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Measurement of Regional Resilience: ANN Modeling of the Carpathian Area's Homeostasis Effect

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***Abstract*: This research focuses on the interpretation and assessment peculiarities of the region's resilience. There has been assumed that appearing of the resilience is connected with homeostatic effect in response to outer disturbance. The object of the investigation was regions of the Carpathian Area of Ukraine, formalized in the aspect of ANN models. Scenarios of the models usage foresaw the input of factors of different disturbance level for each region. In the case of some factors and parameters, modeling has discovered the fact of different intensity homeostasis as well as its absence. The results adequacy is sustained by an effective learning of ANN model and the coordination of the built resilience arrays using the data of official ranking of the regions under investigation. The mentioned above confirmed the assumption of the possible use of homeostatic effect as the basis of the regional resilience estimation. Furthermore, ANN modeling has shown that the regions under investigation reacted to the outer disturbance as an integral system.**

Keywords: regional resilience, ANN model, homeostasis effect, Data Mining, regional management**.**

I. Introduction

Within the last 20 years the notion of resilience has gained a great popularity in regional management. And one of its consequences is dealing with perturbations such as economic crises, pandemics and climate change requirements [1]. It is supposed that the notion of resilience was introduced by ecologist C.S. Holling in 1973 to describe the resilience and stability of ecosystems [2]. The absence of a single definition to the term resilience though leads to the arguments as to the behavior of the object under investigation and management regularities peculiar to it. The problem is complicated by the existence of similar terms, e.i. stability, resistance, vulnerability i.e.

The consolidating factor when studying resilience and other close notions is its recognition as a system characteristic [1]. In this case system characteristics of different nature, not only ecological, but also social and economic ones should be considered [3], [4].

The methods of system approach and system analysis allowed stating several interpretations of the concept resilience. Thus C.S. Holling defined it as a measure of how far the system could be perturbed without shifting to a different regime [2].

There is defined engineering [5] and ecological resilience [6]. The system stability is a close notion to resilience. Stability is the ability of a system to return to an equilibrium state after a temporary disturbance. The more rapidly it returns, and with the least fluctuation, the more stable it is [2]. Though, the estimation of system stability is based on short-term and insignificant disturbances, unable to provoke its system peculiarities.

In the case of regional management, resilience is a distinct management category, which should be quantitatively interpreted and measured. The available attempts of the resilience estimation determine the complicacy of the object as main obstacles – when considering the region as a system, in particular a social and economic one. The need to study regions as unique economic, social or biophysical entities [1] is highlighted, and correspondently makes the studied object complex and complicated.

Not taking into account the described above complexity, there are many attempts to estimate resilience. Some scientists defines resilience of farming regions as structural pressure that appears in the case of trade conditions decrease and changes in productivity, connected with the changes in policy, technology, resources and climate [6]. Another approach is the introduction of thresholds as criteria for measuring resilience [7], [8], though in the case of social and economic systems thresholds are difficult to find.

In the whole, the described above approaches to measuring resilience are based on two types of analysis: equilibrium analysis and complex adaptive systems analysis [9], where studying the region state is common, as the consequence of real or fictitious influence of outer disturbances. The accent on the object of resilience – the region, and some aspects of its functioning disregards the fact that resilience is a universal system characteristic. Moreover, according to the concepts of system approach such characteristic should be equally manifested for systems of different nature: ecological, biological physical, as well as social and economic systems. Having accomplished the search of such fact, it is thought that homeostasis reaction of biological systems on the outer irritant activity has no alternatives and is stated as a universal system characteristic. In many works that describe the behavior of biological systems, the homeostasis reaction is described according to C.S. Holling [2] as a dome-shaped curve that is close to quadratic or cubic dependency. Dependencies of such type describe different inner characteristics of living organisms [10], population dimensions etc., even psychological process [11], that confirm the universal nature of the suggested concept of homeostasis reaction. In Fig.1 there is provided the example of such behavior (blue solid curve suggested by Shmoop Editorial Team [12]).

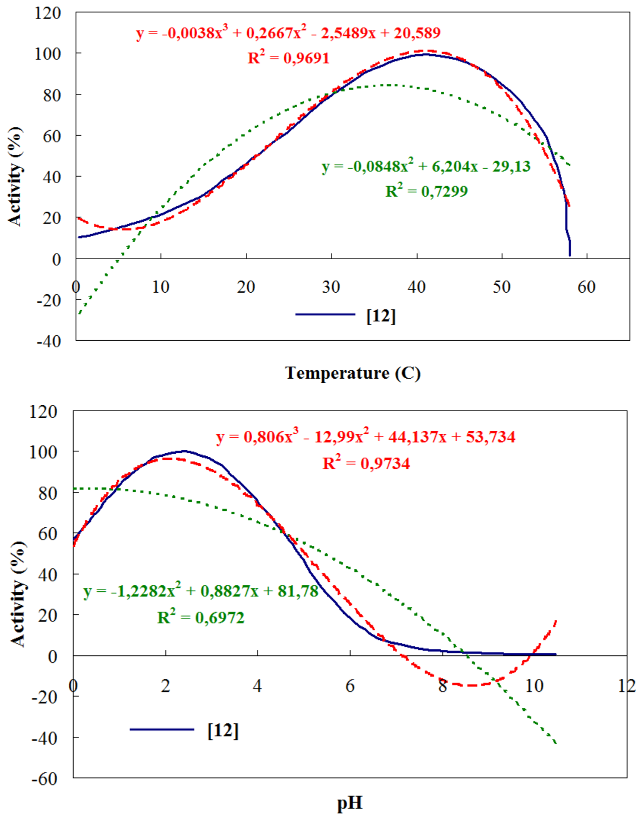


Figure 1. Example of an enzyme homeostatic behavior manifestation (a – depending on the action of the temperature irritant, b – depending on the action of the pH irritant)

Figure 1 confirms the suggestion that the behavior of homeostasis is the most accurately described by cubic and quadratic regression equations (red dotted curves). R^2 is a statistical measure of how close the data are to the fitted regression line (sometimes it is called the coefficient of determination).

The cubic and the quadratic shape of the homeostasis reaction foresees the following: the presence of thresholds, when system resilience is critically low; multiple equilibria (described by R. Pendall and others [13]) when the system dynamics may respond the irritant by several quadratic function extreme points. Moreover, such approach does not contradict the existence of stable equilibrium (i.e., in the neighbourhood of a stable focus or node) [14].

The goal of this paper is to reveal the regional resilience manifestation on the basis of the dynamic analysis of social and economic indices of the Carpathian area regions, in particular, using ANN modeling. The flow of this paper is organized as follows: in Section II the object of investigation is described (regions of the Carpathian area), in Section III the parameters of the object under investigation are outlined, in Section IV there is a description of building ANN model, in Section V there is the analysis of using ANN model and the obtained results and finally the conclusions to the paper are discussed in Section VI.

II. The object of the research

In regional management there are many conceptions of describing the notion of the region, distinguished by three approaches geographic, functional or administrative [15]. Besides that, there are also the attempts to differentiate regions by the number of similar social and economic features [16]. Nevertheless the key peculiarity of defining the region as an object of regional management is using the system approach. So the region is a system with a number of system peculiarities and subsystems: economic, ecological, social nature, etc.

The object of investigation of this paper is the regional system formed by the Carpathian area, situated to the west of Ukraine. It consists of: Lviv region, Ivano-Frankivsk region, Transcarpathian region, Chernivtsi region (Fig. 2). The area occupies 56,6 thousand km² (9,4 % territory of Ukraine), of which Lviv region occupies 21,8 thousand km², Ivano-Frankivsk region – 13,9 thousand km², Transcarpathian region – 12,8 thousand km², Chernivtsi region – 8,1 thousand km².

Geographical position of the area is rather specific and is characterized by a number of positive and negative features that is principally an ordinary phenomenon for every social and economic region of the state. The Carpathian area is situated near the centre of Europe, on the border of its Central and Eastern parts. From south-west to north-east the Main European watershed crosses the area. To the north the area borders on Volynsky region, to the east – on Podil's'ky social and economic districts. To the west and to the south the Carpathian area has direct access to such European countries as Poland, Slovakia, Hungary, Romania, and Moldova. The location stipulates for beneficial traits of economic and geographical position of the area. Close border location to European countries is favorable for the formation of cooperative relations on the level of some enterprises as well as of the whole branches. The developed network of railways (Kyiv – L'viv – Uzhhorod - Praha, Brest – L'viv – Chernivtsi – Bucharest, Kyiv – L'viv – Warsaw), highways (Kyiv – L'viv – Warsaw, Kishinev – Chernivtsi – L'viv – Krakiv, Kyiv – L'viv – Budapest, Odessa – L'viv – Krakiv), gas and oil pipelines («Soyuz», «Braterstvo», «Prohres», Urengoy – Pomary – Uzhhorod and then to Hungary and Slovakia, oil pipeline «Druzhba»), ammonia pipeline Kalush – Tysauyvarosh (Hungary) help setting close relationships with the countries of Central and Eastern Europe.

The intentions of Ukraine to enter the European Union stipulate for the necessity of prognostication and improvement of the border territories resilience as to the global and inner disturbances. The main expectations of quick acquiring the European level of development and integration into European economic and social space are set on the Carpathian area. The basis of such integration is achieving the same level of resilience as the nearest neighbors have. That's why the clear estimation of the resilience that will be based on the statistic data and methods of system analysis will define the future development of the whole country.

Figure 2. The Ukrainian part of the Carpathian area (1 – L'viv region; 2 – Transcarpathian region; 3 – Ivano-Frankivsk region; 4 – Chernivtsi region; 5 – Borders of the Ukrainian part of the Carpathian area; 6 – Borders of regions)

III. Data Set Used

The model formalization is connected with a number of peculiarities. Thus, the accuracy when describing regional processes under investigation will be directly proportional to the number of regional social and economic system parameters (i), outer environment/disturbances (j) and time points that will describe the state's discrete dynamics in a definite time horizon. So, the optimizing task of taking into account the maximum possible number of model variables that can be mathematically described, considering the limitations of modern development in mathematics and computer techniques is under investigation. On the other hand, the built model, as well as the results of its work, should be available for interpretation of some certain user (administrator) and serve as a functional element of the system that supports when adopting decisions system.

As parameters of the Carpathian area regions there have been selected 14 national/regional indices from the State Statistics Service of Ukraine (http://www.ukrstat.gov.ua/), that by their nature allow estimating the areal social and economic development in total and the outer influence of the national social and economic system (Table 1). The main criteria when selecting indices – were describing all the chapters from the National Accounts System; availability of statistic data for Ukrainian regions during 2005–2016; avoiding duplicating the indices interplay.

IV. Building ANN Model

Considering the stated above, one of the suggested model formalization approaches is using the technology Data Mining, in particular building the model of Artificial Neural Network (ANN).

Table 1. The studied object parameters.

Parameters	Shortening symbols for national social and economic system	Shortening symbols for the regions of the Carpathian area
GDP (GRP) per capita, UAH.	UA 1	ZK1/CH1/IF1/LV1[a]
Available income per capita, UAH.	UA 2	ZK2/CH2/IF2/LV2
Consumer Price Index	UA 3	ZK3/CH3/IF3/LV3
Export, thous. USD	UA 4	ZK4/CH4/IF4/LV4
Industrial production index	UA 5	ZK5/CH5/IF5/LV5
Agricultural production index	UA 6	ZK6/CH6/IF6/LV6
Direct investments, mln. USD	UA 7	ZK7/CH7/IF7/LV7
Capital investments, ln. UAH	UA 8	ZK8/CH8/IF8/LV8
Index of completed construction work volume	UA 9	ZK9/CH9/IF9/LV9
Transport goods by road, mln. t.	UA 10	ZK10/CH10/IF10/LV10
Passenger transportation by road, mln. pas.	UA 11	ZK11/CH11/IF11/LV11
Volume of return turnover of enterprises (legal entities), mln. UAH	UA 12	ZK12/CH12/IF12/LV12
The unemployment among working-age population	UA 13	ZK13/CH13/IF13/LV13
Economically active working-age population, thous. people	UA 14	ZK14/CH14/IF14/LV14

[a)] *Zki – Transcarpathian region; CHi – Chernivtsi region, IFi – Ivano-Frankivs'k region, LVi – L'viv region.*

The potential of using ANN modeling of complex processes and systems is acknowledged by numerous successful objects under investigation in medicine, biology, sociology, economics, etc. As to the regional administration, it is complex by its nature and contains many components: ecological, economic, social, educational, population, resource etc. That is why, undoubtedly, ANN is widely used for solving the problems of regional administration [17] or for some peculiar problem constituents: local production [18], public sector workers motivation [19], state economic forecasts [20], urban planning [21] etc. where the object of investigation may be considered as a black or a grey box.

The structure of ANN reflects to some extent the biological neural processes of the human brain. Thus the interrelation between correlating variables are represented in the form of neurons or nodes models [22]. Such biological ontology of ANN makes it the instrument when solving methodic problems of nonlinearity, high parallelism, robustness, fault and failure tolerance, learning, ability to handle imprecise and fuzzy information, and their capability to generalize [23]. Though ANN models are empiric by their nature, they are able to describe the objects that were previously investigated only with the help of the direct experiment or field observations [24]. Moreover, ANN can build the models of the objects with undefined structure and unknown parameters [25] by means of building adequate black or grey boxes. In the case of the present research, ANN provides the opportunity to receive the analogue of the problematic object of the Carpathian region and to do model resilience analysis experiments with it, that are similar to the approaches used when studying technical or physical systems.

In general, ANN models are formed on the basis of trained using a set of examples of inputs and outputs of the object under investigation. The final result of it is the formation of weight dependencies between nods of the network, which can predict the values of outputs from new set inputs (problems).

ANN contains an input layer, hidden layers, and an output layer. Neural network inputs multiplied by a corresponding weight, sum the product, and process the sum using a nonlinear transfer function. “Learning” the network consists in selecting such weights between the nodes that lead to minimal error between the inputs and outputs [26]. The basis of the success was the connectionist architecture of ANN and its universal approximation ability that emerges from the interactions among its neurons. Taken separately, a single neuron has no real abilities; it is capable only of performing extremely simple operations such as addition and multiplication [27], [28].

Formation the ANN model foresees establishing the type and structure of the network that is a combination of best professional judgment, heuristic rules, and trial and error [29]. Neural network structure and number of neurons in hidden layers should correspond to the nature of the phenomenon under investigation that is a complicated task in particular on initial stages, where the trial and errors approach is still dominant [30]. The number of hidden layers is also important. It is considered that one hidden layer is sufficient to approximate continuous functions [31]. Two or more hidden layers are able to describe functions with discontinuities [32]. If the quantity of neurons on hidden layers is increased, the model will learn better, but there may emerge the problem of overlearning (overfitting) [33]. If the number of neurons is low, the model will not represent the object under investigation. Unfortunately, today there is no unique approach to calculating the exact number of hidden nodes. As the example the number of hidden nodes selected per model was equal to one-half the total number of inputs plus outputs with the following adjustment according to the training tolerance [22]. To solve the tasks with high nonlinearity and hysteresis there is suggested another approach that presupposes the beginning with a small number of hidden nodes with further increase due to monitoring the error on both the training and test subsets [24].

Though the most effective is the selection of the neuron number on the basis of the observing the error on both training and test subsets. Thus in a well-selected architecture the error on both training and test subsets is decreasing monotonically but slowly [24]. Taking into account the mentioned approach there was accomplished the neural network architecture formation. So, in the process of architecture selection, there have been tested more than 10 types with different number of concealed layers and neurons to reach the acceptable exactness of the analysis.

Firstly, in the case of one hidden layer with any combination of neuron number there appeared the situation when the error on both the training and test subsets dropped to certain levels but did not change later.

The next stage was the introduction of two hidden layers. At first there was taken the case when the number of neurons in the first layer was bigger than in the second one. In the process of learning such architecture the error on the training subset reduced to a very low index but the error on the test subset reduced to a high index and remained then unchanged. The similar error behavior was in the case of the excess of hidden layers neuron number over the number of ANN inputs and outputs.

The final architecture of the built neural network consists of 14 inputs, 2 hidden layers, that have 7 and 14 neurons accordingly and 14 outputs (Fig.3). The limit number of hidden elements is agreed with the investigation approach [34] and the behavior of the error on both training and test subsets is decreasing monotonically but slowly to indices lower than 0,5 %.

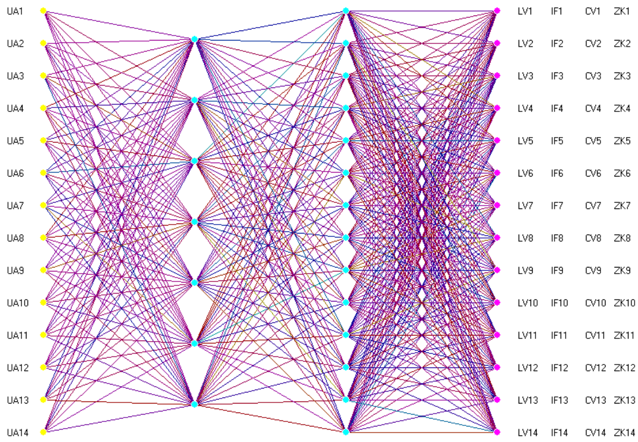


Figure 3. Neural network model

There should be also mentioned that in the conceptual basis of ANN model there was put the dynamic-deterministic view of the outer environment factors influence (according to A. Reggiani [14]) on the regions’ state in the Carpathian area.

The academic version of the program Deductor Studio Lite 5.1 released by Base Group Labs was chosen as the applied environment for neural network building.

The procedure of learning the neural network presupposed the input the selected annual outer factors indices (UAi) on the inputs and the annual indices of one of the studied regions (ZKi/CHi/IFi/LVi) on the outputs alternately for the period 2005-2016 pp. The entries were divided into learning and test sets in the proportion 70 and 30 per cent accordingly. The selection of the weight coefficients ceased when the error of the test subset was lower than the error of the training set, but the minimal number of epochs was higher than 10000.

Likewise, there was used sigmoid as an activation function of neurons (1):

$$f(t) = \frac{1}{1+e^{-t}} \qquad (1)$$

where t represents the weighted sum of the input for a node in the hidden layer, and e denotes the natural exponential function [29].

The learning process of ANN model was held by using the back propagation algorithm that fits the weights from the output layer through the input layer [35], [36].

Normalization of the input data occurred automatically in the environment of the program Deductor Studio according to the algorithm (2):

$$Y_i = \frac{y_i - y_{\min}}{y_{\max} - y_{\min}} \qquad (2)$$

where, Y_i means the normalized values of y_i, y_{min} and y_{max} represent the minimum and maximum value of y_i [37].

V. Model Scenario Realization

In the process of neural network training (learning) there were received 4 ANN models of the Carpathian area regions

(Chernivtsi, Lviv, Ivano-Frankivsk and Transcarpathian) of the above described architecture 14*7*14*14. The selected weight coefficients between the nods of neural networks represent all inner regularities of regions' interaction with input factors of outer environment. Realization of the model scenario foresees using the neural network learned by the iteration selection of neurons weight coefficients according to the task set.

To define the influence of outer disturbance during the last statistic period (2016), there was model increase and decrease of the quantity of every other input factor in the model (UAi) on 5%, 10%, 15%, 20%, 25% and 30%. The main aim of the above stated was the attempt to model provoking the regions under investigation by disturbance their outer environment. The selection of these particular dimensions of the provoking factor changes was taken on the basis of:

- analogy of homeostasis manifest in biological systems (e.i. Fig.1);
- taking into account really possible fluctuations of outer factors on the basis of the available retrospective statistic data for example, outer micro parameters fluctuation UAi is impossible more than 30% per year, when statistic data show 0-20% for the last 10 years).

In Fig.4 as the example there is shown the reaction of «GDP per capita» parameter on the outer factors disturbances UAi (see the description of the factors values in Table 1) in Transcarpathian region.

The held model experiment showed that the response of the system parameters on the outer factor change was either linear (Fig. 4– a, b, d, g, j, k), or cubic (Fig. 4 – c, e, f, h, i, l, m, n). Besides that, the cubic behavior of the system parameter to the disturbance was of two types: with the obvious maximum (Fig. 4 – c, e, i, l, m) and the presence of the saturation zone when there was the increase of the disturbance factor value (Fig. 4 – f, h, n). The obtained data are coordinated with the described by Y. Maru basins of attraction [1].

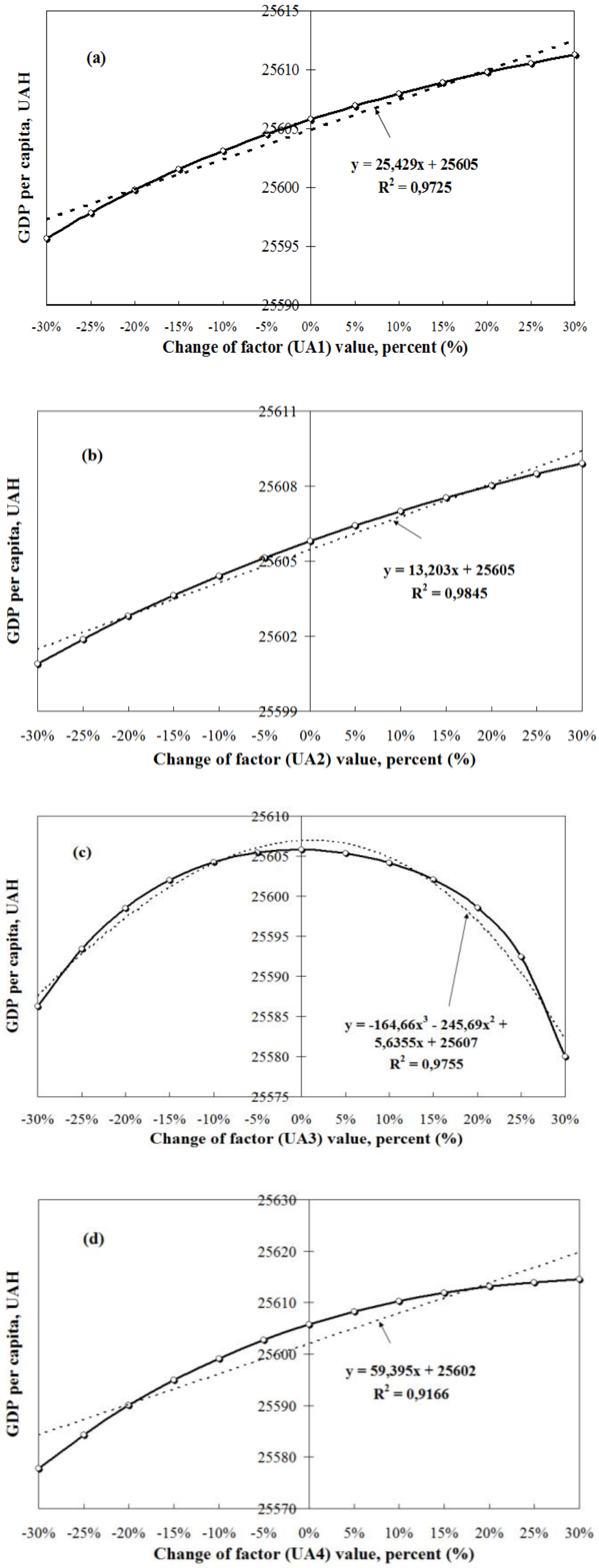
Similarly, there was calculated the influence of all 14 factors of outer environment (UAi) on inner parameters of 4 regional social and economic systems (ZKi/CHi/IFi/LVi) and received the answers to 784 dependencies. To systematize the received dependencies there was conducted their segmentation into 3 categories, the manifestation of which was described earlier:

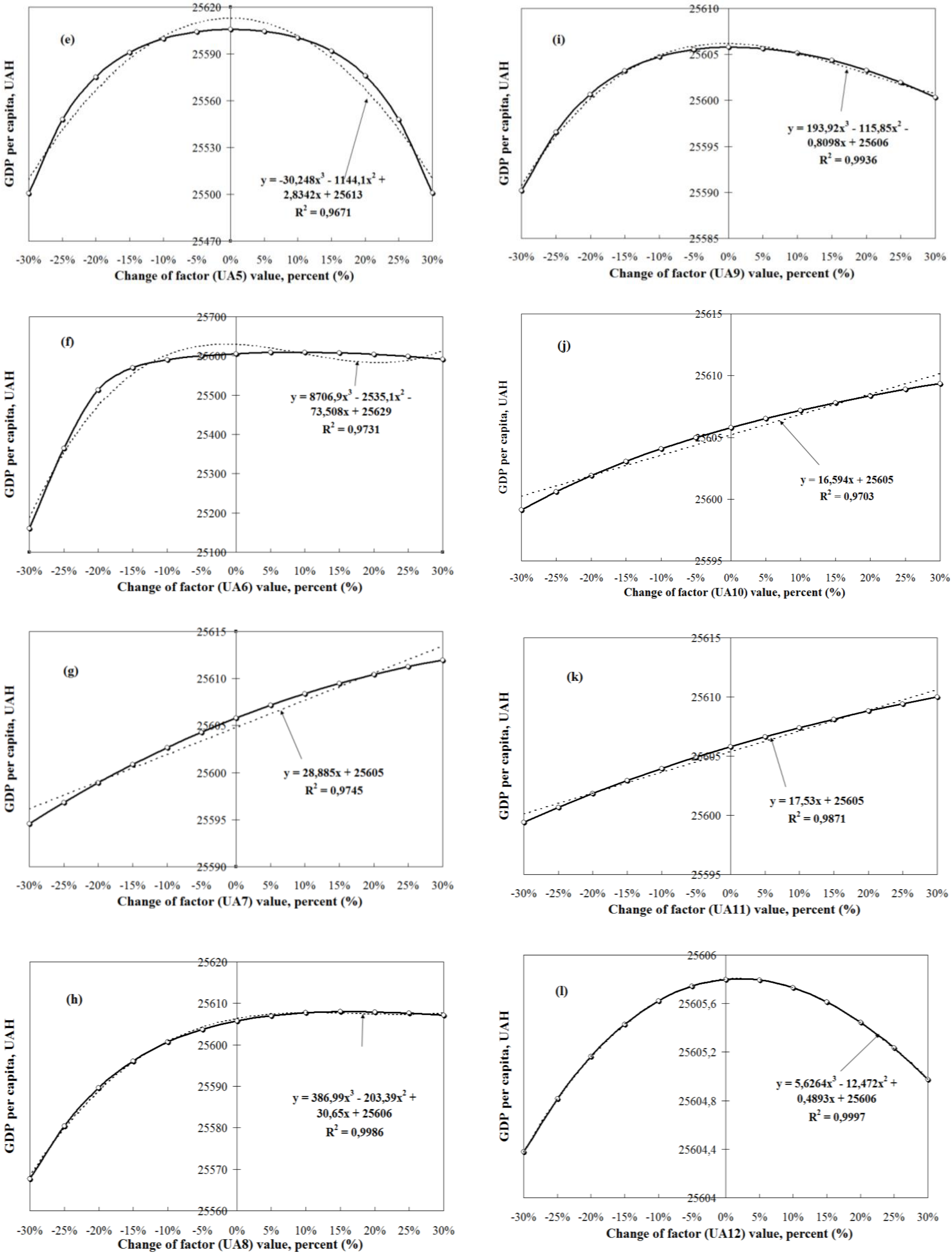
1) S - a strong manifestation of homeostasis (dependencies with highly obvious maximum);

2) M - a moderate manifestation of homeostasis (presence of the saturation zone when the disturbance factor value increases);

3) - the absence of homeostasis (linear response of the parameter on the disturbance).

Taking the approach of B. Walker [38] as a basis about the importance of resilience determination, as the dependency of a separately taken inner factor on a separately taken outer one there was built, the so-called, resilience arrays of the regions in the Carpathian area (Tables 2-5). In the columns of the arrays there was shown the response of some parameters to the outer factor disturbance (horizontal rows) of the all 4 ANN models of the Carpathian area regions.




(e)
GDP per capita, UAH
$y = -30,248x^3 - 1144,1x^2 + 2,8342x + 25613$
$R^2 = 0,9671$
Change of factor (UA5) value, percent (%)
(i)
GDP per capita, UAH
$y = 193,92x^3 - 115,85x^2 - 0,8098x + 25606$
$R^2 = 0,9936$
Change of factor (UA9) value, percent (%)
(f)
GDP per capita, UAH
$y = 8706,9x^3 - 2535,1x^2 - 73,508x + 25629$
$R^2 = 0,9731$
Change of factor (UA6) value, percent (%)
(j)
GDP per capita, UAH
$y = 16,594x + 25605$
$R^2 = 0,9703$
Change of factor (UA10) value, percent (%)
(g)
GDP per capita, UAH
$y = 28,885x + 25605$
$R^2 = 0,9745$
Change of factor (UA7) value, percent (%)
(k)
GDP per capita, UAH
$y = 17,53x + 25605$
$R^2 = 0,9871$
Change of factor (UA11) value, percent (%)
(h)
GDP per capita, UAH
$y = 386,99x^3 - 203,39x^2 + 30,65x + 25606$
$R^2 = 0,9986$
Change of factor (UA8) value, percent (%)
(l)
GDP per capita, UAH
$y = 5,6264x^3 - 12,472x^2 + 0,4893x + 25606$
$R^2 = 0,9997$
Change of factor (UA12) value, percent (%)

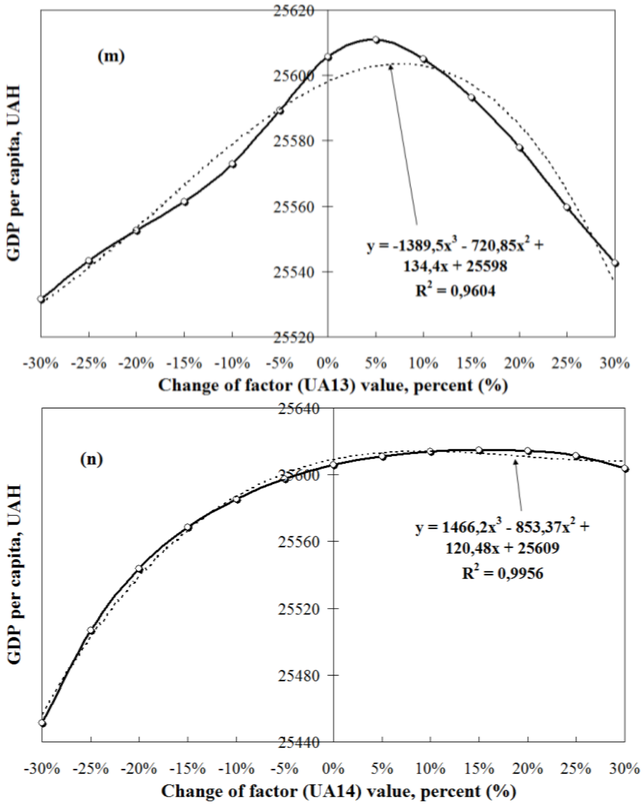


Figure 4. Example the reaction of "GDP per capita" parameter on outer factors disturbances in Transcarpathian region (empty points show the calculated values of ANN model, point-to-point curves – interpolated dependencies)

The availability of different zones of resilience for one and the same disturbance factor in different regions corresponds with the statement of A. Reggiani that measuring the resilience in one and the same system may be different depending on the tendency of the disturbance [14]. Undoubtedly, array resilience is not an element for prognostication the region's behavior, but only reflects the inner feature of studied systems, that meets the statement of C.S. Hoiling about the importance of resilience manifestation prognostication that lies not in the quantitative but in the qualitative plane of its presence [2].

Using the resilience arrays is important in the case of national and regional development strategies coordination. On the other hand taking into account the distinct resilience assessment in regional management practice still demands its comprehension. Not of less importance is the confirmation of the array results adequacy.

Thus, the use of other methods for the obtained calculations check is still controversial. First of all, it is about the correlation and regressive analysis. However, it is unable to extrapolate the data if there are a lot of inputs and outputs (of dependent parameters) and to the value that is higher than the range of the input data [39], [40]. Moreover, neural networks are better than multiple regression models in the case of prognosticating difficult processes [22], [24], [41], [42]. There was also considered the possibility of using Group method of data handling (GMDH) that was first developed by Ivakhnenko [43] as a multivariate analysis method for complex systems modeling and identification. GMDH, though, is unable to build a coherent model of the region with 14 inputs.

Table 2. Resilience array of Transcarpathian region.

		System Parameters											
		ZK1	ZK2	ZK3	ZK4	ZK5	ZK6	ZK7	ZK8	ZK9	ZK10	ZK11	ZK12
Disturbance factors	UA1												
	UA2												
	UA3	S	M					S		S			S
	UA4									S			
	UA5	S	S		M		S	S	S	M			S
	UA6	M	M		S				M				
	UA7									S			
	UA8	M	M			S	S						
	UA9	M	S	M		S	M						M
	UA10									M			
	UA11												
	UA12	S											M
	UA13	S	M										S
	UA14	M	M					M	M	S			M

Table 3. Resilience array of Chernivtsi region.

							System Parameters							
		CV1	CV2	CV3	CV4	CV5	CV6	CV7	CV8	CV9	CV10	CV11	CV12	CV13
Disturbance factors	UA1		S											
	UA2					S								
	UA3							M						M
	UA4	M	M		M	S			S		S		M	
	UA5	S	S					M					S	
	UA6	M	M		S		S		S				M	
	UA7													
	UA8	S	S		S	M	S						S	S
	UA9					M	M	S	S				M	M
	UA10													
	UA11					M								
	UA12													
	UA13	S	S	S			S	M			M		M	
	UA14	M	M		S		M	S	M				S	

Table 4. Resilience array of Ivano-Frakivs'k region.

							System Parameters							
		IF1	IF2	IF3	IF4	IF5	IF6	IF7	IF8	IF9	IF10	IF11	IF12	IF13
Disturbance factors	UA1			S										
	UA2			S										
	UA3	S	M		S						M	S	S	
	UA4													
	UA5		M				M		M					
	UA6	S	S			M	S				M	S	S	
	UA7			S										
	UA8				S						M			
	UA9	S	M			M	M				M	M	M	
	UA10									M				
	UA11													
	UA12			S										
	UA13	M	M		M					M	M	S	M	
	UA14	M	M							S	S	M	S	

Table 5. Resilience array of L'viv region.

							System Parameters						
		LV1	LV2	LV3	LV4	LV5	LV6	LV7	LV8	LV9	LV10	LV11	LV12
Disturbance factors	UA1						M						
	UA2					S		S					
	UA3	M	M			S			M				M
	UA3	M	M			S			M				M
	UA5			S			S			S		M	
	UA6									S			
	UA7						S						
	UA8									S	S	S	
	UA9								M				
	UA10			M						S			
	UA11	M		S					M				
	UA12						S			S	S		
	UA13	S	S		S	S	M		S				S
	UA14	S	S	M			M		S	S	S	S	S

So, for the verification of the results adequacy there were used statistic data of the stability manifestation of the regional systems under investigation form the point of view of other approaches. Thus, with the aim to sustain the results adequacy there was taken the ranking of the regions of Ukraine on the period 2015-2017. Accordingly to the rank assessment of the social and economic development led by the government of Ukraine (http://www.minregion.gov.ua) regions were rated from the most developed to the least developed. The assessment was held on the basis of comparing more than 100 regional social and economic indices.

For ranking the obtained results of modeling in tables 2-5,

the following numerical values were conferred to the grids:
- a strong manifestation of homeostasis (S) – 2 points;
- a moderate manifestation of homeostasis (M) – 1 point;
- the absence of homeostasis – 0 points.

All the points were summed up for each region and there was built their stability ranking (Table 6). The total count of points showed the rating of regions stability from the most stable to the least stable:
1st place - Chernivtsi (71 points);
2nd place - L'viv (62 points);
3rd place - Transcarpathian (56 points);
4th place - Ivano-Frankivs'k (54 points).

Table 6. Official ranking and ranking according to the homeostasis presence in the Carpathian area regions

	Official ranking for 2015	Official ranking for 2016	Official ranking for 2017	Ranking according to the homeostasis presence
Chernivtsi region	1	1	1	1
Ivano-Frakivs'k region	2	2	2	4
L'viv region	3	4	3	2
Transcarpathian region	4	3	4	3

So, there may be observed a moderate correspondence of the resilience arrays data with the regions' ranking data, except L'viv and Ivano-Frankivs'k regions. Moreover, in the case of regions' economical development ranking (official data http://www.minregion.gov.ua) L'viv region outgoes Ivano-Frankivs'k one, that strengthens the adequacy of the obtained results.

VI. Conclusion

In this paper there have been studied the peculiarities of the concept resilience interpretation and the difficulties with its estimation in modern scientific literature in regional management. Basing on the fact that resilience is a universal system characteristic there have been assumed that its manifestation is connected with the homeostatic effect emergency as the response to the outer disturbance. The main feature of the homeostatic effect is considered the appearing of cubic and quadratic behavior of the regional social and economic system index depending on the level of the outer factor, identically to the biological systems.

The object of the investigation was the regions of the Carpathian area of Ukraine. The model parameterization was held by selecting social and economic regional indices and outer factors for periods 2005-2016 The model formalization was realized in dynamic-deterministic approach by building the ANN model of architecture (14*7*14*14). Scenarios of model use predetermined the input of factors of different magnitude of perturbation in the case of every region.

In the case of some factors and parameters, modeling showed the homeostasis of different sizes (estimated on the basis of the received system responses proximity to the cubic dependence) as well as its absence (linear parameter response to the disturbance). Final results were placed in the so-called resilience arrays that can be used in the case of the national and regional development strategy coordination.

The adequacy of the results is confirmed by a successful learning of ANN model and coordination of resilience arrays with the data of official rating of the studied regions.

Thus there have been substantiated the suggested assumption as to the possibility of the homeostatic manifestation effect as the basis of the regional resilience estimation. Besides that ANN modeling corroborated the fact that the studied regions reacted to the outer disturbance as a integral system.

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References

[1] Y.T. Maru. "Resilient Regions: Clarity of Concepts and Challenges to Systemic Measurement", *Socio-Economics and the Environment in Discussion (SEED) CSIRO Working Paper* Series 2010-4 CISRO, Canbera, pp. 38, 2010.

[2] C.S. Holling. "Resilience and stability of ecological systems", *Annual Review of Ecology and Systematics 4*, pp. 1-23, 1973.

[3] A.A. Batabyal. "The Concept of Resilience: Retrospect and Prospect", *Environment and Development Economics*, 3, pp. 235-239, 1998.

[4] S.A. Levin, S. Barrett, S. Aniyar, W. Baumol, C. Bliss, B. Bolin, P. Dasgupta, P. Ehrlich, C. Folke, I.-M. Gren, C.S. Holling, A. Jansson, K.-G. Ma¨ler, D. Martin, C. Perrings, and E. Sheshinski. "Resilience in Natural and Socioeconomic Systems", *Environment and Development Economics*, 3, pp. 222-235, 1998.

[5] C.S. Holling. "The Resilience of Terrestrial Ecosystems: Local Surprise and Global Change", in W.C. Clarck and R.E. Munn (eds.), *Sustainable Development of the Biosphere*, Cambridge: Cambridge University Press, pp. 292–317, 1986.

[6] A.S. Masten, K. M. Best, and N. Garmezy. "Resilience and development: Contributions from the study of children who overcome adversity", *Development and Psychopathology*, 2, pp. 425-444, 1990.

[7] S.R. Carpenter, B.H. Walker, J.M. Anderies, N. Abel. "From metaphor to measurement: resilience of what to what?", *Ecosystems*, 4, pp. 765-781, 2001.

[8] B.H. Walker, C.S. Holling, S.R. Carpenter, and A.P. Kinzig. "Resilience, adaptability and transformability in social-ecological systems", *Ecology and Society* 9 (2): 5. [Online] URL: http://www.ecologyandsociety.org/vol9/iss2/art5/, 2004.

[9] R. Pendall, K.A. Foster and M. Cowell. "Resilience and Regions: Building Understanding of the Metaphor", *Prepared for Building Resilient Regions, Research Network Sponsored by the MacArthur Foundation, Institute for Urban and Regional Development*, University of California, Berkeley, 2007.

[10] Laura C.D. Pomatto and Kelvin J.A. Davies. "Adaptive homeostasis and the free radical theory of ageing", Free *Radical Biology and Medicine*, [Online] URL: https://doi.org/10.1016/j.freeradbiomed.2018.06.016, 2018.

[11] R.A. Cummins. "On the trial of the gold standard for subjective well-being", *Social Research Indicators*, 35, pp. 179-200, 1995.

[12] Shmoop Editorial Team. "Biology Homeostasis - Shmoop Biology", *Shmoop. Shmoop University*, Inc., 11 Nov. 2008. Web. 3 Aug. 2018.

[13] R. Pendall, K. A. Foster, and M. Cowell. "Resilience and Regions: Building Understanding of the Metaphor", *Cambridge Journal of Regions, Economy and Society*, 3 (1), pp. 71-84, 2010.

[14] A. de Reggiani, T. Graff, P. Nijkamp. "Resilience: an evolutionary approach to spatial economic systems", *Networks and Spatial Economics*, 2, pp. 211-229, 2002.

[15] J. Taylor. "Data Issues for Regional Planning in Aboriginal Communities", *Seminar presented in the Contemporary Indigenous Issues in North Australia series*, Darwin. [Online] URL: http://naru.anu.edu.au/publications.php, 2003.

[16] Y.T. Maru and V.H. Chewings. "How can we identify socio-regions in the rangelands of Australia?", *The Rangeland Journal*, 30(1), pp 45-53, 2008.

[17] T.J. Barth, E. Arnold. "Artificial Intelligence and Administrative Discretion", *The American Review of Public Administration*, 29(4), 332-351, 1999.

[18] Chung, W. W. C., Wong, K. C. M., & Soon, P. T. K. "An ANN-based DSS system for quality assurance in production network", *Journal of Manufacturing Technology Management*, 18(7), pp.836-857, 2007.

[19] D. Manolopoulos. "An evaluation of employee motivation in the extended public sector in Greece", *Employee Relations*, 30(1), pp. 63-85, 2007.

[20] J. V. Hansen, R. D. Nelson. "Neural networks and traditional time series methods: a synergistic combination in state economic forecasts", *IEEE Transactions on Neural Networks*, 8(4), 863–873, 1997.

[21] B. Rubenstein-Montano. "A survey of knowledge-based information systems for urban planning: moving towards knowledge management", *Computers, Environment and Urban Systems*, 24(3), pp. 155-172, 2000.

[22] M. Kaul, R. L. Hill & C. Walthall. "Artificial neural networks for corn and soybean yield prediction", *Agricultural Systems*, 85(1), pp. 1-18, 2005.

[23] A.K. Jain, J. Mao, K.M. Mohiuddin. "Artificial neural networks: a tutorial". *In Comput. IEEE March*, pp. 31-44, 1996.

[24] I. Basheer & M. Hajmeer. "Artificial neural networks: fundamentals, computing, design, and application", *Journal of Microbiological Methods*, 43(1), pp. 3-31, 2000.

[25] A. Jain, S. Srinivasulu. "Development of effective and efficient rainfall-runoff models using integration of deterministic, real-coded genetic algorithms and artificial neural network techniques", *Water Resources Research*, 40(4), 2004.

[26] B. Pradhan, & S. Lee. "Regional landslide susceptibility analysis using back-propagation neural network model at Cameron Highland, Malaysia", *Landslides*, 7(1), pp. 13-30, 2009.

[27] R.M. Basse, H. Omrani, O. Charif, P.,Gerber & K. Bódis. "Land use changes modelling using advanced methods: cellular automata and artificial neural networks. The spatial and explicit representation of land cover dynamics at the cross-border region scale", *Applied Geography*, 53, pp. 160-171, 2014.

[28] H. Bersini, "De l'intelligence humaine_a l'intelligence artificielle", *Ellipses Editions*, 2006.

[29] X. Dai, H. Shi, Y. Li, Z. Ouyang & Z. Huo. "Artificial neural network models for estimating regional reference evapotranspiration based on climate factors", *Hydrological Processes*, 23(3), pp. 442-450, 2009.

[30] W. Huang, C. Murray, N. Kraus & J. Rosati. "Development of a regional neural network for coastal water level predictions", *Ocean Engineering*, 30(17), pp. 2275–2295, 2003.

[31] I. Basheer. "Selection of methodology for modeling hysteresis behavior of soils using neural networks", *J. Comput.-aided Civil Infrastruct. Eng.*, 5 (6), pp. 445-463, 2000.

[32] T. Masters. "Practical Neural Network Recipes in C++", *Academic Press*, Boston, MA, 1994.

[33] S.L. Özesmi, C.O. Tan, U. Özesmi. "Methodological issues in building, training, and testing artificial neural networks in ecological applications", *Ecol. Mod.*, 195, pp. 83-93, 2006.

[34] R.H. Nielsen, "Kolmogorov's Mapping Neural Network Existence Theorem", *Proceedings of the IEEE First International Conference on Neural Networks*. – San Diego, pp. 11-13, 1987.

[35] M. Kaul, R.L. Hill, C. Walthall. "Artificial neural networks for corn and soybean yield prediction", *Agric. Syst.*, 85, pp. 1-18, 2005.

[36] Fernando J. Pineda. "Generalization of back-propagation to recurrent neural networks", *Physical review letters*, vol. 59.19, pp. 2229-2232, 1987.

[37] J. Choi, H.J. Oh, J.S. Won, S. Lee. "Validation of artificial neural network model for landslide susceptibility mapping", *Environmental Earth Sciences*, 2009.

[38] B.H. Walker. "Ecological resilience in grazed rangelands: a generic case study". In L.H. Gunderson and L. Pritchard Jr. (eds). *Resilience and the Behavior of Large-Scale Systems*, pp. 183-194. Washington, DC: Island Press, 2002.

[39] R. Alvarez. "Predicting average regional yield and production of wheat in the Argentine Pampas by an artificial neural network approach", *European Journal of Agronomy*, 30(2), pp. 70-77, 2009.

[40] C. Bishop. "Neural Networks For Pattern Recognition", *Oxford University Press*, Oxford, 1995.

[41] Andrew C. Comrie. "Comparing Neural Networks and Regression Models for Ozone Forecasting", *Journal of the Air & Waste Management Association*, 47:6, pp. 653-663, 1997.

[42] C.-C. Hsu, C.-Y. Chen. "Regional load forecasting in Taiwan-applications of artificial neural networks", *Energy Conversion and Management*, 44(12), pp. 1941-1949, 2003.

[43] N. Amanifard, N. Nariman-Zadeh, M. Borji, A. Khalkhali & A. Habibdoust, "Modelling and Pareto optimization of heat transfer and flow coefficients in microchannels using GMDH type neural networks and genetic algorithms," *Energy Conversion and Management*, 49(2), pp. 311-325, 2008.

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