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Food Security and Socioeconomic Aspects of Sustainable Rural Development in Ukraine

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Foreword

This report summarizes the results of research made by the author during the 2009 Young Scientists Summer Program. The research focused on the development of an integrated modeling approach to support policy recommendations for sustainable rural development in Ukraine aimed at ensuring food security, socioeconomic sustainability and environmental safety goals. The author has analyzed the main negative trends of previous agricultural reforms, the author has formulated novel two-stage stochastic optimization model that permits to evaluate and support policy decisions with respect to sustainable agriculture development consistently within identified goals and constraints reflecting possible governmental interventions.

The introduced goals and constraints aim at ensuring stable provision of food products, environmental safety, and socioeconomic sustainability in rural areas. The proposed stochastic model includes criteria of the LEADER programs on preservation and improvement of environmental quality and increasing rural capacities for improving agricultural competitiveness. Stochastic parameters of the model represent uncertainties of expert estimates regarding potential reversal migration of labor in agriculture production activities and infrastructure development. Specific attention is paid to regions, where socioeconomic and environmental distortions are especially considerable.

The proposed two-stage stochastic optimization model for ensuring food security and socioeconomic aspects of sustainable rural development in Ukraine is a valuable tool for actual use by decision-makers. The proposed advanced methodology integrates stochastic optimization methods with multi-criteria analysis for support policy decision-making. It incorporates diverse software and approaches, dealing with massive data to be analyzed for use in the final decision procedures, and a proper visualization of the received results.

Abstract

In this paper we analyze current agriculture development trends in Ukraine. Using the results of the analysis, collected data and experts estimates we develop an integrated approach to assist decision making regarding long-term and robust agricultural policies that ensure socio-economic goals, food security and environmental safety. The proposed stochastic geographically explicit model for the analysis of robust rural development strategies adopts different criteria, among others are satisfying local demands consistent with the country-wide food production targets. The paper discusses application of the model with selected results on the level of Ukrainian oblasts'.

Acknowledgments

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About the author

Oleksandra Borodina prepared this research during Young Scientists Summer Program at the International Institute for Applied Systems Analysis (IIASA). Oleksandra is currently a postgraduate student at the Institute of Economics and Forecasting, National Academy of Science of Ukraine. Her main scientific interests are in the field of long-term strategic modeling for agriculture, integrated approach to support agriculture policy decision-making.

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Introduction

The aim of the research is to analyze current agriculture development trends in Ukraine induced by several recent agricultural reforms. Using the results of the analysis, collected data and experts estimates we develop an integrated approach to assist decision making regarding long-term and robust agricultural policies that ensure socio-economic goals, food security and environmental safety.

Agricultural and rural development policies play an important role for sustainable economic development in Ukraine. Rich and highly productive land resources of the country established Ukraine as a major supplier of agricultural and livestock products in the former USSR with 70% of land in Ukraine occupied by agriculture production. Despite these facts, the lack of proper consistent agriculture policy after 1990 resulted in dramatic drop of agriculture production (more than 60% drop) since Ukraine declared independence. The focus on economic growth and short-term market orientation with priority on large-scale enterprises resulted in significant distraction of rural settlements, income polarization, loss of welfare, depopulation, increase of unemployment and criminality. For example, over 400 rural settlements simply disappeared from the map of Ukraine during 1991-2005 (for comparison, in some regions of Ukraine there are in all 400-500 rural settlements).

Rapid emergency of large intensive agricultural enterprises and agro holdings which now dominate in the agricultural sector of Ukraine and as a rule are efficient business projects with easy access to capital, markets, policy facilitation and innovation contribute positively to agricultural sector growth in Ukraine. However, the induced agricultural production intensification resulted in adverse consequences, which became a topic of major concern requiring proper policy corrections. Several major impacts of agriculture intensification may be distinguished, showing rapid worsening of livelihood in rural areas in Ukraine. This trend became profound specifically after 2000. The major dilemma is that the growth of large enterprises contributes societal deterioration.

The structure of the paper is as follows. In Section 2 we summarize main consequences of the recent agrarian reforms and outline negative trends associated with current agricultural production intensification in Ukraine. In Section 3, we present general description of the rural community development approach for improvement of the current situation. Also in this Section we outline proposed model-based approach for the analysis of alternative scenarios and strategies to support rural community developments in Ukraine aiming at ensuring food, socioeconomic and economic safety.

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The main purpose of developed stochastic model is to support sustainable agriculture policy decision-making with respect to all possible scenarios. Proposed stochastic model includes criteria of LEADER programs on preservation and improvement of environmental quality and increasing rural capacities for improving agricultural competitiveness.

Stochastic parameters of the model represent uncertainties of expert estimates regarding potential reversal migration of labor in agriculture production activities and infrastructure development. Uncertainties related to the imperfection of government policy (e.g. bureaucracy) represented as additional costs in the goal function. Specific attention is paid to regions, where socioeconomic and environmental distortions caused by large scale enterprises (LSE) are especially considerable. Section 3 discusses model application with selected numerical experiments and in conclusions we summarize main findings of the research and outline future plans.

Analysis of Consequences of Agriculture Reforms in Ukraine

This Section analyzes current trends in Ukrainian agriculture focusing on the aspects we use in the model of Section 3. Even though Ukraine officially introduced a market economy after independence, the production structure of the old “kolhozes” and “sovhozes” remained almost unchanged till 1999 and the new production units rarely emerged. The tasks of production planning and allocation remained as state prescription and were still dominated by soviet-style politics. The regional administrations had the right to strongly influence economic decisions on the farms, for instance by ordering the cultivation of certain crops. The system of the state orders (1990-1995) and its successor, the state commodity credits (1996-1999), in fact continued the soviet system of providing inputs to the farms in exchange of a certain amount of output that had to be delivered to state procurement entities. This policy approach, even though it represented the attempt to lead the Ukrainian farm sector into a market framework, was rather likely to distort prices and incomes and thus management incentives, leading to a situation where farm managers restrained, rather than expanded production. It is therefore unlikely that substantial structural changes in the sector occurred during this period. As for the development of production, the output of agricultural raw commodities halved until the end of the 90s.

A more fundamental reform was introduced by a Presidential Decree in December 1999. According to it, the collective agricultural enterprises were forced to distribute the land shares to their members. Furthermore, the members of the collectives were assigned the right to withdraw from the collective farms in order to establish own farming entities or to lease the land and receive rental payments for their land shares. These measures have initiated a fundamental change in the ownership structure and corporate governance of Ukrainian farms involving real privatization of the former state agricultural production and requiring the withdrawal of the state from all economic and managerial farm operations. An essential driver of the second-stage reform that promoted initiative and increased profitability is that the agricultural entrepreneurs obtained freedom to decide on which commodities to produce giving priority to highly demanded cash crops. Profits from farming have risen as producers have been give incentives to keep the profits, reinvest them and to even attract additional capital investments. While in the period from 1990 to 1999, the farms of all sizes reported primarily losses, starting 2000, the farms for the first time experienced positive profits [1]. The second stage agricultural reform is characterized by rapid emergency of large intensive agricultural enterprises which now dominate the agricultural sector of Ukraine. Also a number of social, demographic, and environmental negative changes have taken place, which deserve further investigation and correction.

In the following, we analyze the changes in farm structure, production, socioeconomic situation, depopulation and environmental trends that took place after agrarian transformations in Ukraine. The data used for analysis have been taken from farm balance sheets collected by the State Statistical Committee of Ukraine for 1990-2009, IEF NASU Ukraine, and expert estimations.

2.1 Structural changes in Ukrainian agricultural sector: production structure

The on-going processes in Ukrainian agriculture in the best way may be characterized by the Figure 1, showing the evolution dynamics of large private agricultural enterprises and agro holdings with the land of more than 10000 hectares. The total number of agricultural enterprises includes agricultural co-operatives, private enterprises, and large farmer enterprises, national and other enterprises with more than 100 hectares or number of employees more than 50.

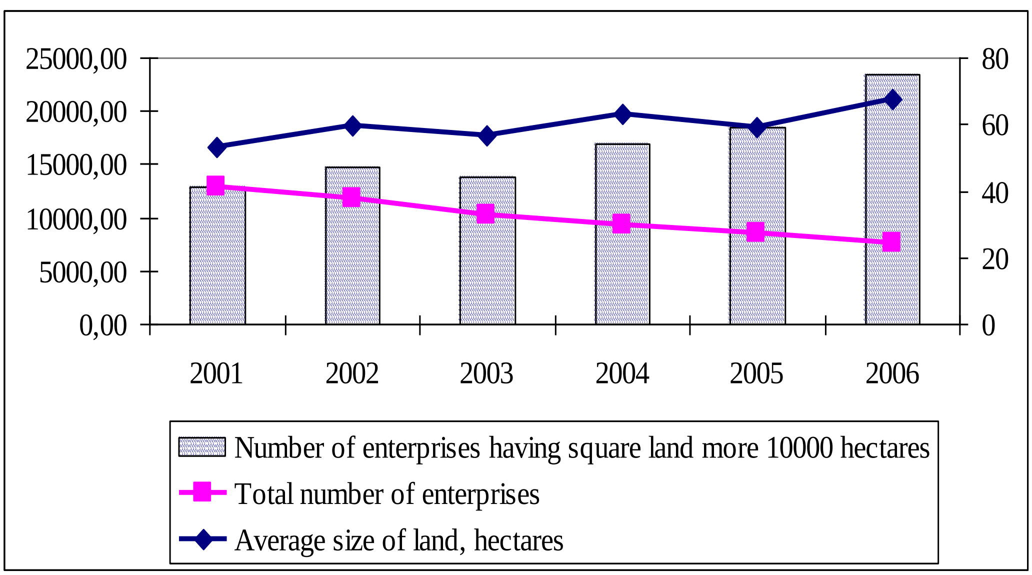


Figure 1. Dynamics of agricultural enterprises having more 10000 hectares.
Source: [5]

While the average size of land operated by enterprises increases, the total number of enterprises is considerably going down. LSEs orient their businesses towards international markets and, as a rule, focus on intensive production of profitable cash crops. In the recent years because of high international demand, the LSEs have concentrated primarily on the production of raw materials for biofuels (rapeseed, wheat, sunflower, soy, etc). This has essentially disturbed the supply of grains for direct consumption.

The imbalanced and unstable structure of grains production negatively influences the development of the livestock sector, foremost, large animals and cows that is reflected in the model in Section 3. At the beginning of the reforms, the loss of State subsidies following the collapse of the Soviet Union increased feed and production costs and reduced profitability for livestock enterprises. The increasing inability of large agricultural enterprises (i.e., former State and collective farms) to maintain livestock operations, due largely to inefficient management and farms' inability to ensure sufficient feed supplied, resulted in increased dependence on imports, private producers and households farms to satisfy demand for beef and pork. Sustainable performance of the sector is always subject to the grain market conditions and trade policies especially when grain production if focused on cash crops.

Of course, the reasons for rash decrease of animals are quite different for different years characterized by different policy implementations. For example, in 2003, 2004 and 2005 the large animals experienced especially bad years because of rapid international trade for grain and relatively low yields, which drove high the prices for feeds. The majority of livestock herd was killed in these years [10]. Killing of animals in 2004-2005 resulted in essential increase of meat prices. From March 2004 to March 2005 the price for meat increased by 56.8%. The share of meat in the goods basket used to measure inflation is 12.4%. Consequently, meat contributed high percentage points increase to the yearly inflation rate of about 14.7%. This example shows that imbalanced policies in agricultural sector produce dramatic and long-lasting effects not only within the sector but also spill over to the whole economy.

Large systems of bovine meat production turned to be very sensitive to frequently changing reforms and governmental regulations. Therefore, currently, large animals (among them cows) and bovine meat production in Ukraine prevailingly concentrate in households. Given high risks, the majority of these producers does not will and manage to invest at a larger scale into the technological improvement of their production processes. Households will likely remain on the same production level or even decrease because of strict requirements to products quality imposed by the WTO accession. With no changes in this sector it is predictable that households will remain with the largest production shares of bovine and pork meat in 2009 and on, indicating no essential large scale developments in these risky sectors of meat production.

Figure 2 shows the dynamics of raise and fall of the livestock/production. The major decrease in the number of livestock in the period from 1985 to 2000 is especially visible for large livestock. The trend of pigs and production has fallen down in the period from

1990 to 2000 and as of then resumed slow growth. Large livestock and bovine meat production have demonstrated no sign of recovery.

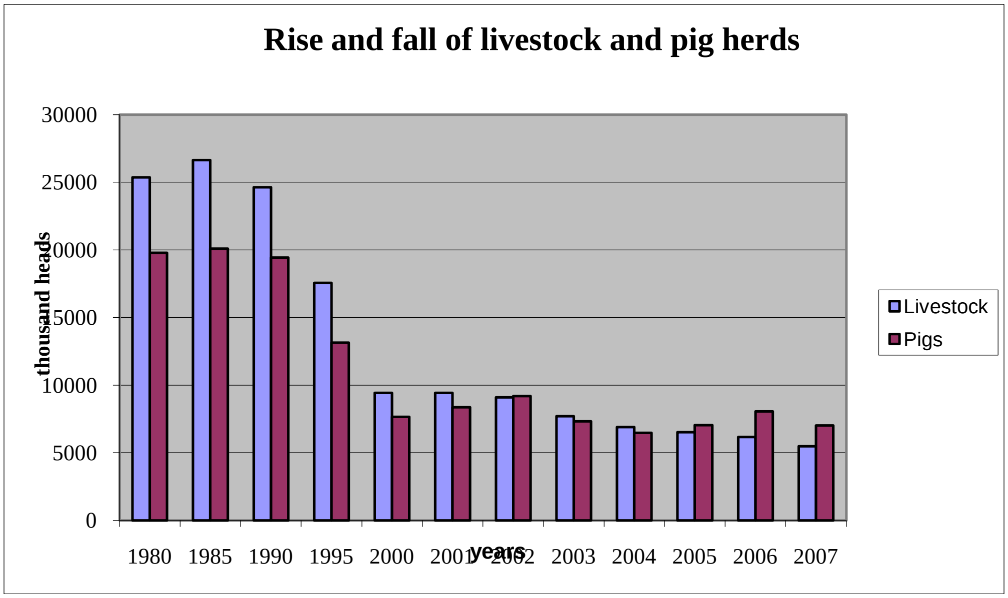


Figure 2. Raise and fall of Ukrainian livestock herds.
Source: Calculated based on Statistical bulletin for January-December 2007

As opposite to bovine and pork, the poultry sector expansion takes off at a very high rate primarily because of the governmental support through state agricultural support system and crediting. Incentives and investments into the poultry industry since 2000 significantly changed the meat supply in favor of poultry products.

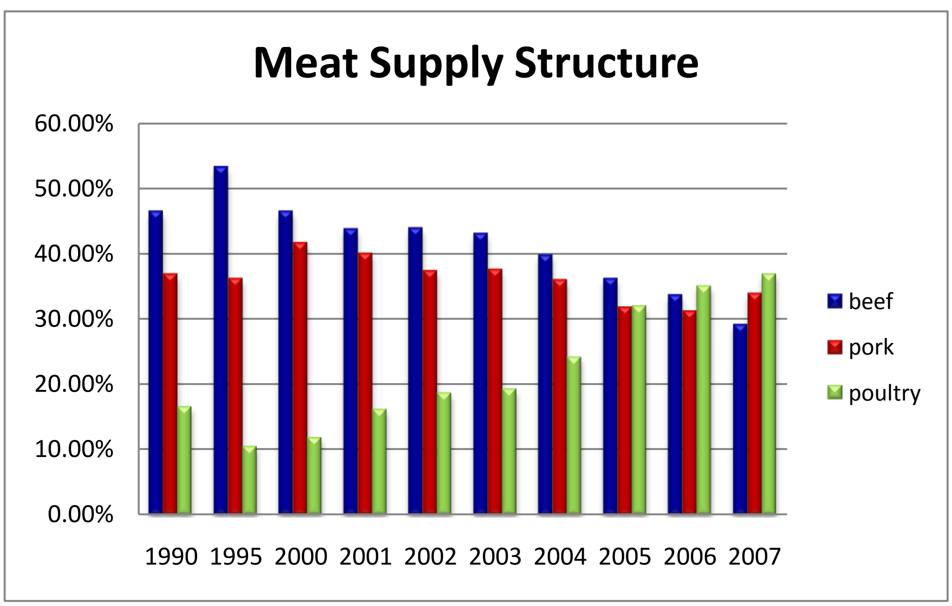


Figure 3. Dynamics of meat supply structure by types.

Source: Done based on data from State Statistical Committee of Ukraine

If domestic meat production is compared to demand by types of meat, the diagram in Figure 4 shows that starting 2004, the poultry meat was essentially overproduces. In fact, the attempt to "substitute" bovine and pork meat (vertical line shows the level of "overproduced" good) by poultry failed. Thus, in spite of ample poultry production, the quality and security of food still remains as number one problem. During the years of reforms, caloric content of food ration per capita dropped almost by one quarter compared to 1990. With respect to animal proteins, it dropped by half indicating inelastic substitution between meat types [9, 10].

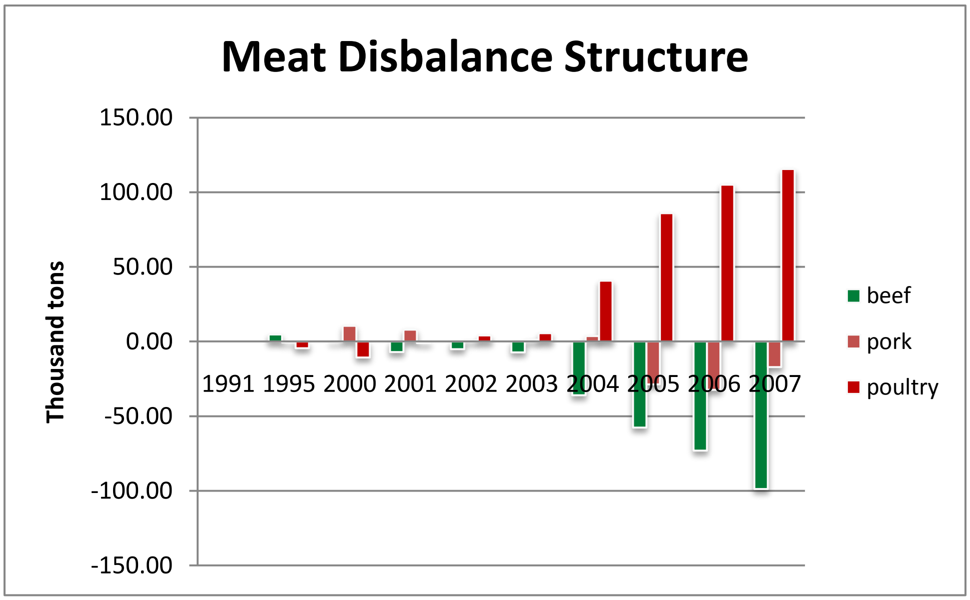


Figure 4. Dynamics of meat imbalance structure by type.
Source: Done based on data from State Statistical Committee of Ukraine

The gap between the domestically produced bovine meat and the demand for these products is usually compensated by the low quality imported products coming as a rule through black market without adequate inspection. Import low-quality food products to Ukraine, creating serious food security concerns. In spite of the different controversial points for the country, intensive agriculture production is a main object for state support agriculture policy. In the developed model we use specific regulatory constraints to deal with this negative trend. The need for regulations and incentives to correct behavioural problem of various producers is currently discussed as an important problem.

2.2 State agriculture support system

Large-scale enterprises have higher opportunities regarding state agriculture support system, e.g., subsidies, privileged credits, etc. Only one-third to one-half of Ukrainian farms have access to commercial credit, and banks seldom grant loans to small farms. Clearly, many farms will not survive, and high-risk farms with few liquid assets, heavy debt, bad credit history, and poor management will collapse [1,10]. Interest rates on commercial loans currently stand at around 28 percent. The government estimates farmers' annual financing needs at nearly $2 billion, while only about $0.6 billion is currently available via commercial bank loans. Loan requests are reviewed carefully by commercial banks based on the farms' credit history and access to collateral. Since many farms, especially small, are already heavily in debt to banks or suppliers of fertilizer and plant-protection chemicals and since agricultural loans are not guaranteed by the government, banks are largely unwilling to make long-term loans. Most credits are extended in the form of seasonal loans (six to ten months) used almost exclusively for the purchase of fertilizer and plant protection chemicals. Commercial interest rates typically range from 25 to 30 percent. The State provides assistance to farms by paying 50 percent of the interest on agricultural loans. Banks typically require 200 to 300 percent collateral, depending on the farm's credit history and the risk level. Future crop usually serves as collateral, but collateral can also be offered in the form of livestock, farm machinery, or the personal property of the farm director. Under current legislation, land cannot be used as collateral, nor can most farm machinery because it typically is old and of little value.

The difficulty for farms, especially small and medium scale, in obtaining anything other than short-term loans at interest rates of roughly 25 percent places severe constraints on their ability to invest in long-term capital improvements, such as agricultural machinery or grain-storage facilities. In many cases, the best option is for a farm to enter into an agreement with an investor who can provide operating capital and collateral to enable the farm to secure loans. This can be an attractive arrangement for the non-agricultural investment partner also.

A joint company can be registered as an agricultural enterprise if at least fifty percent of its income is derived from agricultural operations. The income of registered agricultural enterprises – including income from the company's non-agricultural activities – is taxed at a lower rate than for other, non-agricultural businesses. It is also true that these agroholdings are registered in metropolitan areas and therefore tax revenues from their activities are paid in the cities, causing outflow of financial resources from rural areas. In essence, this means that after using "facilities" in rural areas, the LSEs do not return or invest back. This situation is especially difficult for environment in rural areas, as long as uncontrolled intensive production pollute natural resources. Integrated modeling approach allows analyzing necessity governmental interventions by introducing constraints and "penalty" terms associated with taxes and subsidies.

2.3 Environmental aspects of production intensification in Ukraine

Increasing production intensification made acute the problems related to imbalanced land utilization, soil/water/air contamination, worsening physio-chemical properties of soils. Ukraine has the world's greatest area of chernozems. The land area of Ukraine is 60.4 million hectares. Predominantly rich fertile soils and favourable climatic conditions have ensured a very high degree of economic development in 92 percent of the territory. The area of agriculturally developed lands exceeds 70 percent, and this index is one of the highest in the world. The same applies to the arable land area (56 percent).

Due to the increased profitability of agriculture and shortage in reserves of vacant land, the allocation of agricultural lands for production, especially of cash crops, continues very fast. Nearly 200 000 hectares of land are destroyed annually because the level of their recultivation is inadequate. The intensification of agriculture, an increased technogenous load on land resources, and the uncontrolled use of chemicals with a low level of technological culture has resulted in an accelerated degradation of the soil and a decline in its fertility. In 25 years, the humus content in soils in Ukraine dropped from 3.5 to 3.2 percent, the area of acid soils increased by 30 percent, and that of saline and leached soils increased by 25 percent [5].

The condition of agricultural land has deteriorated due to the low quality of land reclamation works. In accordance with the data on land use, in recent years eroded (washed away) agricultural land in all categories of farms in Ukraine has made up 13.3 million hectares (31.8 percent of their total area), including slightly eroded - 66.5 percent; and medium- and strongly eroded, 33.5 percent. Degraded land extended by 19.4 million hectares (46.2 percent of their total area), their main area being concentrated in the southern (41.7 percent), and northern and central Steppe (33.1 percent). Due to the lack of protection, 450 million tonnes of soils (16.6 t/ha of total eroded lands) are being lost in Ukraine annually because of water and wind erosion.

Land is being polluted with heavy metals and other components of wastes, and the residues of fertilizers and pesticides are accumulating in the soil at a high rate. The accumulation in soils of great amounts of toxic substances have a negative effect on the quality of plant growth and livestock farming. This problem has become much more urgent in recent years due to the increased influence of human activity on the soil covering, particularly due to large-scale land utilization, the uncontrolled application of mineral fertilizers, chemical agents, methods of pest, plant and animal diseases control, and increased physical loads on soils from agricultural machinery.

The soils in Ukraine are characterized, in general, by a high natural productivity, and it is extremely important to preserve these soils for future generations. There are no strict regulations existing to impose norms and taxes for the overuse of land and water resources. Instead of taking some land out of agricultural operations, the arcridge of arable land in Ukraine is being contioniously expanded also to other forms of land utilization classes, e.g., pastures. Managers of LSEs and agroholdings often do not have adequate agronomic education and are not able to care for land quality preservation in accordance with scientific methods. The land is continuously being exhausted through intensive production of cash crops without necessary crop rotation, uncontrollable and often unreasonable use of mechanization and fertilizers. At the same time, such intensive production do not require a lot of labor to be involved, which caused significant unemployment rates in rural area. In the model of Section 3 we assume so far, that in our research this can be regulated through investments term of the model and constraints on pastures. The need for regulations and incentives to correct behavioural problem of various producers is currently discussed as an important problem.

2.4 Employment in rural areas

Production intensification and land concentration led to many adverse problems in agriculture, but most harmful are impacts on demographic and socioeconomic situation in rural areas. Foremost, this relates to the high rate of unemployment. Intensive large scale enterprises and agro holdings are not interested in hiring many employees. They require much fewer workers than Soviet-type agro businesses. They make use of wide-section qualified labor force from cities, better educated with necessary skills and experience and thus neglect the possibility and need of retraining the rural people and investments in local human capital. LSE may hire some rural people for non-qualified job with one issue - using extremely difficult situation with employment in rural areas, they are reducing level of payment on a human capital of rural people to increase their own profits.

Table 1 summarizes average salary levels of workers in Ukraine. Currently, employees in agriculture receive extremely low salaries. In 2006 the average per-hour rate for employee in agriculture was ~ 0,72$, with the highest in Kiev region (0,93$) and the lowest in Khmelnicky region (0,53$). In comparison with the other countries these figures looks really dramatically.

Table 1. Dynamics of monthly average salaries of agricultural workers in comparison with other branches of economics for 1990-2005.

	karb.	UAH			
	1990	2000	2002	2004	2005
Agriculture	232	111	178	295	415
Industry	278	302	485	743	967
Rate of salary level in agriculture, *% level*					
in industry	83,4	36,7	36,7	39,7	42,9
total in economics	95,1	48,3	47,3	50	51,5

Source: Economic activity of the population of Ukraine for 2005: Statistical Bulletin - К: Derzhkomstat of Ukraine, 2006.

At the same time, not only between rural and urban, but also between rural areas in different oblasts, the income differentiation in Ukraine is rather high. Such situation influenced migration processes in Ukrainian rural area, which bring depopulation of rural territories. There exist expert's estimations on potential reverse migration of rural population, which is subject for example to improvements of rural infrastructure and better provision of population with public goods in rural areas. In our model we treated these uncertainties by using sets of plausible expert scenarios.

2.5 Depopulation and depressiveness of rural areas

Rural reforms induced drastic decline in the livelihood conditions and living standards, rapid growth of unemployment, lack of social security, rising psycho-social tension caused by the lack of hope for the future – all these side effects undoubtedly worsened the demographic situation and the population's state of health in Ukraine, and, in particular, in its rural areas. Especially, the second stage reform focusing on increasing profitability of agriculture and short-term market orientation with priority on large-scale enterprises resulted in significant distraction of rural settlements, income polarization, loss of welfare, depopulation, increase of unemployment and criminality [5], [17].

The lack of employment, low incomes and social and health provision in rural areas in Ukraine induced high rate of outflow of rural population to cities and the accelerated rate of the population's ageing. For example, over 400 rural settlements disappeared from the map of Ukraine during 1991-2005 (for comparison, in some regions of Ukraine there are in all 400-500 rural settlements).

The essential changes are visible even in average tendencies. There are even more profound changes in demographic and social problems in Ukraine at local levels, which are shown in conducted researches, [5, 7], analyses situation in rural areas of Ukraine on "rajon" and "oblast" levels in the period from 1990 to 2007. The aim of the research is to highlight current spatial distribution of problematic zones and identify future rural area depopulation and degradation trends. Two main criteria were selected to distinguish the areas by their level of depopulation and degradation. For example, the areas are defined as "depopulated" if there depopulation rate exceeding 15% (calculated as an average over three years' rate of depopulation, 15 people per 1000). These places are put on the list of demographic crisis areas. Locations having 50% of inhabitant in retirement age (for areas with less than 200 inhabitants, the percentage is assumed to be 40%) are identified as depreciated and abandoned areas. These two criteria essentially correlate with rural infrastructure degradation. Currently, several governmental programs are planned to support the rural areas identified as "depressive" according to the coincidence of the two criteria. Among the most depressive territories are rural areas in Chernihiv, Sumy, and Poltava oblasts, which already in 2001 had the so-called "black spots" with the level of depressiveness essentially beyond 80-90%. Even central oblasts such as Kievskaja, Poltavskaja, and Cherkaskaja in 2001 ranked as second in the list with the index varying between 60 and 90 %. Figure 6 shows projected expansion of the trend to 2015.

Figure 6. Expected depopulation on rural territories in Ukraine in 2015.
Source: [7]

As it is seen, if nothing will be changed in rural policy, in the nearest time in 2015 we will be able to observe strong depopulation in almost every region of Ukraine. No doubt, such difficult situation in rural territories in Ukraine requires an integrated approach for investigating and policy decision-making. As one of the ways to the policy for sustainable economic development in Ukrainian agriculture sector we define rural community development, which have been widely used in many developed countries and shown good results.

3. Long-term Economic Development Strategy: An Integrated Approach

3.1 Rural community development approach in Ukraine

The trends in rural communities highlighted in previous Sections are alarming and require scientifically justified approaches for correction. The set of principles for sustainable rural community development has already been implemented in the USA as well as in EU. These are the well-known LEADER I, LEADER II, LEADER+ programs [2]. For example, as an integral part of Rural Development Programs in the EU Member States, the Leader+ approach is supported under Council Regulation (EC) 1698/2005 for rural development by the European Agricultural Fund for Rural Development (EAFRD). LEADER originally stands for “Liaison Entre les Actions de Development Rural”, the English translation meaning “Links between actions of rural development”. The program analyzes incentives to encourage the implementation of integrated, high-quality and original strategies for sustainable development, has a strong focus on partnership and networks of exchange of experience. The program supports the development of local funds and support systems to finance LEADER+ local actions.

In the context of Ukraine, closely resembling LEADER program is a recent initiative introduced by the Ukrainian Government [16]. The initiative includes a number of financial and fiscal reforms to improve rural conditions by stimulating local budgets. Main goals that govern distribution of budgets are to improve life quality in rural areas including public and private services; to create local funds to support/subsidize local economy in rural areas including social and health services for inhabitants and visitors; to ensure policies for preservation and friendly use of environmental and cultural values in rural areas; to stimulate implementation of structural and financial measures for environment and landscape improvement; for introduction, utilization, and expansion of new technologies and markets of local products and services. It summarizes a number of vital revisions to the new governmental budget accounting for the needs of rural communities [16].

In what follows, we develop a model that permits to derive insights into the necessary level of required rural community "adjustments" to attain the identified development goals. We demonstrate the model-based concept only with a few measures: introduction of new agricultural and service facilities by locations and creation of local or state funds to support the establishment of these additional rural activities. The funds may receive investments from different sources, e.g., as mentioned in [16], from government or Agriholdings that otherwise escape tax payments, which is discussed above.

3.2 Analysis of pathways towards sustainable rural area development: an integrated model based approach

The implementation of the rural community development goals calls for cooperative local solutions coherent with national plans. The model presented below evaluates optimal portfolio of regional and national measures permitting to improve rural life conditions. It aims at supporting policy recommendations regarding robust expansion, i.e., allocation and intensification, of agricultural production.

The main goal of the sustainable development policy is to create additional agricultural production facilities and rural services by locations to satisfy food demand and to create jobs for potential migrants. The problem of migration between oblasts and between urban-rural locations is very urgent in Ukraine. Because of financial crises, many short-term employees were laid off in cities. It is expected that they either return to places which they come from, primarily in rural areas, or travel within Ukraine in search for jobs. Optimal production levels by geographical locations are derived as a tradeoff between costs minimization, e.g., of investments and production, the goal to ensure targeted production and creation of additional rural jobs, and the suitability criteria of locations to expand agricultural production and to accommodate workers of agricultural and service type businesses. For the case of livestock production allocation, the suitability criteria include feeds and pastures requirements pet unit livestock.

The model is spatially and temporally explicit. So far it involves only two time intervals, current and future, and it is implemented on country level for 25 Ukrainian oblasts. The model is comprised of the three main modules: socioeconomic, environmental and agricultural: the socioeconomic module defines a balance between the criteria for costs minimization and social goals including additional production to ensure jobs and food security; the environmental module controls pressure stemming from agricultural production in locations;

The goal is to allocate targeted amount of additional production and rural workers in “depressive” regions. The targets are estimated based on expert opinion and data available in Institute of Economics and Forecasting, NAS Ukraine and other institutions by taking into account pre-reform levels of production in respective locations and current trends with jobs availability in cities. We treat some of these values as uncertain random variables.

Denote by $x_{ijl} \geq 0$ the required increase in production of commodity i in region l and management system j to meet the required targets d_i, $i = 1,2,...$, which creates rural agricultural and nonagricultural (service) jobs. Define $\beta_{ijl} \geq 0$ as a number of workers to produce a unit of commodity x_{ijl}, and L_l - as a targeted level of new rural employees to “revive” rural developments in location l. The goal to ensure required employment in location l is defined by the constraints which can be written symbolically as the following:

$$\sum_{i.j} \beta_{ijl} x_{ijl} \geq L_l \,. \qquad (1)$$

In general, L_l may not be defined with certainty as it is difficult to predict, for example, how many people are likely to return from short-term urban jobs to rural home places. Therefore, exact specification of constraint (1) as well as of the constraints (2) can be given in terms of probabilistic constraints (7)-(8) or within general two-stage stochastic optimization framework defined by functions (11)-(18) Migration of labor force between rural-urban areas, within regions (oblasts) depends on various factors, including availability of infrastructural (schools, trade centers, etc.), health and social provisions, transportation networks, entertaining and cultural centers, incomes, etc. The model may account for these behavioral components in a way similar to IIASA LUC program model developed for China case studies [11], [12] where behavioral criteria were combined with strictly planned governmental policies. In general, variable L_l may be characterized by alternative development scenarios.

Establishing of new rural businesses and production units requires appropriate services and employees. Data provided by IEF allows also to estimate the employment rate in infrastructure per unit of product x_{ijl}. The targeted levels S_l by oblast l are derived with a help of experts. Note, that values S_l may again be random or correspond to alternative development scenarios. The willingness to work in infrastructure, for example in schools, depends on gender, age, educational level, etc. Scenarios of S_l can be derived using results of available questionnaires, for example, expert opinions and/or statistical data. Thus, in addition to equation (1), the goal of the model is to find such $x_{ijl} \geq 0$ that also satisfy the condition on people involved in rural infrastructure development:

$$\sum_{i.j} \gamma_{ijl} \beta_{ijl} x_{ijl} \geq S_l \,. \tag{2}$$

Of course, the development of new production and services requires additional investments. This is defined either as an overall budget constraints or minimization of costs and investments:

$$\sum_{i.l} V_{il} (\sum_j x_{ijl}) + \sum_{ijl} c_{ijl} x_{ijl} + \sum_l C_l (y_l) + \sum_{kl} c_{kl} y_{kl} \,, \tag{3}$$

where c_{ijl} are expenditures associated with wages or costs of employees involved in production x_{ijl}. The investments V_{il} depend on the level of current development – less developed, depressive regions require, in general, higher investments. In addition, cost functions C_l and c_{kl} may be associated with required transportation of feeds between regions, as explained below.

Food security and environmental constraints of the model are represented by the equations (4) (5) (6) respectively:

$$\sum_{jl} x_{ijl} \geq d_i \,, \tag{4}$$

$$\sum_{ij} \delta_i x_{ijl} \leq a_l + y_l + \sum_k y_{kl} - \sum_k y_{lk} \,, \tag{5}$$

$$\sum_{ij} \sigma_i x_{ijl} \leq b_l \,. \tag{6}$$

Constraint (4) ensures that new production $x_{ijl} \geq 0$ satisfies the required national targets d_i by a commodity i, which reflects food security considerations. For example, equation (5) ensures that allocation $x_{ijl} \geq 0$ satisfies availability of feeds in locations l, where δ_i is a technical coefficient defining feed requirements per unit livestock. Variables $y_i \geq 0$ represent the possibility to expand feeding capacity a_l at costs $c_l(y_l)$, and variables y_{lk} stand for possibility of feed trading between different regions at costs c_{kl}. The same type of additional decision variables can be introduced in equations (4) for trading production commodities. Equations (6) allows production expansion only to areas with sufficient resources such as pastures or cultivated land thus ensuring recycling of wastes and manure associated with new x_{ijl} units of production, σ_i may be an ambient coefficient on availability of diverse recycling capacities (also, manure storage and processing facilities). Constraints (5) and (6) comprise the environmental module that guarantees environmental targets and land use and agronomic norms.

Stochastic variables/scenarios S_l, L_l require further model specification. We admit that information on S_l, L_l may be available only with some certainty, and the solution x_{ijl} needs to satisfy constraints (1)-(2) with guaranteed certainty in case of all possible scenarios S_l, L_l. Say, chances that constraints (1)-(2) are satisfied (for x_{ijl}) must be higher than imposed levels $0 \le p_l \le 1$, $0 \le q_l \le 1$. This requirement is naturally expressed in terms of probabilistic constraints

$$\operatorname{Prob}\{\sum_{ij} \beta_{ijl} x_{ijl} \ge L_l(\omega)\} \ge p_l\,, \tag{7}$$

$$\operatorname{Prob}\{\sum_{ij} \gamma_{ijl} \beta_{ijl} x_{ijl} \ge S_l(\omega)\} \ge q_l\,, \tag{8}$$

$0 \le p_l \le 1$, $0 \le q_l \le 1$, which are similar to the well-known in engineering safety or reliability constraints. In insurance business, they reflect solvency constraints of insurance companies or banks and often are defined by p_l, q_l of about 1- 10^{-3}, insolvency may be regulated as an event that may occur once in 1000 years.

Constraints (7)-(8) describe in a sense a stochastic supply – demand relations regarding employment: the demand $\beta_{ijl} x_{ijl}$ may not be completely satisfied by the random supply $L_l(\omega)$; similar relates to $\gamma_{ijl} \beta_{ijl} x_{ijl}$ and $S_l(\omega)$. To account for possibly highly discontinuous equations (7)-(8), we convert them into a multicriteria problem of minimization of convex functions

$$E \max\{0, L_l(\omega) - \sum_{ij} \beta_{ijl} x_{ijl}\}\,, \tag{9}$$

$$E \max\{0, S_l(\omega) - \sum_{ij} \gamma_{ijl} \beta_{ijl} x_{ijl}\}\,. \tag{10}$$

Minimization of function (9)-(10) implies the cost of π_l, ψ_l to decrease the gaps or expected deficit of additional employment in agriculture and infrastructure services. Therefore, functions (9), (10) are modified to the following cost functions

$$\pi_l E \max\{0, L_l(\omega) - \sum_{ij} \beta_{ijl} x_{ijl}\} \quad (11)$$

$$\psi_l E \max\{0, S_l(\omega) - \sum_{ij} \gamma_{ijl} \beta_{ijl} x_{ijl}\}. \quad (12)$$

Accounting for goals (3) and (11)-(12), the problem can be formulated as the following: find production x_{ijl} minimizing the function

$$\begin{aligned} &\sum_{i.l} V_{il}(\sum_j x_{ijl}) + \sum_{ijl} c_{ijl} x_{ijl} + \sum_l C_l(y_l) + \sum_{kl} c_{kl} y_{kl} \\ &\quad + \pi_l E \max\{0, L_l(\omega) - \sum_{ij} \beta_{ijl} x_{ijl}\} \\ &\quad + \psi_l E \max\{0, S_l(\omega) - \sum_{ij} \gamma_{ijl} \beta_{ijl} x_{ijl}\} \end{aligned} \quad (13)$$

subject to constraints (4)-(6).

Function (13) can be considered as a stochastic version of scalarization function, traditionally used in multicriteria analysis. Formally, the scalarized function (13) corresponds to a multicriteria stochastic minimization model with criterion function (3) and the criteria functions (11)-(12). As analyzed in [4], [12], appropriate choice of values π_l and ψ_l allows control of safety/security constraints (7), (8). We may also formulate a robust stochastic optimization model with an alternative scalarization function:

$$\begin{aligned} &\sum_{i.l} V_{il}(\sum_j x_{ijl}) + \sum_{ijl} c_{ijl} x_{ijl} + \sum_l C_l(y_l) + \sum_{kl} c_{kl} y_{kl} \\ &\quad + E \max_l \pi_l \max\{0, L_l(\omega) - \sum_{ij} \beta_{ijl} x_{ijl}\} \\ &\quad + E \max_l \psi_l \max\{0, S_l(\omega) - \sum_{ij} \gamma_{ijl} \beta_{ijl} x_{ijl}\}, \end{aligned} \quad (14)$$

i.e., instead of the aggregate "expected" deficit defined in (13) as the sum of functions (11), (12), function (14) focuses on extreme deficits of the most suffering regions. In other words, the advantage of this optimization problem is its focus on country-wide extreme scenarios regarding the supply $L_l(\omega)$ and $S_l(\omega)$. If parameters of the formulated model do not depend on x_{ijl}, the minimization of functions (13), (14) may be reduced to the linear programming problem by using so called second-stage decision variables.

Let us consider this only for the minimization of function (13) subject to constraints (4), (5), (6). This problem can be viewed as a so-called two-stage stochastic optimization model. In general, ex-ante decisions x_{ijl} may lead to deficits defined by (9), (10). Two-stage models assumes that after the observation of real random parameters L_l^s and S_l^t, the arising deficit can be corrected by second stage ex-post decisions Z_l^s and U_l^t. In our model, the second stage decisions Z_l^s in constraint (1) and U_l^t in constraint (2) may be associated with the use of better technologies or more qualified employees with higher wages. Let us formulate this more precisely. Decision variables Z_l^s and U_l^t ensure satisfaction of constraints

$$\sum_{i.j} \beta_{ijl} x_{ijl} + Z_l^s \geq L_l^s, \tag{15}$$

$$\sum_{i.j} \gamma_{ijl} \beta_{ijl} x_{ijl} + U_l^t \geq S_l^t \tag{16}$$

for all possible random realizations (scenarios) L_l^s and S_l^t, $s = \overline{1:N_l}$, and $t = \overline{1:M_l}$. Therefore, the second-stage feasible variables Z_l^s and U_l^t are, in general, random ($Z_l = Z_l(\omega)$ and $U_l = U_l(\omega)$) and depend on x_{ijl} and L_l^s and S_l^t. The two-stage stochastic programming problem is formulated as minimization of the following function:

$$\begin{aligned} &\sum_{i.l} V_{il}(\sum_j x_{ijl}) + \sum_{ijl} c_{ijl} x_{ijl} + \sum_l C_l(y_l) + \sum_{kl} c_{kl} y_{kl} \\ &\qquad + \sum_l \pi_l EZ_l(\omega) + \sum_l \psi_l EU_l(\omega) \end{aligned} \tag{17}$$

subject to constraints (4), (5), (6), (15), (16). If costs V_{il} and c_l, c_{kl} are linear (or piecewise linear convex function), then (17) may be solve by linear programming methods. Assume that $L_l(\omega)$ and $S_l(\omega)$ are represented by scenarios L_l^s, $s = \overline{1:N_l}$, and S_l^t, $t = \overline{1:M_l}$, with probabilities $\vartheta_l^1, \ldots, \vartheta_l^{N_l}$ and $\mu_l^1, \ldots, \mu_l^{M_l}$. This is a natural assumption since results of questionnaires and experts opinions are usually quantified by a number of scenarios and their likelihoods, e.g. with equal probabilities. Let us denote by Z_l^s and U_l^t the ex-post decision under scenarios L_l^s and S_l^t. Then, the proposed model can be formulated as the following linear programming problem: minimize

$$\sum_{i.l} V_{il}(\sum_j x_{ijl}) + \sum_{ijl} c_{ijl} x_{ijl} + \sum_l C_l(y_l) + \sum_{kl} c_{kl} y_{kl}$$
$$+ \sum_l \pi_l \sum_s \vartheta_l^s Z_l^s + \sum_l \omega_l \sum_t \mu_l^t U_l^t \quad (18)$$

subject to constraints (4), (5), (6), (15) and the constraints (15)-(16). It is easy to see that optimal decisions Z_l^s and U_l^t are calculated as $Z_l^s = \max\{0, L_l^s - \sum_{ij} \beta_{ijl} x_{ijl}\}$, $U_l^s = \max\{0, S_l^s - \sum_{ij} \gamma_{ijl} \beta_{ijl} x_{ijl}\}$, for all scenarios $s = \overline{1:N_l}$ and $t = \overline{1:M_l}$. Therefore, the model defined by equations (4), (5), (6), (18), (19), (20) is indeed equivalent to the model defined by equations (4), (5), (6), (13), (15), (16) under random scenarios L_l^s and S_l^t.

3.3. Numerical application

This Section summarizes some results of the case study addressing problems of imbalances agricultural production and scarcity of rural jobs for workers migrating among different oblasts l in Ukraine, $l = \overline{1:25}$. For simplification of exposition, we illustrate the model application only with an example of livestock sector and rural services. The problem of planning new rural activities is very urgent. As shown in Section 2, there is a large potential of migrants from urban to rural areas. The scenarios of potential migrants L_l^s and S_l^t in (15)-(16) are derived in IEF (Institute of Economics and Forecasting, Kiev, Ukraine) by economic experts using national surveys. About 100 alternative scenarios have been identified by ranges[1] (see Figure 11).

Necessary expansion of current rural activities to employ potential migrants is estimated as a trade-off between minimization of total investments (3), minimization of labor deficits (15)-(16) under suitability constraints (4)-(6). The model may operate in two modes: the deterministic and the stochastic. In deterministic mode, the model derives a solution with respect to only one scenario of migrants, e.g., expected numbers. In stochastic – it assumes that the number of migrants is not known in advance, and derives a robust conclusion regarding the level of necessary activities which minimizes the costs and maximizes employment accounting for a guaranteed percentage of the migrants defined by the safety constraints (7)-(8).

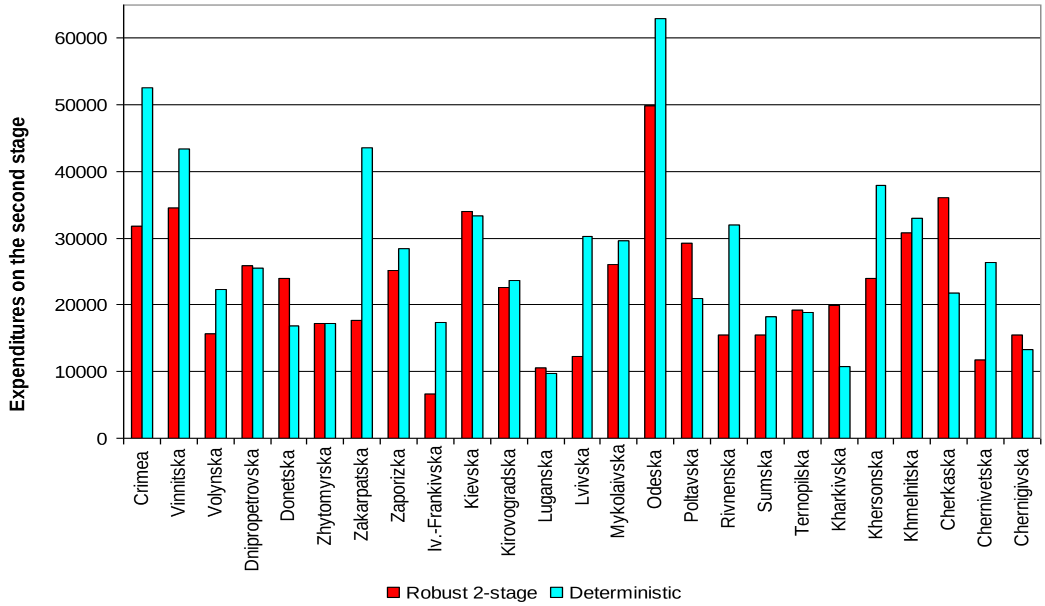
Let us summarize main differences and advantages of the robust solution. The deterministic model performs under a strict assumption that the number of migrants is

[1] Model parameters are summarized in ANNEX 1. Costs per animal operations, the ranking of oblast by depreciation level, transportation and production costs are available from the Statistical Year Books of Ukraine.

exactly known before additional activities are created, which, in essence, restrains the analysis to the only one scenario $s=1$ and $t=1$ in (15)-(18). In this case, it may happen that the jobs are created with respect to an expected or "targeted" number of people, while the real number may turn to be lower or higher. Both alternatives lead to direct and indirect losses. In case when the activities are expanded (which includes, e.g., infrastructure – roads, schools, medical and cultural facilities, etc.) but not enough workers come, the investments are either lost or the situation may require to offer hire incomes and privileges in order to attract the required workers. In the opposite situation, if jobs and facilities are in undersupply, this may either cause regret situations among population or would require more upfront investments in order to immediately accommodate the newcomers.

In contrast to deterministic, the robust two-stage solution is derived assuming that the number of migrants is not known in advance. In this case, the costs associated with both situations arising due to the deterministic approach, are controlled by the second stage. The idea of the robust solution is to choose such levels of activities x_{ijl} before knowing the true number of migrants that the investments associated with x_{ijl} and the costs of their corrections determined by the second-stage decisions Z_l^s and U_l^t are minimized. In the event of "more-than-expected" migrants, the costs of Z_l^s and U_l^t may reflect immediate investments into additional infrastructure, houses, farms, roads, etc. In the "less-than-expected", these may correspond to increased incomes or social benefits to attract laborers.

According to the data and expert estimates, in Ukraine it is expected that the number of migrants may considerably exceed expected values (Figure 11). Total costs of the deterministic and the robust solutions are depicted in Figure 7-8. For the deterministic solution, the costs include initial investments and additional expenditures to match the "reality", which are essentially higher than the costs associated with the robust solution. Total costs for robust and deterministic solutions are 55 and 70 (10^5) monetary units, respectively.



Figures 7-8. Costs associated with improving the situation in case number of work places is lower than the true number of migrants *(for the robust and for deterministic solutions)*

Figures 9-10 and Table in ANNEX 2 depict geographical distribution of the created rural activities (in terms of people-work places) to accommodate migrants, in deterministic and robust case respectively. As a robust policy recommendation, it is suggested to create higher number of work-places than for an average deterministic situation.

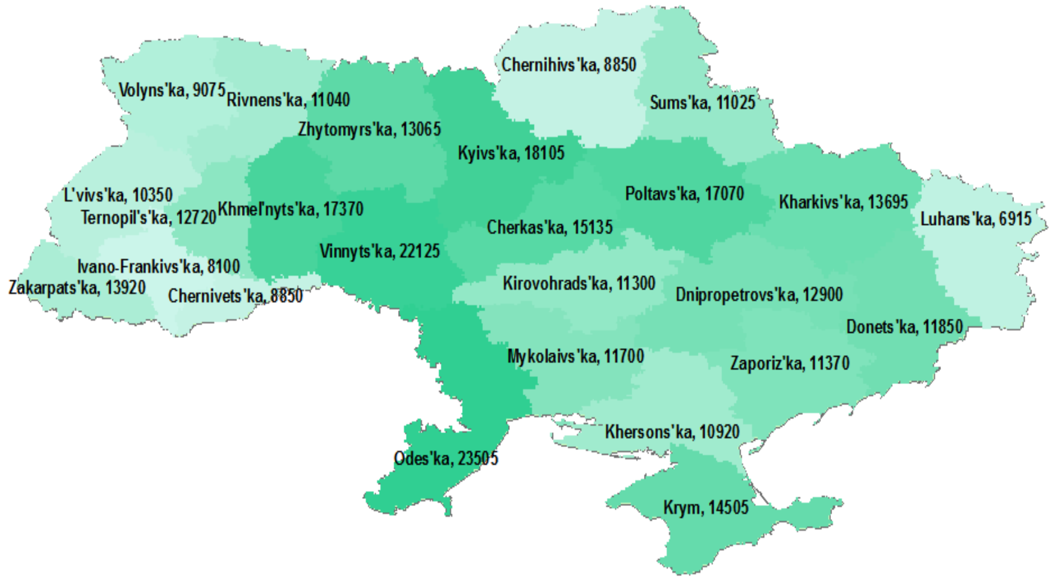


Figure 9. Allocation of new rural activities (agricultural and rural services) in people work-places *(deterministic solution)*

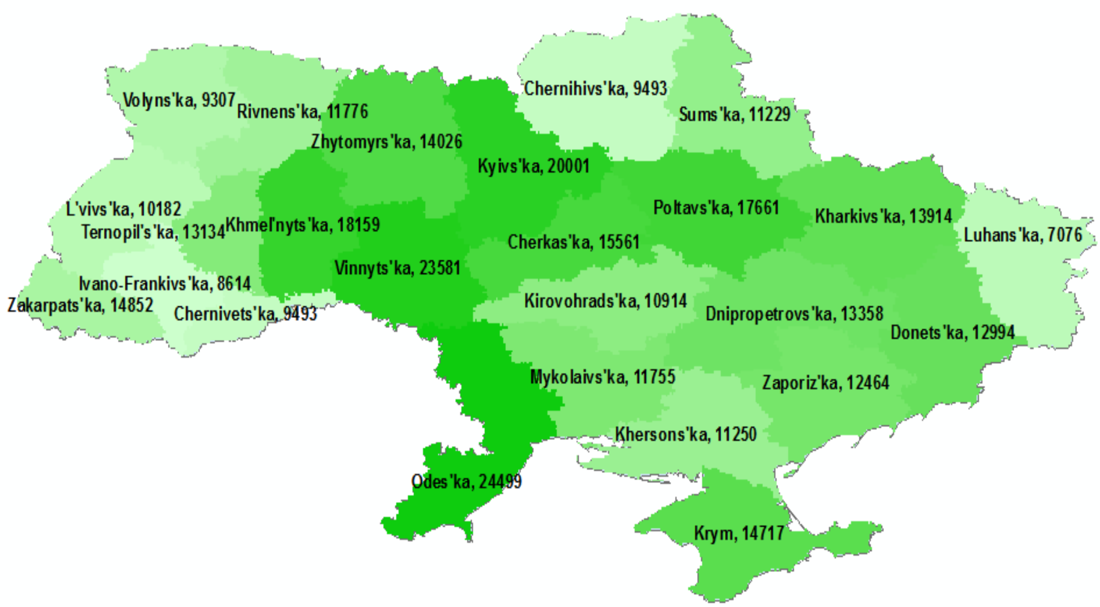


Figure 10. Allocation of new rural activities (agricultural and rural services) in people work-places *(robust solution)*

Figure 11 displays the deterministic and the robust solutions (in terms of people work-places) on the same scale to compare them explicitly. Gray bullets visualize alternative scenarios of migrants which essentially deviate from the expected scenario (blue bullets). The robust solution (red bullets) for some oblasts considerably differ from the deterministic one since it accounts for a percentile of all migrants' scenarios, while the deterministic scenario tends to hit expected "targeted" level of migrants. Notice, that the derived results so far provide only an aggregate oblast-level perspectives regarding the development alternatives. The results must be further downscaled to rajons' (region) level using, e.g., downscaling technique developed in [13].

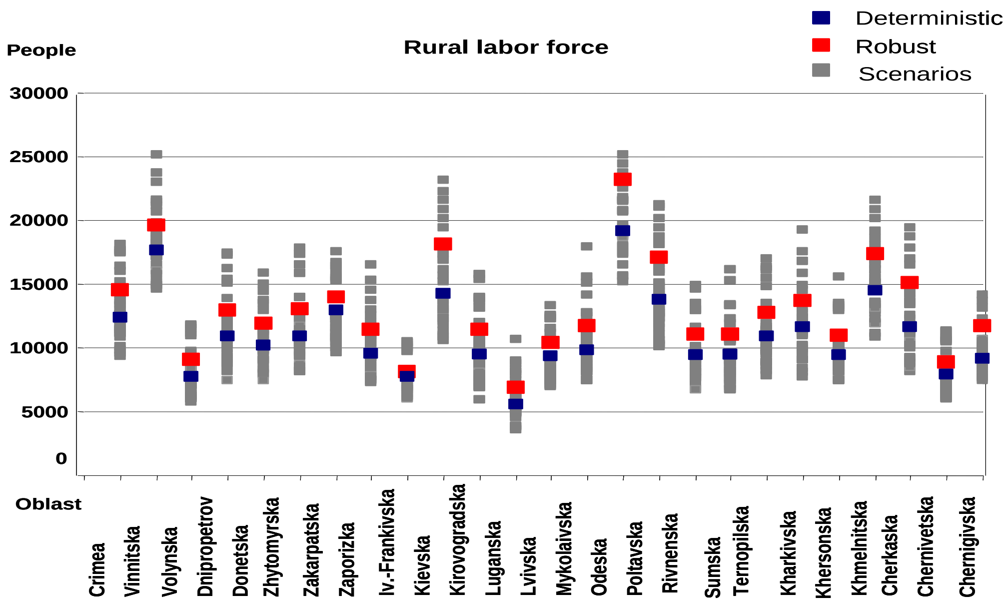


Figure 11 Deterministic and robust allocation of new rural activities *(in people work-places, to accommodate unknown in advance number of people; scenarios are depicted with grey color)*

Figures 12-13 show geographical distribution of the livestock production in regions, deterministic and robust solutions respectively.

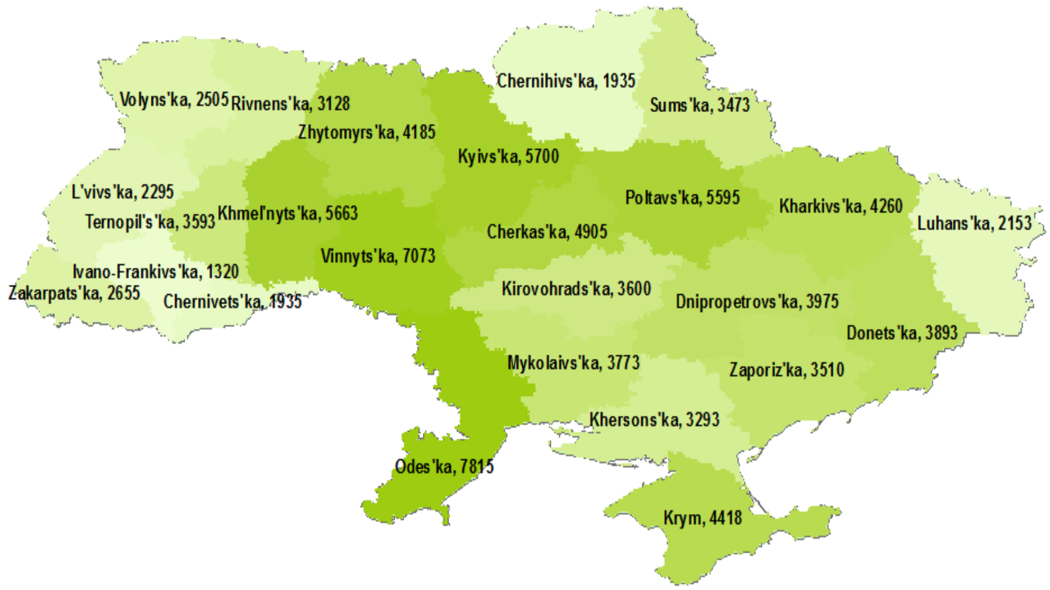


Figure 12. Allocation of new livestock production (livestock heads), deterministic solution.

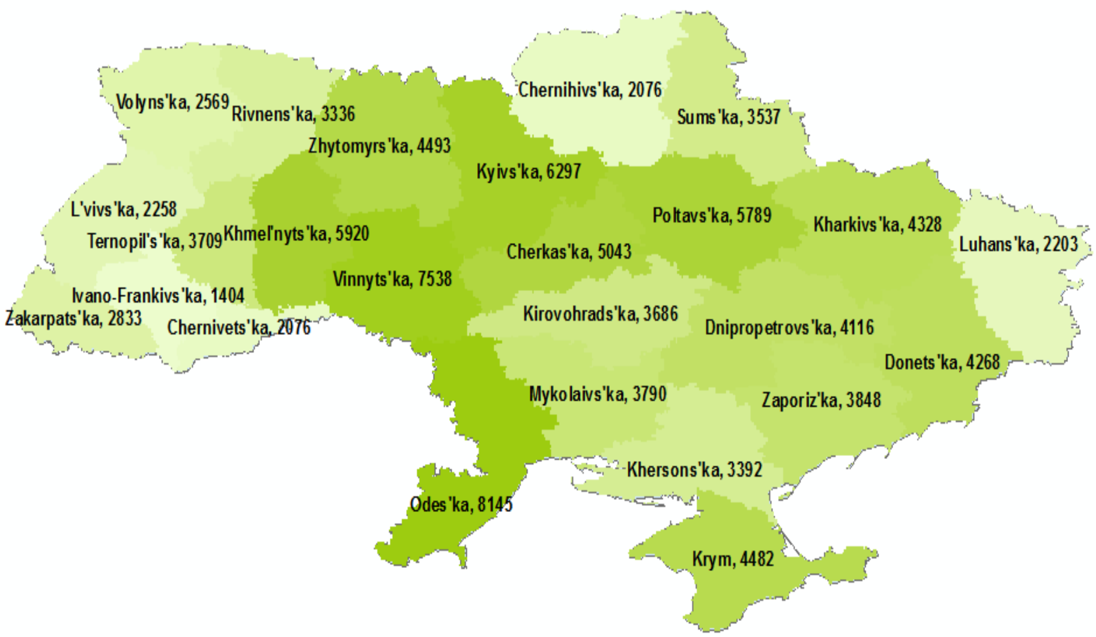


Figure 13. Allocation of new livestock production (in livestock heads), robust solution.

Regarding financial support, it is estimated that additional livestock production allocation may require about 400 thousand $US investments. These may come either in the form of voluntarily contributions or taxation of the intensive enterprises and part of the investments may be covered by governmental support or through other investments.

Conducted numerical experiments demonstrate the differences and advantages (e.g. cost effectiveness) of the robust solution optimal with respect to multiple scenarios in contrast to the deterministic solution optimal with respect to only one expected scenario for the long-term rural development strategy for rural area of Ukraine. Thus, in deterministic case, the costs to adjust the decisions if the number of migrants is larger than expected are much higher than the costs associated with the second-stage decisions in the stochastic optimization framework. Table 3 in ANNEX 2 shows comparison of the 2 types development's solutions (deterministic and robust) with a strong favor of the results to the robust optimal solution.

Conclusions

Planning robust expansion of agricultural activities in Ukraine requires integrated methodologically sound approaches. This paper focuses on agricultural developments in Ukraine in the period from 1990 to current. It summarizes diverse impacts of production intensification and land concentration stimulated by the second agricultural reform in 2000 on the socio-economic and demographic conditions in rural areas of Ukraine. Because of complex interactions and long-term planning horizons, the problem of rural development planning should be addressed in a framework of integrated model-based analysis. The proposed model emphasizes the need for a long-term sustainable development of agriculture to correct short-term purely market approaches by taking into account different aspects of rural life.

The model is applied for planning new activities and jobs in livestock sector and rural services. In Ukraine it is expected that large number of short-term urban workers will migrate between oblasts and from urban to rural areas, however, how many of them will return and their exact distribution by oblast is not known in advance. Scenarios of possible migration are derived from expert estimation. Therefore, the solution derived with the model gives a clue as to the level of additional expansions optimal with respect to all possible migrants' scenarios. Numerical experiments demonstrate the differences and advantages of the robust solution optimal for multiple migrants scenarios in contrast to the deterministic solution optimal with respect to the only one expected scenario.

In other words, developed integrated model-based approach to support long-term rural development planning in Ukraine indicates robust paths of the future agriculture development in Ukraine aimed to improve socioeconomic and environmental aspects of rural life and ensure food security of the country.

In future we are planning further development of presented framework with downscaling the results to rajon level. Also, uncertainties related to the imperfection of government policy and state regulation of agriculture are subject for the future research.

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ANNEX 1: Table 2. People employed in agricultural activities and services in rural areas and targets to be achieved with model allocation, by oblast

Oblasts	Targets		Employed		Need to increase		Total
	serv	agric	serv	agric	serv	agric	
	in thd.ppl		In thd.ppl		In thd. ppl		
Crimea	43	68	38	59	6	9	15
Vinnitska	61	108	53	94	8	14	22
Volynska	31	38	27	33	4	5	9
Dnipropetrovska	38	61	33	53	5	8	13
Donetska	31	60	27	52	4	8	12
Zhytomyrska	36	64	31	56	5	8	13
Zakarpatska	66	41	57	35	9	5	14
Zaporizka	33	54	29	47	4	7	11
Iv.-Frankivska	42	20	36	18	5	3	8
Kievska	51	87	45	76	7	11	18
Kirovogradska	28	59	25	51	4	8	11

Luganska	20	33	17	29	3	4	7
Lvivska	44	35	38	31	6	5	10
Mykolaivska	32	58	28	50	4	8	12
Odeska	60	120	53	104	8	16	24
Poltavska	45	86	39	75	6	11	17
Rivnenska	37	48	32	42	5	6	11
Sumska	31	53	27	46	4	7	11
Ternopilska	42	55	37	48	6	7	13
Kharkivska	40	65	35	57	5	9	14
Khersonska	33	50	29	44	4	7	11
Khmelnitska	46	87	40	76	6	11	17
Cherkaska	41	75	36	65	5	10	15
Chernivetska	38	30	33	26	5	4	9
Chernigivska	33	57	28	50	4	7	12
Ukraine	1005	1513	874	1316	131	197	328

ANNEX 2: Table 3. Comparison of two scenarios – Utopia and alternative.

Oblasts	Utopia Scenario				Alternative Scenario				Targeted jobs in ppl		Tot
	livestock	jobs	in		livestock	jobs	in				
			Agri.	Serv.			Agri.	Serv.	Serv.	Agri.	
Crimea	4418	15	9	6	4811	16	10	6	6	9	15
Vinnitska	7073	22	14	8	7338	23	15	8	8	14	22
Volynska	2505	9	5	4	3162	11	6	5	4	5	9
Dnipropetrovsk	3975	13	8	5	4618	15	9	6	5	8	13
Donetska	3893	12	8	4	4664	14	9	5	4	8	12
Zhytomyrska	4185	13	8	5	4997	16	10	6	5	8	13
Zakarpatska	2655	14	5	9	3930	21	8	13	9	5	14
Zaporizka	3510	11	7	4	3580	12	7	4	4	7	11
Iv.-Frankivska	1320	8	3	5	1438	9	3	6	5	3	8
Kievska	5700	18	11	7	6541	21	13	8	7	11	18
Kirovogradska	3840	11	8	4	4851	14	10	5	4	8	11
Luganska	2153	7	4	3	2463	8	5	3	3	4	7

Lvivska	2295	10	5	6	2468	11	5	6	6	5	10
Mykolaivska	3773	12	8	4	4936	15	10	5	4	8	12
Odeska	7815	24	16	8	8051	24	16	8	8	16	24
Poltavska	5595	17	11	6	7264	22	15	8	6	11	17
Rivnenska	3128	11	6	5	3530	12	7	5	5	6	11
Sumska	3473	11	7	4	3903	12	8	5	4	7	11
Ternopilska	3593	13	7	6	4331	15	9	7	6	7	13
Kharkivska	4260	14	9	5	4495	14	9	5	5	9	14
Khersonska	3293	11	7	4	3343	11	7	4	4	7	11
Khmelnitska	5663	17	11	6	6544	20	13	7	6	11	17
Cherkaska	4905	15	10	5	5034	16	10	5	5	10	15
Chernivetska	1935	9	4	5	2132	10	4	5	5	4	9
Chernigivska	3720	12	7	4	3846	12	8	4	4	7	12
Ukraine	98670	328	197	131	112270	375	225	151	131	197	328