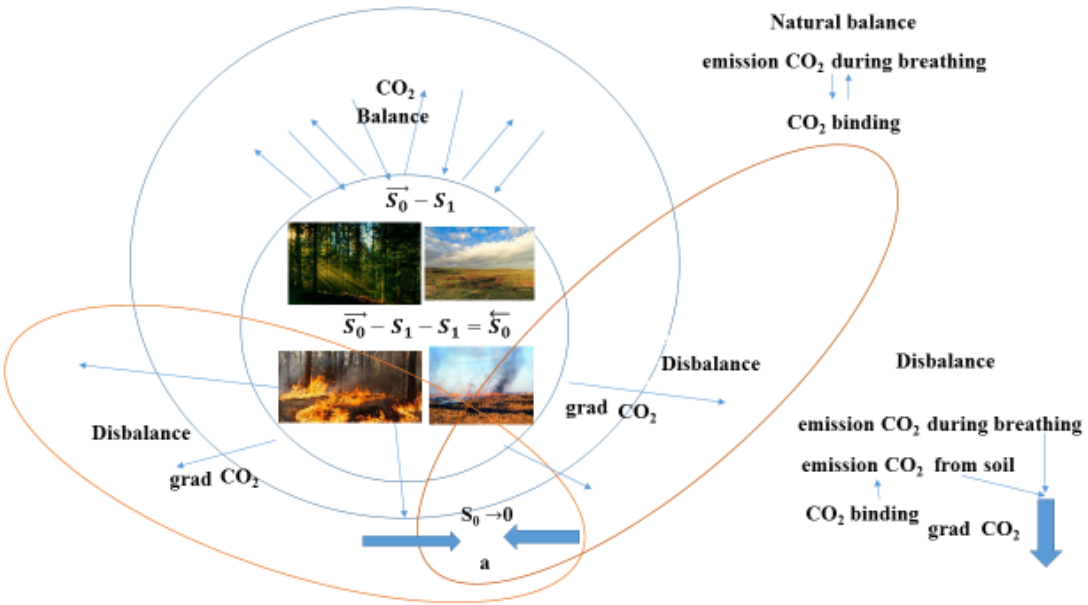

Fig.1. Scheme of turbulent flows impact after burning on the formation of entropy decrease gradients for ecological system.

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Taking into account the presence of the sum of squared diagonals of the Reynolds stress tensor, in this case, there may generate a new system of coordinates that can have counter tensors. The presence of such tensor, according to Einstein's rule, increases the distance of impact. From another hand, the counter tensor in equation 8, should reduce entropy to the side of the zero value (fig.1 a). So, the system loses chaos and moves to the side of an equilibrium state.

At the same time, increasing the distance of impact raises the probability of the formation zone with low entropy located outside the region where there were turbulent phenomena. Thus, the presence of only one territory with direct fluxes of chemical compounds (in our case – carbon dioxide) leads to environmental consequences, which form a region with minimal entropy (the region without the capability to recover by itself). So, the level of entropy loss is the factor assigning the level of destroy the ecological system.

THE MODEL OF THE REGION DURING AND AFTER WARFARE. Now let's look at the sustainable state model of any region (fig. 2). This state is formed by the equiprobable overlap of the three components (ecology, economy, and social sector) [20]. Such overlap can take place only in the case of the spherical symmetry of these components. In this case, a certain area is formed with a uniform overlap of these states (Table1, fig. 2, a).Violation of such symmetry in the basic ecological system leads to the destruction of the model of sustainable development in the region with warfare. And also sharply increases the likelihood of violation of the such development in neighboring regions (fig. 2, b).

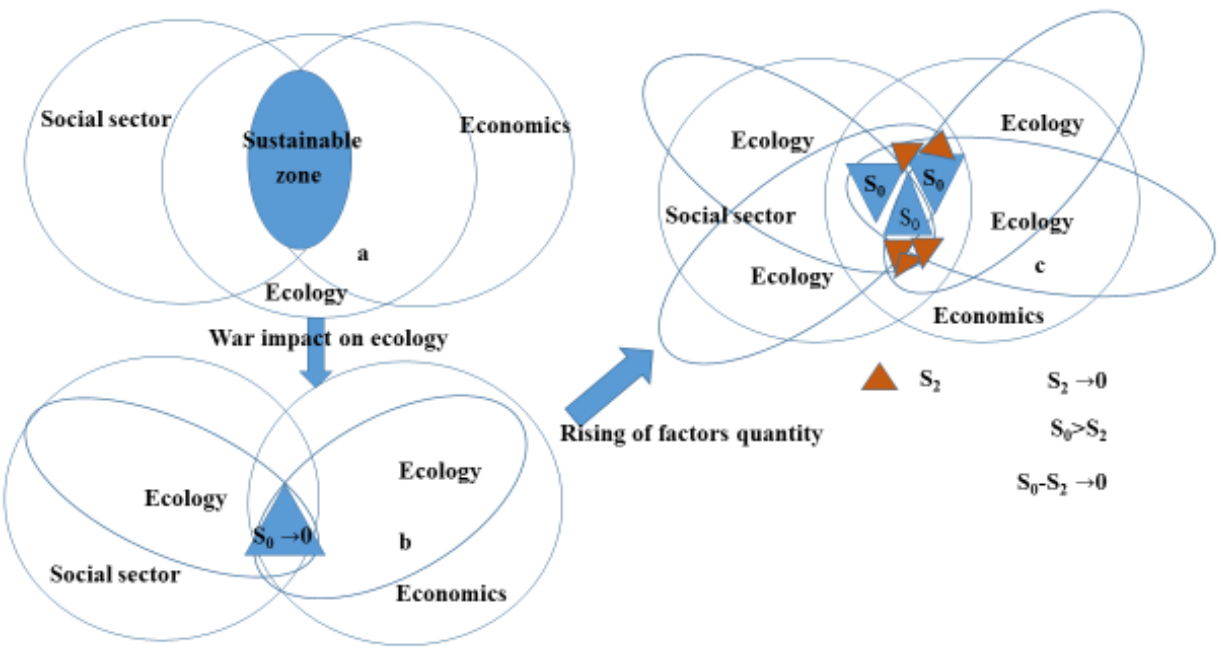

Fig. 2. Scheme of changing the model of sustainable state of the region under warfare, taking into account two and four factors of influence.

What happens to the environmental component of such a system in the presence of only fires due to hostilities. It leads to the loss of spherical symmetry of the ecological base and the appearance of areas with low entropy All this leads to a loss of the possibility of forming any stable zone (Fig. 2, b). With increasing the number of factors (such as nitrogen compounds or other toxic chemicals), there is a high probability of additional zones with even lower entropy values formation. In this case, another "steady-state" area is formed. And this region has no the own ability to function (fig. 2, c). Moreover, with the increase in the number of influencing factors, especially in large areas, the probability of loss and narrowing of regions with a stable state in neighboring regions increases sharply. All these factors make it impossible to implement the model of sustainable development not only in regions with war but also in neighboring regions.

CONCLUSIONS. The physical sense of the "negentropy" as the direction of spontaneous transformation in the ecological system is discribed. Using the changing of entropy (ΔS) as a measure of chaos was shown that level of entropy decreasing correlated with the level of the ecological system destruction. By implementation of the Reynolds stress tensor and collective degrees of freedom, the model of decreasing entropy in turbulence flow was proposed. The phenomenological model for the description impact of warfare on the sustainability of regions was received using the change of entropy after burning plants and soils. The destruction of the region's sustainable development was described use the spherical symmetry of the components in the sustainable development model and its violation.

ЩО ТАКЕ НЕГАТИВНА ЕНТРОПІЯ І ЯК ВОНА ВПЛИВАЄ НА СТІЙКІСТЬ РЕГІОНІВ ПІД ЧАС ВІЙНИ.

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Вплив війни в одному регіоні на інші регіони було показано за допомогою базових фундаментальних законів термодинаміки та тенденцій зниження ентропії. Фізичний зміст негентропії на основі хімічної термодинаміки було описано як напрям спонтанного перетворення в екологічній системі. Використовуючи як основний параметр величину зміни ентропії за неконтрольованої дії на знищення рослин і ґрунтів, отримано рівняння та феноменологічна модель для опису впливу бойових дій на екологічну частину регіону. Відповідно до цієї моделі система, в якій немає рослин і всі ґрунти зруйновано, вже переходить у стан, коли неможливо реалізувати реакції окислення ΔH <0 і реакції фотосинтезу ΔS <O. Така система без зовнішніх додаткових факторів не може існувати. Наявність зони з турбулентними потоками дуже підвищує схильність утворення станів із меншою ентропією, ніж ентропія в критичному стані. При збільшенні кількості факторів (наприклад, виділення сполук азоту або інших токсичних хімічних речовин) існує висока ймовірність появи додаткових зон зі ще нижчими значеннями ентропії. Збільшується ще одна «постійна» зона з відсут-

ністю можливості власного функціонування. Формування цієї зони буде розташовуватися за межами регіону, де відбувалися турбулентні явища за рахунок утворення спрямованих потоків речовин. Зі збільшенням кількості факторів впливу, особливо на великих територіях, різко зростає ймовірність звуження та повної втрати стабільного стану територій у сусідніх регіонах.

Ключові слова: негентропія, війна, стійкість, термодинаміка, відкрита система, довкілля.

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