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MODEL OF REGION'S BALANCED AGRICULTURAL DEVELOPMENT USING THE BIOMASS ENERGY POTENTIAL

Abstract. Ensuring food and energy security is an important issue facing every country, because it underpins social welfare. One of the reasons for the problem being so urgent is that there is unlimited demand for consumer goods and energy; another reason is that the resources which can resolve the problem are limited and non-renewable. In Ukraine, non-renewable energy sources make up to 99% of the country's energy balance. The world's energy sources are being exhausted rapidly. For this reason, there is an urgent need to find an optimal solution to renewable energy development, including bioenergy production. The research employs strategic analysis methods, the abstract logical method, the analogy method, and the methods of calculation, construction, and modelling. The paper presents a systemic approach to solving the problems of energy and food security in Ukraine through balanced agricultural development. From this point of view, the authors design a model of balanced agricultural development with the usage of biomass potential and propose a systemic algorithm of balanced agricultural development based on bioenergy production. In the applied evaluation and interpretation of the designed model, the authors consider its structural constituents, parameters, factual data and statistics, as well as a system of expected economic, social and ecological results. The applied scientific research results are an innovative model of balanced agricultural development with the view to bioenergy development, which offers real prospects for solving the country's food and energy problems.
Keywords: biomass energy; agriculture; model; balanced development; bioenergy.
JEL Classification: Q13, Q20, Q42

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МОДЕЛЬ ЗБАЛАНСОВАНОГО РОЗВИТКУ СІЛЬСЬКОГО ГОСПОДАРСТВА РЕГІОНУ ЗА ВИКОРИСТАННЯ ПОТЕНЦІАЛУ ЕНЕРГІЇ БІОМАСИ

Анотація. Забезпечення продовольчої та енергетичної безпеки є важливими проблемами, які має розв'язати держава для уможливлення нормальної життєдіяльності населення. В енергетичному балансі України частка виробництва енергії з невідновлювальних джерел складає 99%. Наявні у світі запаси енергоресурсів швидко вичерпуються. Тому потребують дослідження питання, пов'язані з пошуком оптимальних рішень щодо розвитку енерговиробництва із відновлювальних джерел енергії, у т.ч. біоенергетики. Авторами розроблено модель і системний алгоритм забезпечення збалансованого розвитку сільського господарства в умовах використання потенціалу енергії біомаси. Здійснено прикладну оцінку та інтерпретацію цієї моделі на рівні регіону.
Ключові слова: сільське господарство, джерела енергії, біоенергетика, біомаса, збалансований розвиток, модель.

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МОДЕЛЬ СБАЛАНСИРОВАННОГО РАЗВИТИЯ СЕЛЬСКОГО ХОЗЯЙСТВА РЕГИОНА ПРИ ИСПОЛЬЗОВАНИИ ПОТЕНЦИАЛА ЭНЕРГИИ БИОМАССЫ

Аннотация. Обеспечение продовольственной и энергетической безопасности являются важными проблемами, которые должно решить государство для создания нормальных условий жизнедеятельности населения. В энергетическом балансе Украины доля производства энергии из невозобновляемых источников составляет 99%. Имеющиеся в мире запасы энергоресурсов быстро исчерпываются. Поэтому нуждаются в исследовании вопросы, связанные с поиском оптимальных решений для развития энергопроизводства из возобновляемых источников энергии, в том числе биоэнергетики. Авторами разработаны модель и системный алгоритм обеспечения сбалансированного развития сельского хозяйства в условиях использования потенциала энергии биомассы. Осуществлена прикладная оценка и интерпретация этой модели на уровне региона.

Ключевые слова: сельское хозяйство, источники энергии, биоэнергетика, биомасса, сбалансированное развитие, модель.

Introduction. A country's stable development depends on how it is able to resolve a number of vital problems; in this respect, Ukraine is no exception. Such problems include, first and foremost, food, energy, and social security. All the three aspects are interrelated and complementary. The paper deals with food and energy (bioenergy) as determinants of national security. Obviously, they both depend on agricultural development.

This research is aimed at solving a number of topical issues in Ukraine related to a low level of domestic agricultural development, great dependence on imported energy sources, worsening ecological situation (especially land use), and increasing social problems in rural areas. Undoubtedly, some measures are being taken in order to improve the current situation; the measures concern legislation, for instance the laws of Ukraine «On energy conservation» (from April 1, 1994), «On alternative energy sources» (from February 20, 2003), «On amendments and changes to some laws of Ukraine on fixing a green tariff» (from September 25, 2008), «On the development of biological fuel production and consumption» (from May 24, 2012). However, the current legislation is narrow; it disregards rural, social and ecological problems and cannot help to achieve the goals. The existing scientific and applied research is mostly fragmentary, aimed at developing agriculture for improving the efficiency of various economic entities such as agrarian enterprises and rural communities.

Therefore, at the present stage it is necessary to conduct scientific and applied research on improving the current legislation on agricultural development, renewable energy, and especially bioenergy, and a complex of measures for systematic changes in the agricultural development priorities in Ukraine.

Brief Literature Review. The theoretical and practical aspects of researching into the issue of agricultural bioresource production and consumption, assessing and realizing the energy potential of biomass in agriculture have been highlighted by Ukrainian and foreign researchers. Smiths E. (2008) [1], Vis M. (2010) [2], Geletukha G. G. (2010) [3], Zhelezna T. A., Zhovmir M. M., Matveev Yu. B., Vasylyshyn R. D. and Lakyda P. I. (2011), Rahman M. and Jukka V. (2012) have elaborated and investigated the methodology of calculating biomass potential in agriculture, assessed the energy potential of primary and secondary agricultural waste by using a resource oriented approach, which includes statistical and spatial methods allows to calculate the theoretical and practical potential of biomass.

According to the findings of Andryushchenko B. V., Demyanchuk V. V., Kyrylenko I. I. (2010) [6], a comprehensive solution to the energy problem, the agrarian sector development and environmental improvements in Ukraine are possible through the development of biofuel market by establishing a system of economic motivation of biofuel production and consumption.

Plieninger T., Bens O., and Huttl R. F. (2006) [7] emphasize that biomass production and use as energy source solves economic problems; additionally, bioenergy can offer solutions to ecological and social problems and opens up possibilities of agricultural development.

Kaletnik H. M. (2008) [8], Nazarenko A. V. (2010) [9], research into the peculiarities of forming the market of energy crops and biofuel.

Dzhedzhula V. (2013) [10] researches into the problem of improving the investment attractiveness of energy conservation measures and evaluates the effectiveness of renewable energy production.

However, there is no unified approach to identifying an optimal structure of producing biomass resource potential on the basis of nature and climatic conditions and production capacity of a region; it is necessary to provide a more comprehensive theoretical and methodological foundation and principles of a coherent system of bioenergy development in order to solve energy problems; the establishment and development of bioenergy demands more detailed legislation and institutional monitoring; it is necessary to determine the impact of bioenergy issues on national economy in terms of ensuring ecological, economic and social security in a region; it is important to identify what impacts the formation and production of alternative energy sources.

Purpose. This research objective is to devise an applied organizational project on balanced agricultural development with a view to solving social, economic, ecological and energy problems in Ukraine.

The starting hypothesis is that a balanced agricultural development which is capable of producing and processing agricultural commodities in necessary quantity and quality, organic farming development and bioenergy production will contribute to solving the country's social, economic, ecological and energy problems.

Results. At present, Ukraine's agriculture faces a lot of challenges. Agricultural production is mostly concentrated in semi-subsistence farms, which have low productivity. In terms of resource management, Ukraine's agricultural enterprises have been less successful than its Western European neighbours. Bioenergy production development faces similar challenges. In fact, renewable energy sources make up less than 1% of Ukraine's energy balance; according to expert estimates, however, it is possible to produce 81mln tons oil equivalent of renewable energy per year, with bioenergy production being 10mln tons oil equivalent [11, p. 58-59]. Therefore, at the current stage of the country's development it is necessary to design and implement a model of balanced agricultural development through the use of biomass potential. Such a model can facilitate a simultaneous development of both the agrarian sector and bioenergy.

The purpose of the model is to ensure balanced agricultural development through optimizing the structure of horticulture and cattle breeding for more efficient food production and organic farming which can be achieved by using livestock and horticultural waste to produce bioenergy and by taking into account the social and ecological conditions of rural areas (Figure 1).

The main component of the model is the organizational algorithm of balanced agricultural development aimed at promoting bioenergy (Figure 2).

This model is based on the mechanism of ensuring balanced agricultural development which will promote the development of bioenergy in Ukraine due to being oriented at horticultural commodities and cattle breeding as bioenergy sources. At the starting point, the biogas facilities at farms will generally produce bioenergy, biogas, high quality organic fertilizers for their own consumption, but there is much prospect of it becoming an important source of the farms' income. It is important to

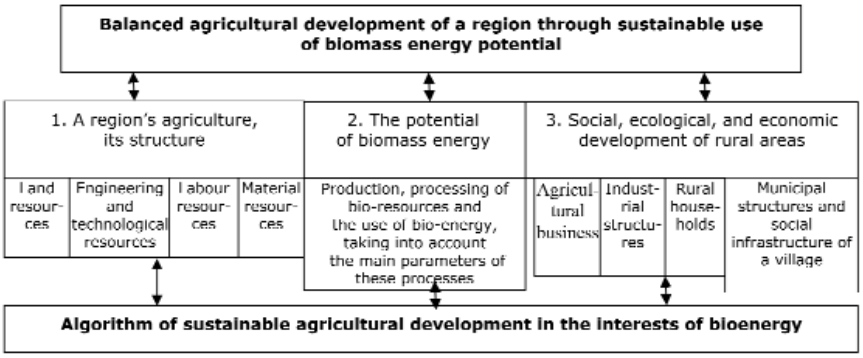


Fig. 1: **The model of balanced agricultural development of a region through sustainable use of biomass energy potential**
Source: Own research

preserve a balance between the development of agriculture and bioenergy not only for economic and energy reasons, but also in important social and ecological respects. The main structural components of the theoretical model, alternative input data and statistics being used, and their interrelation are represented at the Figure 3.

Evaluation of the model. Let us assume that 24 regions of Ukraine grow a certain quantity of a horticultural commodity (taking into account the commodities produced by agricultural enterprises and rural communities). Suppose that all commodities (except for those meant for food safety, local consumption and forage) are used as biomass.

The bioenergy produced at a biomass recycling facility is consumed in the following ways at a regional level: 1) by agricultural businesses; 2) by manufacturing plants; 3) private farms, households and 4) enterprises owned by municipal authorities and the social infrastructure of the village. Their productivity is constrained by the corresponding manufacturing capacity.

According to Ukraine's Energy Strategy 2030, bioenergy is expected to constitute 20% of the total domestic energy consumption. Therefore, total bioenergy consumption must not exceed this limit.

It is possible to achieve this goal through optimizing the structure of cultivated areas and rationalizing the location of agricultural enterprises across Ukraine. The main optimization criteria are maximum gross output of a certain horticultural commodity per 100 hectares, maximum gross profit and maximum net profit from selling a certain horticultural commodity for bioenergy production.

The necessity of comprehensive analysis of Ukraine's agricultural production structure will allow finding the most relevant solution, the so-called suboptimal solution. The results of every decision are analyzed while studying the specialization and integration factors in line with the conditions of every region; the next step is a plan of action aimed at deeper understanding of agricultural production structure.

While maximizing the target function, certain constraints have to be imposed: on the quantity and structure of cultivated areas, on the ways of mechanization and labour resources, on seeding, on satisfying the region's needs for high quality forage, on guaranteeing a certain horticultural output and commodity.

A mathematical solution of the model is done with the help of optimal planning methods (for instance, the simplex method, Monge-Kantorovich problems, etc.). The process of bioenergy production and consumption must concern the relevant quantitative, qualitative, structural, value and spatial constraints (based on the law of gravitational interaction).

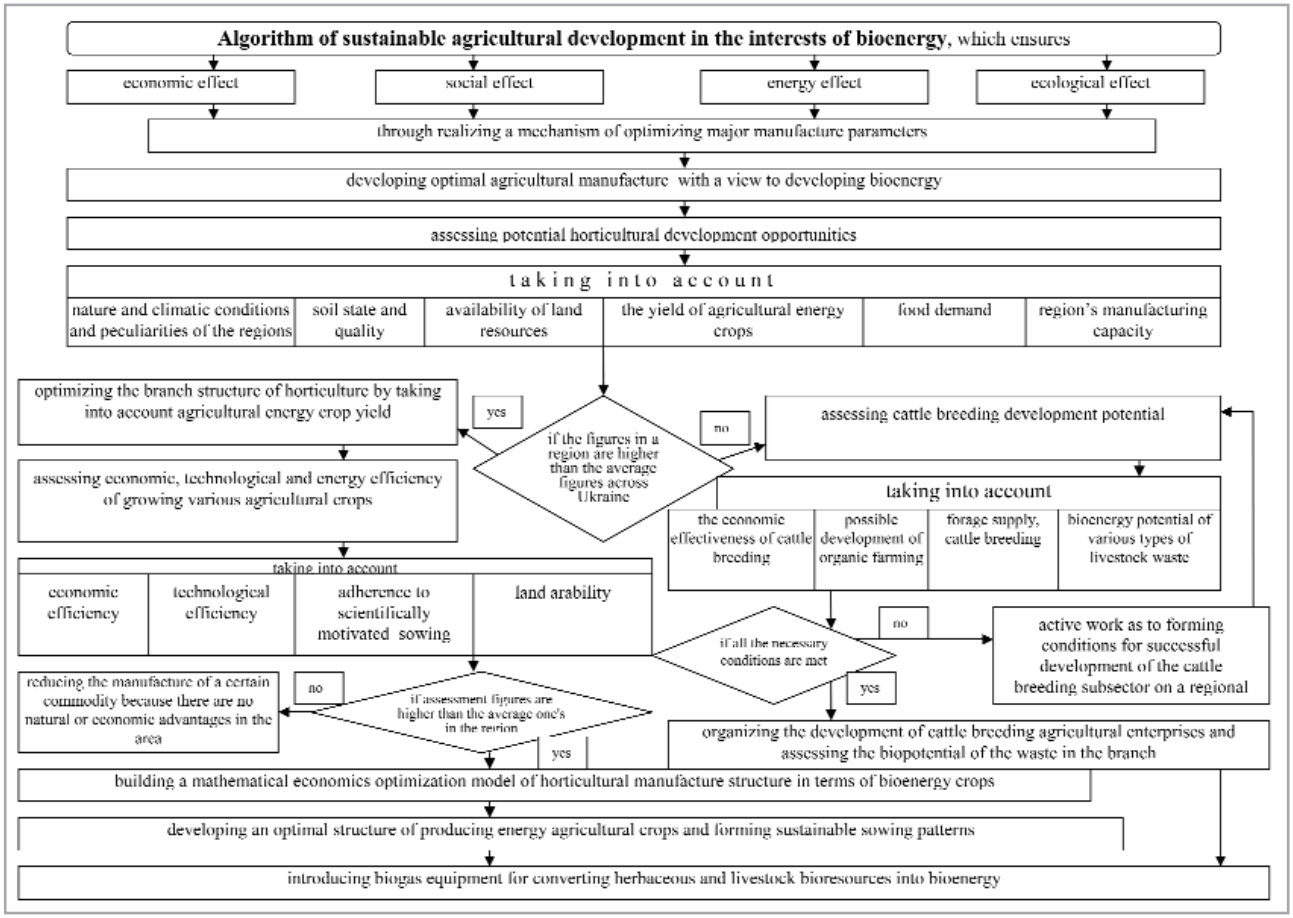
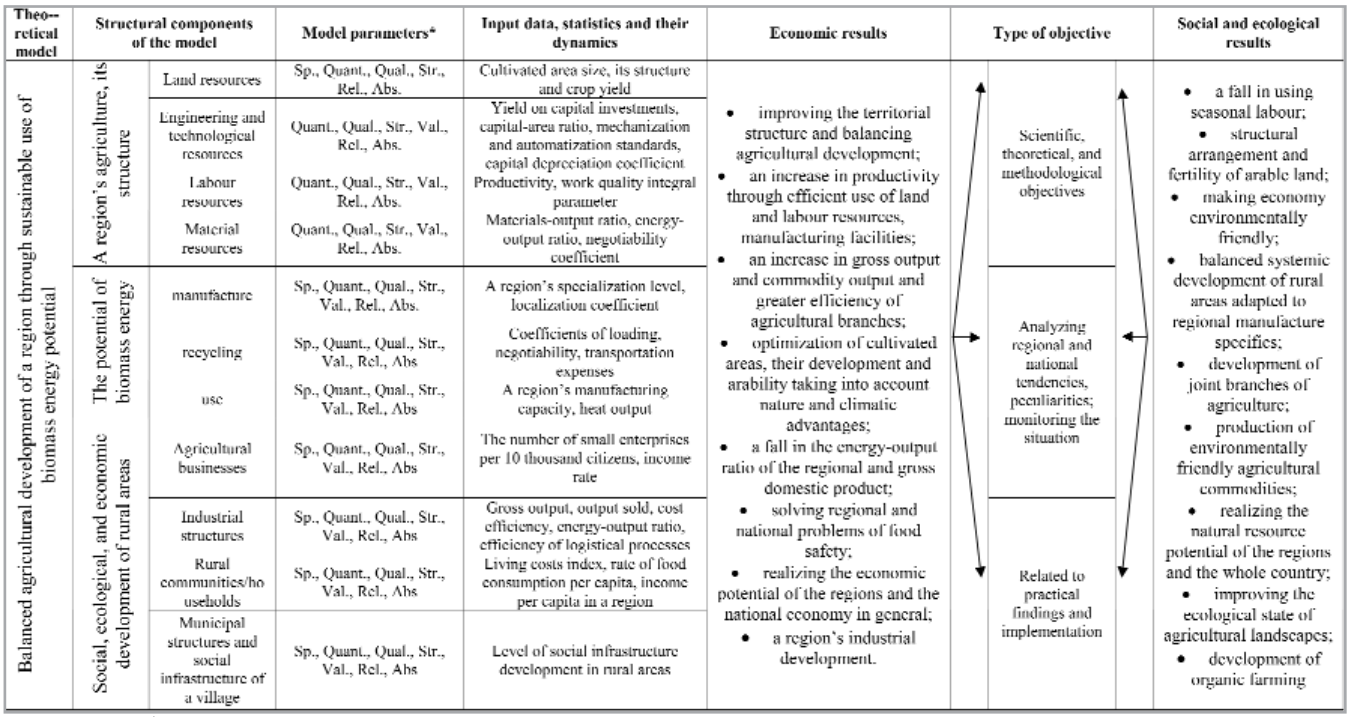


Fig. 2: **Algorithm of sustainable agricultural development in interests of bioenergy**
Source: Own research



Theoretical model	Structural components of the model		Model parameters*	Input data, statistics and their dynamics	Economic results	Type of objective	Social and ecological results
Balanced agricultural development of a region through sustainable use of biomass energy potential	A region's agriculture, its structure	Land resources	Sp., Quant., Qual., Str., Rel., Abs.	Cultivated area size, its structure and crop yield	• improving the territorial structure and balancing agricultural development; • an increase in productivity through efficient use of land and labour resources, manufacturing facilities; • an increase in gross output and commodity output and greater efficiency of agricultural branches; • optimization of cultivated areas, their development and arability taking into account nature and climatic advantages; • a fall in the energy-output ratio of the regional and gross domestic product; • solving regional and national problems of food safety; • realizing the economic potential of the regions and the national economy in general; • a region's industrial development.	Scientific, theoretical, and methodological objectives	• a fall in using seasonal labour; • structural arrangement and fertility of arable land; • making economy environmentally friendly; • balanced systemic development of rural areas adapted to regional manufacture specifics; • development of joint branches of agriculture; • production of environmentally friendly agricultural commodities; • realizing the natural resource potential of the regions and the whole country; • improving the ecological state of agricultural landscapes; • development of organic farming
		Engineering and technological resources	Quant., Qual., Str., Val., Rel., Abs.	Yield on capital investments, capital-area ratio, mechanization and automatization standards, capital depreciation coefficient			
		Labour resources	Quant., Qual., Str., Val., Rel., Abs.	Productivity, work quality integral parameter			
		Material resources	Quant., Qual., Str., Val., Rel., Abs.	Materials-output ratio, energy-output ratio, negotiability coefficient			
	The potential of biomass energy	manufacture	Sp., Quant., Qual., Str., Val., Rel., Abs.	A region's specialization level, localization coefficient		Analyzing regional and national tendencies, peculiarities; monitoring the situation	
		recycling	Sp., Quant., Qual., Str., Val., Rel., Abs	Coefficients of loading, negotiability, transportation expenses			
		use	Sp., Quant., Qual., Str., Val., Rel., Abs	A region's manufacturing capacity, heat output			
	Social, ecological, and economic development of rural areas	Agricultural businesses	Sp., Quant., Qual., Str., Val., Rel., Abs	The number of small enterprises per 10 thousand citizens, income rate			
		Industrial structures	Sp., Quant., Qual., Str., Val., Rel., Abs	Gross output, output sold, cost efficiency, energy-output ratio, efficiency of logistical processes		Related to practical findings and implementation	
		Rural communities/households	Sp., Quant., Qual., Str., Val., Rel., Abs	Living costs index, rate of food consumption per capita, income per capita in a region			
		Municipal structures and social infrastructure of a village	Sp., Quant., Qual., Str., Val., Rel., Abs	Level of social infrastructure development in rural areas			

Note. *Model parameters: spatial (Sp.), quantitative (Quant.), qualitative (Oual.), structural (Str.), value (Val.), relative (Rel.), absolute (Abs.)

Fig. 3: **Major structural components of the theoretical model, alternative input data and statistics being used and their interrelation**

Source: Authors' elaboration

Additionally, the model addresses the need to optimize agricultural production structure with a view to obtain bioresources for bioenergy development. Such a model is based largely on assessing the development potential of the horticultural sector in Ukraine's regions by taking into account the climatic advantages of a region, average crops, food demands and manufacturing capacity of the regions. A mathematical economics optimization model is available for the regions of Ukraine having good economic and technological record of growing horticultural energy crops. For regions with a low level of economic specialization (horticultural commodities), this project assesses the economic, technological, social and energy potentials for cattle breeding development and offers mechanisms for establishing the cattle breeding sector with a view to obtaining bioresources such as livestock waste.

The model of optimizing the structure of agricultural production of bioenergy allows for a possibility of assessing whether it is worth while establishing a horticultural and livestock biomass recycling facility by way of analyzing a complex of social and ecological factors. The expected positive results of the model implementation can be possible on the condition that the main methodological principles are followed; the project offers innovative solutions in the theory and practice of agricultural economics and bioenergy.

Conclusions. Therefore, our innovative model is the basis for resolving the urgent problems of food and energy security facing Ukraine today. The model suggests a complex mechanism of interrelated measures and a detailed algorithm of their implementation, which will ensure balanced agricultural development with a view to food and bioenergy production. The authors argue for the possibility of applying the model by evaluating and interpreting its structural constituents, parameters, factual data and statistics, a system of expected economic, social and ecological results. The model of balanced agricultural development through the use of biomass potential is an important alternative to solving the problems of food and energy security under conditions of unlimited demand for food and energy in modern society.

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