Joint Research Project

between National Academy of Sciences of Ukraine and
International Institute for Applied Systems Analysis

1. Title of the NASU-IIASA project: Integrated modeling of food, energy and water security management for sustainable social, economic and environmental developments

2. Key words: global changes, food, energy, water, security, sustainable developments, systemic risks, public-private partnership, coherent policies, robust solutions, stochastic programming

3. Duration: January 2012 to December 2016

4. Applicant information

4.1. NASU's participants

Priniple Investigator (Ukraine): NASU Vice-President, Deputy Chairman of the NASU Committee for Systems Analysis, Ukrainian representative at IIASA, Professor Dr. A. Zagorodniy

Institute of Cybernetics, NASU: Director, Academician Prof. Dr. Ivan V. Sergienko, Academician Prof. Dr. Vyacheslav M. Shestopalov, Academician Prof. Dr. Vasyl S. Deyneka, Prof. Dr. P. S. Knopov, Dr. V.S. Kyrylyuk, Ph.D. K.L. Atoev, Ph.D. T.V. Pepelyaeva, Ph.D. O.M. Golodnikov, Dr. E.F. Galba, Ph.D. M.V. Belous, Ph.D. Yu.F. Rudenko, Ph.D. M.I. Zheleznyak

Scientific Centre of Aerospace Research of the Earth, NASU: Director, Academician Prof. Dr. Vadym I. Lyalko, Assoc. Prof., Ph.D. Yuriy V. Kostyuchenko, Assoc. Prof., Ph.D. Olexiy I. Sakhatsky, Ph.D. Dmytro Movchan, Ph.D. Galina Zholobak, M.Sc. Maxim Yuschenko, M.Sc. Olexandr Apostolov

Institute of General Energy, NASU: Director, Academician Prof. Dr. Mykhaylo M. Kulik, Dr. S.V. Dubovsky, Ph.D. O.Ye. Malyarenko, Ph.D. I.Ch. Leschenko, Ph.D. S.V. Shulzhenko

Institute of Economics and Forecasting, NASU: Director, Academician Prof. Dr. Valery M. Heyetz, Dr. O.M. Borodina, PhD. S.V. Kyryzyuk , PhD. G.Yu. Lopatynska, PhD. R.Z. Podoletz, PhD. O.A. Dyachuk

Institute of Demography and Social Studies, NASU: Director, Academician Prof. Dr. Ella M. Libanova, PhD. L.M. Cherenko, M.Sc. O.A. Vasiliev, M.Sc. A.G. Reut

Institute of Applied Systems Analysis, National Technical University, Ministry of Education of Ukraine, NASU: Director, Academician Prof. Dr. M.Z. Zgurovsky, Prof. Dr. N.D. Pankratova, PhD. O.M. Yefremov.

Participants of the joint Russian-Ukrainian project „Analysis and optimization of uncertain stochastic systems with applications to reliability and security", coordinated with IIASA and supported by the Russian and Ukrainian Funds for Fundamental Researches: Prof. Dr. V. Norkin, leading scientist, Institute of Cybernetics, NASU; Prof. Dr. A. Kibzun, head of department, Moscow Aviation Institute, Russia.

4.2. IIASA's participants

Principal Investigator, Academician Prof. Dr. Y. Yermoliev (ASA) will coordinate collaboration between NASU's institutes, IIASA's team and the Ukrainian NMO, and will contribute to preforming the integrated modeling tasks. Prof. Yermoliev's scientific intersts focus on decision processes in the presence of risks and uncertainties, non-smooth stochastic and dynamic systems optimization, optimization on networks, nonlinear dynamics, systemic risks, security management, and robust solutions. Prof. Y. Yermoliev is a co-editor of four books on "Coping with Uncertainties", Springer Verlag, 2004, 2006, 2010, 2012.

Dr. T. Ermolieva (ASA) will contribute to the development of models for robust coherent policies and data harmonization (up-scaling, downscaling). Dr. T. Ermolieva has rich experience in modeling complex socio-economic, environmental and agricultural systems under risks and incomplete information.

Dr. J. Linnerooth-Bayer (RAV), Dr. R. Mechler (RAV), Prof. Dr. A.Schvidenko (EMS), Dr. F. Wagner (MAGG), Dr. W. Winiwarter (MAGG), Dr. D. Wiberg (Water), Dr. M. Strubegger (Energy) will provide intellectual support, without dedicated efforts in terms of person/months.

5. Abstract

On-going global (including climate) changes dramatically increase interdependencies between food, energy and water security inducing potential systemic risks which may threaten sustainability of social, economic, and environmental developments. This calls for new policies providing coherent strategic coordination and regulations among food, energy and water sectors. The lack of such policies in Ukraine led to uncontrolled agricultural production intensification, imbalanced land utilization, and soil, water, air pollution/contamination by heavy metals and other components of wastes and residues of agricultural activities, application of fertilizers and pesticides. Land concentration with focus on profits led large enterprises to reducing payment on humans capital resulting in massive rural-urban migration, destructions of rural settlements, income polarization, loss of welfare, depopulation, increase of unemployment. New dynamic mixed strategy of rural-urban migration create high risks of poverty and criminality.

The proposed project will investigate coordinated robust sustainable developments derived accounting for complex linkages and differences in spatial and temporal scales between agriculture, energy and water security, potential systemic risks and new coherent feasible policies at a country level taking into account interregional and international trades, global pollution, related risks, insurance markets, direct and indirect exchange of resources. In contrast to numerous existing isolated studies using different research principles and data treatments from diverse regions at different time intervals, this project aims at new integrated multidisciplinary approaches by a research team from five non-profit institutes of the National Academy of Sciences, Ukraine, working in collaboration with International Institute for Applied Systems Analysis. The project aims to develop a harmonized strategic approach for integrated modeling secure sustainable supply of food, energy and water under natural and human-related intentional and unintentional threats. In order to achieve robust policies, both interdependent strategic long-term (anticipative, ex-ante) decisions and short-term (adaptive, ex-post) decisions (adjustments) will be incorporated within integrated stochastic optimization models based on general ideas of "Public-private partnership" principle. Quantile-based indicators will be used to cope with systemic risks and extreme events shaped by decisions of various stakeholders and potential adversaries. The methodology will be elaborated and tested in case study regions of Ukraine. A harmonized Ukrainian resource data base will be compiled to serve as modesl input.

6. Project Description

6.1. Introduction

In the project, security is understood as an ability to fulfill the needs of the society for food, energy and water under standard requirements for their qualities and quantities. On-going global changes critically increase interdependencies among food, energy and water sectors requiring coordinated coherent robust policies. At the same time, on regional and local levels in these sectors, especially energy and agriculture, we can observe inconsistent decentralization and deregulation processes creating many independent producers and distributors which decide their production plans and other activities usually according to instantaneous (short-term) market conditions. In this case, the lack of proper coordinating coherent policies may easily create wrong incentives within disintegrated networks of food, energy, and water supply systems, which may induce systemic risks, extreme events and failures to fulfill in a robust manner the needs of society at large.

The project aims at developing an integrated methodology for analyzing coherent robust policies ensuring security of sustainable functioning of the sectors. The methodological goal of the proposed project is the development of new and adjustment of existing methodologies for managing secure functioning of complex interdependent food, energy and water supply systems under emerging new social, economic and environmental threats connected with on-going global including climate changes. Robustness of solutions with respect to potential variabilities, inherent uncertainties and exogenously as well as endogenously generated threats will be achieved by using quatile-based risk measures. Thus, this project is relevant to the core research areas of IIASA. In particular, from a methodological point of view this projects links to the project "Systemic Risk, Extreme Events, Robust Solutions" of ASA program. The project assumes that an integrated model is not the sum of individual models.

A methodological challenge is that underlying threats may be generated both by natural disasters such as heavy rains, droughts and by intentional or unintentional actions of various agents including agricultural, water and energy stakeholders. These threats shaped by the decisions of different agents are critical for sustainable developments as cascading blackouts and power shortages in California, price surges in Norway, floods from hurricane Katrina, recent events in Japan, and world-wide financial and economic crises have shown.

The importance of coherent integrated modeling approaches for analyzing secure access to food, energy, and water became especially evident for NASU (National Academy of Sciences of Ukraine) researchers after the Chernobyl disaster. Institutes of NASU accumulated significant experience in this area. The recent Bonn Conference on the Water, Energy, Food Security Nexus emphasized that to "ensure the interdependency between water, energy and food security is explicitly identified in decision-making within and across all levels to realize the potential for mutually beneficial action and avoid conflicting policy objectives and unintended consequences (Bonn Conference 2011, see also OECD Studies on Water, 2012).

The lack of such integrated view in Ukraine created large independent market-oriented agricultural enterprises with strong priority for producing highly demanded on international markets crops such as "bioenergy" crops. This led to uncontrolled agricultural production intensification, imbalanced land utilization, soil, water, air pollution (contamination) by heavy metals and other components of wastes and residues of fertilizers and pesticides. Land concentration with focus on profits led large enterprises to reducing investment in humans capital resulting in massive rural-urban migration, destructions of rural settlements, income polarization, loss of welfare, depopulation, increase of unemployment. A new mixed strategy of rural-urban migration created high risks of incomes and criminality.

The integrated modeling under threats which are shaped by decisions of different agents will require approaches based on a "public-private partnership" principle. Therefore, the modeling framework of the project assumes that the first-stage strategic long-term anticipative public decisions are linked to the second-stage adaptive private responses aiming to improve social welfare. In particular, the proposed models will aim to show how to avoid such cascading events as blackouts of electricity networks or markets-related disruptions when the lack of proper regulations may increase, say, bioenergy production by independent producers, change

market demands, induce threats of environmental degradation, destabilize supplies of food and water, and disturb socio-economic developments. The proposed new approaches will be tested and explored in important case study regions of Ukraine.

6. 2. Approach

The project is directed to development, improvement and adaptation of models and systems-analytical approaches for effective robust decision support in field of food, water, energy security and related natural resource management, support of sustainable social, economic and ecological development using case studies in Ukraine. In particular, related economic studies extending previous modeling work [2], [3], [5] will be carried out as cross-cutting activities in WPs 1, 3, 4, 5. Research methods include: systems analysis, mathematical modeling, nonlinear programming, stochastic robust optimization, new “leaders-followers” or two-stage dynamic “public-private” decision analysis under uncertainty, data harmonization, GIS-analysis, thematic interpretation (including remote sensing) data.

In its initial stage, the project will rely on studies where the integrated food security management model has been already analyzed and modeled primarily by researchers from the Institute of Economics and Forecasting, NASU, and IIASA researchers (e.g., [2], [3], [5]) using important case study regions in Ukraine. The developed (with participation of experts and policy analysts) stochastic model has a complex network structure. Calibration of this model showed directions for significant improvements of current trends in rural areas. It is expected to carry out a more comprehensive retrospective analysis of the past developments to understand the degree of robustness of the modeling work. It includes transportation and investments costs. The model has a multiagent "government-regions" or more formally “leader-follower” [1] character taking into account new type of mixed strategy "rural-urban" migration, trading processes including international trades, policy decisions regulating land and water pollution, market`s risks and risks associated with rural-urban migration. This work creates a solid basis for the initial stages of the project.

The future work within the proposed project will be focused on improvement of data treatment, incorporating better synergies between food, energy, and water sectors, and modeling of typical “public-private partnership” character of policy debates in Ukraine with proper representation of links between short-term and long-term decisions, multidimentional risks and extreme events which may be generated by natural disasters and inadequate policies coordinating interdependencies in food, energy, water sectors. This work will require adequate spatio-temporal modeling of food-energy-water interplays shaped by decisions of different stakeholders and other agents. It will also use multilevel sustainable development indicators, cause-effect analysis and scenario generation techniques. The project will analyze a mix of different policy instruments enforthing linkages between long-term strategic (ex-ante) mitigation, short-term (ex-post) adaptations and data monitoring. Market approaches, water trading and cooperative solutions will use ideas proposed at IIASA for CO2 emission permits trading [8].

Production of food essentially depends on balances of water resources which in their turn depend on climate changes and weather related extreme events which will be in the focus of the project. Energy-related devastating extreme events such as cascading blackouts in electricity networks affecting water and food supply may be generated not only by natural disasters but also by failures of policies and regulations influencing decisions of stakeholders. Proper integrated modeling results will be achieved by developing new adequate decision-theoretic approaches in principal agent (PA)- [1], “leader-follower”-, or “public-private”-type situations under inherent uncertainty and "intelligent" risks generated by various agents. This framework in particular will allow to achieve robust short-term solutions from long-term

perspectives using distributional details with explicit treatment of variability and uncertainty rather then aggregate (average) indicators. For example, existing aggregate models easily demonstrate that an irrigation system may significantly improve food supply. More detailed analysis shows that this system may turn out to be unprofitable even in dry seasons depending on spatial details of food production plans, water and energy supply costs, and market prices. The role of ground water resources in Ukraine will be investigated in WP 1 taking into account optimal schemes of their use and spatial dynamics subject to potential disturbances by rainfalls, water use processes, networks of rivers, water reservoirs, etc.

6.3. Building on current and past NASU-IIASA collaborative achievements

The project will be built on relevant past and on-going collaborations of NASU and IIASA's programs.

- Past and on-going collaborative work [2], [3], [5] (see also other publications) between NASU`s Institute of Economic and Forecasting and IIASA`s researchers will be a basis in the first stage of NASU-IIASA project.

- A methodology for policy assistance using the „leader-follower" or "public-private partnership" principle under inherent uncertainty and extreme events will rely on further developments of approaches proposed recently [1] by IIASA-NASU researchers. This methodology has already been successfully applied to (see references in [1], [2], [3], [9]) large-scale problems of energy security, homeland security, food and water security management.

- Security of water multi-purpose supply systems was analyzed in [9].

- A path-breaking stochastic integrated model for long-term global energy developments [10]-[13] under increasing returns and uncertainty was developed by IIASA researchers jointly with researchers from the Glushkov Institute of Cybernetics, NASU. The model has a complex network structure. It was solved by using supercomputers of US energy department and a network of IIASA's computers.

- Path-breaking integrated spatio-temporal catastrophic risk management models incorporating cascading multidimentional extreme events were developed [4], [6], [7], [9] in collaboration with the Glushkov Institute of Cybernetics, NASU. These spatio-temporal models were used to analyze, in particular, the impacts of the optimal robust mixes of policy instruments on mitigation of extreme multidimentional events, e.g. floods, and on welfare growth in regions and countries. The model allows to evaluate in integrated manner robust mixed decisions of central and local governments, insurers and reinsurers, households, floods and other disasters mitigation decisions regarding land use patterns, reliability of dams, vulnerability of infrastructure, and buildings, the role of catastrophe bonds and contingent forward credits, etc. In these studies, integrated catastrophic risk management models will be based on upscaling and downscaling of several related disciplinary models and related multi-scale massive data sets (e.g., hydrological models, engineering vulnerability models, multidimentional stochastic cash flow models, insurance models, and financial market models). References can be found in [1].

- Researchers from NASU's General Energy Institute collaborated with IIASA's programs in global energy assessment studies, assessment of energy pollution, CO2 emission mitigations and trading studies, which are planned to be extended by the project to modeling of water permits trading and water markets [8].

• Researchers from NASU's Remote Sensing Institute collaborated with IIASA's scientists in climate- and water-related studies, in particular, data treatment on ground and surface water levels, their pollution and changes.

• Researchers from NASU's Institute of Demography participated in joint with IIASA studies on scenarios of population growth in Ukraine. Currently they analyze issues of poverty.

• Researchers from the Institute for Applied Systems Analysis, Ministry of Education and NASU collaborated with IIASA's scientists for studying geopolitical and social risks.

• Researchers from NASU, IIASA and Moscow Aviation Institute analyzed new models and methods for assessing security in uncertain stochastic systems.

6.4. Research themes

This subsection provides some specific comments on themes of the research plan described in Section 7 having the following workpackages:

1. Development of models and methods for integrated analysis of coherent robust food, energy and water security policies; multiscale assessment of water resources in complex distributed hydrological systems

2. Analyzing variations of regional water balances, ecosystems productivity and disasters risk distributions using remote sensing data, climate and environmental change assessment

3. Analysis of energy developments and its security under uncertainty and increasing ecological requirements to emissions of noxious and greenhouse gases, and harmful matters

4. Integrated modeling of energy supply in the context of coherent food, water, energy security and sustainable development of Ukraine

5. Modeling of agricultural strategies for sustainable rural development under global changes

6. Analysis of poverty in Ukraine: drivers, emergencies, impacts

7. Integrated sustainable development indicators in regional and global contexts

8. An additional WP will constitute the collaborative IIASA-Russian-Ukrainian project KPKBK 5031050 supported by the Russian and Ukrainian Funds for Basic Research. Duration: January 2012 to December 2013.

These themes reflect critical aspects of food, energy and water sectors and their impacts on sustainable developments according to general conclusions of Bonn Conference 2011, OECD Studies on Water, 2012. In particular, the following issues are incorporated in the WPs:

- Increasing security in one sector affects costs in other sectors
- Water shortages, droughts, floods, heat waves increase the risk of electricity (e.g. blackouts) and food supply
- Increase of energy (water) supply is related to increasing energy (water) supply and reducing energy (water) consumption

- Increase in energy prices are leading to growing interests in bioenergy remaining complex and uncertain issues linking long-term energy developments with short-term location-dependent weather-related extreme events

- Biofuel feedstocks need significant amount of water during photosynthesis. Due to the size of energy markets even a small percentage of biofuels may have critical impacts on water balances and food security

- Biorefineries generate high local water demands

- Increased production of biofuels and agriculture can increase water pollution from nitrogen, phosphorus, pesticides, soil sediment and new emerging contaminants. There are social, economic and environmental costs of pollutants

- Water distribution, collection, treatment, and heating represent a major consumer of energy. Use of groundwater requires energy for well pumping. Much energy is wasted by irrigating lowns and toilets using high quality drinking water

- Pricing and subsidy provide incentives to develop and adopt the most appropriate technologies. Short-term instantaneous adaptive responses on market signals may create wrong individual incentives with lock-in states of insecure and unsustainable developments

- Agriculture, energy, and water systems are vulnerable to climate changes and weather-related extreme events

- The increasing frequency and severity of droughts and floods is often due to the lack of coordinations and regulations leading to increasing costs for local and central governments, farmers, rural and urban communities and insurance industry with potential contributions to poverty. Coherent new policies for land use, agriculture, water and energy security can play a central role in mitigation and adaptation policies for climate change, floods and droughts risk management

- Integrated modeling demonstrates that strengthening linkages between ex-ante long-term decisions (such as floods and droughts risk mitigations) with other short-term ex-post adaptive multi-stakeholders decisions significantly improves the robustness, efficiency and environmental safety of solutions with respect to inherent uncertainty and extreme events

- Secure coherent sustainable food, energy and water management require proper governance equipped with adequate decision support systems

- Robustness of policies can be achieved by using appropriate systemic risk indicators. The use of standard mean values, least square and variance-covariance approaches is not robust under asymmetric variability and uncertainty with non-normal distributions.

6. 5. Scientific goals

The following tasks will be in the focus of the project:

1. Analyze driving forces of threats (the lack of needed quality and quantity of food, decreasing quality of water and land, decreasing stability of energy supply, decreasing energy use efficiency, conflicting policies, etc.) and robust in particular quantile-based indicators of food-energy-water security characterizing coherent policies, strategic ex-ante anticipative and ex-post adaptive mechanisms, monitoring mechanisms, etc.

2. Find feasible sets of linked robust ex-ante (anticipative) and ex-post (adaptive) policies and regulations
3. Collect and properly represent relevant spatio-temporal data on agricultural activities, natural resources, demographic, socio-economic and environmental indicators at the national level and at the level of districts and regions in Ukraine (496 and 25, respectively) from real observations and experts opinions by using appropriate data harmonizing methods, e.g., probabilistic downscaling and upscaling methods, non-parametric estimation, uncertain distributions.
4. Create stochastic scenario generators (including catastrophe generators) for "threats-decisions" interactions.
5. Build integrated multi-objective stochastic optimization model(s) for evaluating robust solutions ensuring secure and sustainable food, energy and water supply under uncertain threats.
6. Investigate incentives behind "mixed strategies" of urban-rural labor migration and their consequences. New types of household and welfare models explaining the mixed strategy migration processes will be explored.
7. Analyze interdependencies between regional sustainability and the main threats to security.

6.6. Connections with IIASA's Strategic Plan.

Global changes are triggered by complex multiscale global-regional-local interactions. Therefore, although this project focuses on Ukrainian food-energy-water interdependencies and security, its results will have global implications. In particular, developing models include international trades, exchanges of resources, GHG emissions. From a methodological point of view the project has direct links to the project "Systemic risk, extreme events, robust solutions" of ASA; ESM, RAV, Energy, Water, MAG IIASA's programs. The methodology being developed within NASU-IIASA project has common character and it is applicable to other case studies having global, regional, local scales.

7. Project Stages, Workpackages and Teams

During the research period the following plans may be adaptively adjusted, therefore, in a sense, they have a tentative character. In particular, plans for 2015-2016 are combined because the work in the final year will be directed by the data sets, which will become available, and by numerical calculations with models developed during previous years.

The WP research teams may have alterations. Work in data analyses and programming will be directed by the senior scientists whose names are given in the WP team lists (see below), and carried out by Ukrainian PhD students and junior scientists whose names are currently not given in the WP team lists.

Workpackage 1. Development of models and methods for integrated analysis of coherent robust food, energy and water security policies; multiscale assessmnet of water resources in complex distributed hydrological systems

Stage	Term	Problems & Key Questions	Deliverables
Analysis of drivers, threats and sustainable	2012	How to formulate correctly security	Set of developed

indicators of food water and energy security Analyze state of hydrological resources, uncertainties of their assessment and corresponding risks to food security in Ukraine		management models using “public-private participation” principle Data collection and analysis Elaboration of security indicators	methods and models, data sets Scientific publications
Collection and preliminary analysis of multiyear agricultural productivity and agro-meteorological information Collection and preliminary analysis of hydrogeological data Create stochastic scenario generators (including catastrophe generators) for “threats-decisions” interactions	2013	Key questions: what is the available data relative reliability and how to estimate corresponding uncertainty of the data? Rescaling and data harmonization	Set of developed methods and models Joint-access databases Scientific publications
Agricultural productivity and agro-meteorological statistical database development Create stochastic scenario generators for agricultural production risk modeling basing on collected data Development of integrated multi-objective stochastic optimization models for evaluating robust solutions ensuring secure agricultural production taking into account climate change and meteorological variations Groundwater dynamics analysis using multi-scale computer modeling before intensive resource utilization	2014	How utilization of groundwater resources will affect integrated water security relatively to traditional practices of surface water utilization? Which assessment methodology is adequate for multi-scale groundwater dynamic analysis under active pumping and with uncertain contamination?	Set of developed methods and models Joint scientific papers Joint-access databases
Development of integrated multi-objective stochastic optimization models and corresponding methods for evaluating robust solutions ensuring secure food, energy and	2015-2016	Development of method for analyzing sustainability of regional water supply as a function of local groundwater dynamics	Set of developed methods, models, and data

water supply under uncertain threats Development of scenarios for groundwater dynamics in Kiev region, identification of regional threats and risks Final modifications and adjustments		(including dynamics of pollutants).	Joint scientific papers Reports

Research Team: Glushkov's Institute of Cybernetics, NASU

#	Name	Title	Position	Involvement
1	Ivan V. Sergienko	Prof., Dr.	Director, Academician	Full time counselor (no salary)
2	Vyacheslav M. Shestopalov	Prof., Dr.	Director, Academician	Full time counselor (no salary)
3	Vasyl S. Deyneka	Prof., Dr.	Director, Academician	Full time counselor (no salary)
4	P. S. Knopov	Prof., Dr.	Head of Dept.	0,5 (6 month/year)
	V.S. Kyrylyuk	Dr.	Leading Research Scientist	0,5 (6 month/year)
	K.L. Atoev	Ph.D.	Senior Research Scientist	0,5 (6 month/year)
	T.V. Pepelyaeva	Ph.D.	Senior Research Scientist	0,5 (6 month/year)
	O.M. Golodnikov	Ph.D.	Senior Research Scientist	0,5 (6 month/year)
	E.F. Galba	Dr.	Leading Research Scientist	0,5 (6 month/year)
	M.V. Belous	Ph.D.	Senior Research Scientist	0,5 (6 month/year)
	Yu.F. Rudenko	Ph.D.	Senior Research Scientist	0,5 (6 month/year)
	M.I. Zheleznyak	Ph.D.	Senior Research Scientist	0,5 (6 month/year)

Workpackage 2. Analyzing variations of regional water balances, ecosystems productivity and disasters risk distributions using remote sensing data, climate and environmental change assessment

Stage	Term	Problems & Key Questions	Deliverables
Collection, preliminary analysis (geo-correction, filtration, etc.) and digital representation of spatial –	2012	Selection of case studies and focus areas: Northern Black Sea region, and Prypjat river basin trans-boundary area.	Set of developed methods and models

temporal data of in-field measurements (including archive records) and satellite observations using regularization techniques; Development of sustainability indicators for agricultural sector and ecological state aimed to secure consumption of food and water resources using remote sensing data		Key questions: what is the available data relative reliability and how to estimate corresponding (both aleatoric and epistemic) uncertainty of the data? What indicators are suitable for the problem description?	Data bases: meteorology measurements reduced to study areas for 1910 – 2015, disaster statistics on study areas 1960 – 2015, bio-productivity on study areas 1990 – 2015; publications on case studies
Development of technique for problem-oriented analysis of geo-referred data of in-field measurements and satellite observations for integrated multi-objective stochastic optimization models evaluating impact of disasters and induced threats to environment in view of regional changes	2013	Which way of metrics reduction is the optimal for analysis of stochastic sets of in-field and satellite observations? How the sets of observation data might be linearized for coupled analysis with multi source data? Analysis of data should be directed to possibility of introducing local peculiarities (in distributions of disaster frequency, bioproductivity, water balance, climatic and with respect to meteorological parameters) toward existing regional and global trends.	Set of developed methods and models Data bases: meteorology measurements reduced to study areas for 1910 – 2015, disaster statistics on study areas 1960 – 2015, bio-productivity on study areas 1990 – 2015; Publications on case studies
dependencies analysis of multivariate distributions for frequency and intensity of different types of disasters, climatic and ecological parameters (using satellite data) Analysis and assessment of drivers and indicators of land-cover changes connected with disasters, climate and environmental changes, its links to bioproductivity and food, energy and water security	2014	Which drivers lead to most dangerous disasters from viewpoint of socio-ecological vulnerability? Should pollution be described as integrated aftermath of complex disasters? What is relative input of meteorological variations, climatic trends, land-use and agricultural practices, water management into registered regional drought statistics? Does statistic reflects climatic conditions or it is indicator of inadequate policies?	Set of developed methods and models Data bases: meteorology measurements reduced to study areas for 1910 – 2015, disaster statistics on study areas 1960 – 2015, bio-productivity on study areas 1990 – 2015; Publications on case studies

Generation and analysis of regional scenarios of disaster impact to environment (including analysis of pollution propagation over surface water bodies) using satellite observation data Generation of regional scenarios of bioproductivity change for varied types of ecosystems, climate changes (both on global and regional scale) and remotely observed environmental changes Final adjustments and modifications	2015-2016	How to introduce the adaptation role of local ecosystems in regional strategies of socio-ecological risks assessment and management of natural and technological disasters under observed climate change? Analysis of integrated contamination/pollution (using bio-indicators and suspended matters) of surface water bodies. Key threats identification for regional and trans-boundary water security. How regional bioproductivity reflects observed global trends of climate change and local water balances?	Set of developed methods and models Data bases: meteorology measurements reduced to study areas for 1910 – 2015, disaster statistics on study areas 1960 – 2015, bio-productivity on study areas 1990 – 2015; Publications on case studies Reports

Research Team: Scientific Centre of Aerospace Research of the Earth, NASU

#	Name	Title	Position	Involvement
1	Vadym I. Lyalko	Prof., Dr.	Director, Academician	Full time counselor (no salary)
2	Yuriy V. Kostyuchenko	Assoc. Prof., Ph.D.	Leading Research Scientist	0,5 (6 month/year)
3	Olexiy I. Sakhatsky	Assoc. Prof., Dr.	Leading Research Scientist	0,25 (3 month/year)
4	Dmytro Movchan	Ph.D.	Junior Research Scientist	0,5 (6 month/year)
5	Galina Zholobak	Ph.D.	Research Scientist	0,25 (3 month/year)
6	Maxim Yuschenko	M.Sc.	Engineer	0,5 (6 month/year)
7	Olexandr Apostolov	M.Sc.	Engineer	0,25 (3 month/year)

Workpackage 3. Energy Security: Technological Aspects. Analysis of energy developments and its security under uncertainty and increasing ecological requirements to emissions of noxious and greenhouse gases, and harmful matters

Stage	Term	Problems & Key Questions	Deliverables
Analysis and formalization of impact factors to energy sector sustainable development including agriculture and	2012	Key threats and impacts factors identification in energy sector, analysis of basic technological links	Set of developed methods and models

water sectors, uncertainties analysis, security analysis and vulnerability from viewpoint of energy sustainable supply, development of discriminative scenarios			
Deterministic and stochastic modeling of technological, economic, physical and market features of energy objects under variable uncertainty	2013	How market variations and technological innovations will reflect on effectiveness of functioning of different objects of energy system?	Set of developed methods and models
Development of integrated stochastic model of energy sector as infrastructural system aimed to efficient and secured energy supply under uncertain influence of external factors (including catastrophic threats)	2014		Set of developed methods and models Joint scientific papers
Development of stochastic scenario generators (including catastrophe generators) for analysis of sustainable development of energy sector and its links with food and water sectors Development of integrated energy sector development scenarios with increasing ecological requirements to emissions of noxious and greenhouse gases, and harmful matters	2015-2016		Set of developed methods and models Joint scientific papers

Research Team: Institute of General Energy, NASU

#	Name	Title	Position	Involvement
1	Mykhaylo M. Kulik	Prof. Dr.	Director., Academician	Full time counselor (no salary)
2	S.V. Dubovsky	Dr.	Leading Research Scientist, Head of Dept.	0,5 (6 month/year)

3	O.Ye. Malyarenko	Ph.D.	Senior Research Scientist, Head of Dept.	0,5 (6 month/year)
4	I.Ch. Leschenko	Ph.D.	Senior Research Scientist	0,5 (6 month/year)
5	S.V. Shulzhenko	Ph.D.	Senior Research Scientist	0,5 (6 month/year)

Workpackage 4. Energy Security: Economic Aspects. Integrated modeling of energy supply in the context of coherent food, water, energy security and sustainable development of Ukraine

Stage	Term	Problems & Key Questions	Deliverables
Identification and analysis of key threats for Ukrainian energy sector and its links (on global, regional and local scale)	2012	Analyze robust diverse mix of alternatives such as energy efficiency, traditional and nontraditional energy supply including bioenergy	Set of developed methods and models
Verification of elaborated approaches to integrated modeling and development foresights of long-term energy supply in Ukraine	2013		Set of developed methods and models Per reviewed publications
Development of analytical tools for assessment of energy security based on partial equilibrium economic-energy model "TIMES – Ukraine"	2014	Introduction of security indicators based on CVaR-type risk measures	Set of developed methods and models Per reviewed publications
Modeling of isolated and integrated impact of potential threats to energy sector and parameters of energy security of Ukraine Identification and numerical analysis of alternative ways of optimal energy supply in the context of food, energy and water secure and sustainable development Further adjustments and modifications	2015-2016	Development and harmonization of existing and new multiscale data sets and data analysis tools	Set of developed methods and models Scientific publications

Research Team: Institute of Economics and Forecasting, NASU

#	Name	Title	Position	Involvement
1	Valery M. Heyetz	Prof. Dr.	Director., Academician	Full time counselor (no salary)
2	G.Yu. Lopatynska	M.Sc.	Junior Research Scientist	0,5 (6 month/year)
3	R.Z. Podoletz	Ph.D.	Senior Research Scientist	0,5 (6 month/year)
	O.A. Dyachuk	Ph.D.	Senior Research Scientist	0,5 (6 month/year)

Workpackage 5. Modeling of agricultural strategies for sustainable rural development under global changes

Stage	Term	Problems & Key Questions	Deliverables
Comparative analysis of approaches and methods for assessment of socio-economic and ecological consequences of natural resources consumption Forming a set of robust suitable indicators Development of problem-oriented data harmonization downscaling/upscaling methods	2012	The role of probabilistic down-scaling and up-scaling methods for multiscale data harmonization	Set of developed methods and models Per reviewed publications
Modifications of developed in collaboration with IIASA food security models. Designing robust cost effective and environmentally safe (especially for water, soil productivity) optimal portfolio of regional crops robust to uncertainties Analysis of possible ex-ante mitigation measures and ex-post adaptations in agrarian sector	2013	Better modeling of rural-urban migration processes as risk mitigation strategies	Set of developed methods and models
Analysis of models based on “public-private partnership” Analysis of	2014	Analysis of multi-level impact (global, regional, local) of climate changes (observed, registered,	Set of developed methods and models

climate change impact on agrarian sector of Ukraine		forecasted according different scenarios) to agrarian and other sectors	
Development of scenarios for designing public and state regulation and for coherent control and strategic agrarian planning under uncertainty including climate change Development of spatial model and designing scenarios of developments for different regions of Ukraine Recommendations on robust secure planning of agricultural production in Ukraine Further modifications and adjustments	2015-2016	It is necessary to address strategic long-term planning incorporating adaptive short-term responses of various stakeholders	Set of developed methods and models, data base, scientific publications and reports

Research Team: Institute of Economics and Forecasting, NASU

#	Name	Title	Position	Involvement
1	O.M. Borodina	Dr.	Leading Research Scientist, Head of Dept.	0,5 (6 month/year)
2	S.V. Kyryzyuk	Ph.D.	Research Scientist	0,5 (6 month/year)

Workpackage 6. Analysis of poverty in Ukraine: drivers, emergencies, impacts

Stage	Term	Problems & Key Questions	Deliverables
Integrated assessment of poverty in Ukraine	2012	Role of absebse coherent and safe food, energy, water policies	Set of developed methods and models
Analysis of economic parameters of poverty	2013	What are impacts of water and food security	Set of developed methods and models Scientific publications Reports
Analysis of health of population, cost of medicine and health	2014	How urban-rural migration affects the poverty risks	Set of developed

insurance toward poverty parameters			methods and models
Education analysis in view of decreasing of households poverty risks	2015		Set of developed methods and models

Research Team: Institute of Demography and Social Studies, NASU

#	Name	Title	Position	Involvement
1	Ella M. Libanova	Prof, Dr.	Director, Academician	Full time (no salary)
2	L.M. Cherenko	Ph.D.	Senior Research Scientist	0,5 (6 month/year)
3	O.A. Vasiliev	M.Sc.	Junior Research Scientist	0,5 (6 month/year)
	A.G. Reut	M.Sc.	Junior Research Scientist	0,5 (6 month/year)

Teams of WPs 7, 8 are not supported financially by NASU. The team of WP 7 is supported by the Ministry of Education, whereas the team of WP8 is supported by funds for Fundamental Researches. Therefore, tables do not have person/month information for these teams.

Workpackage 7. Integrated sustainable development indicators in regional and global context

Stage	Term	Problems & Key Questions	Deliverables
Comparative analysis of models, approaches and techniques for quantitative analysis of socio-economic and ecological components of sustainability on global and regional scales	2012		Set of developed methods and models
Collection, analysis and representation of data on economic, ecological and social components of sustainable development of Ukraine on different scales (accumulated in regional branch of World Data Center) Development of approach to systemic harmonization of multi-source data based on stochastic analysis	2013		Set of developed methods and models
Development of set of tools for quantitative	2014-2015		Set of developed

assessment of sustainability on global and regional context Application of developed tools as web-service			methods and models
Calculation of selected set of indicators of sustainable development in global and regional context, assessment of threats to sustainability Analysis of results and development of managing recommendations for policy makers	2015		Set of developed methods and models Scientific publications

Research Team: Institute of Applied Systems Analysis, National Technical University, Ministry of Education of Ukraine, NASU

#	Name	Title	Position
1	M.Z. Zgurovsky	Prof, Dr.	Director, Academician
2	N.D. Pankratova	Prof, Dr.	Deputy Director
3	O.M. Yefremov	Ph.D.	Research Scientist

Workpackage 8. Development of new models and methods for assessing security in uncertain stochastic systems.

Research Team from collaborative with IIASA joint Russian-Ukrainian project supported by Russian and Ukrainian funds for fundamental researches. Duration: from January 2012 to December 2013.

Deliverables: publications in a leading journal with application to a Ukrainian case study.

Research Team:

#	Name	Title	Position
1	V.I. Norkin	Prof. Dr., NASU	Leading Scientist, Institute of Cybernetics, NASU
2	A.I. Kibzun	Prof. Dr.	Head of department, Moscow's Aviation Institute, Russia

8. Selected publications:

[1] Ermoliev, Y., von Winterfeldt D (2010). Risk, security and robust solutions. IIASA Interim Report IR-10-013, Int. Inst. for Applied Systems Analysis, Laxenburg, Austria.

[2] Borodina, O., Borodina, E., Ermolieva, T., Ermoliev, Y., Fischer, G., Makowski, M., van Velthuizen, H. (2010). Integrated modeling approach to the analysis of food security and sustainable rural developments: Ukrainian case study. IIASA Interim Report IR-10-017, Int. Inst. for Applied Systems Analysis, Laxenburg, Austria.

[3] Kyryzyuk, S., Ermolieva, T., Ermoliev, Y. (2011). Planning sustainable agroproduction for food security under risks. Economics of Agriculture, 9:145-151 (in Ukrainian).

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[6] Ermolieva T., Ermoliev Y., Fischer G., Galambos I. (2003). The role of financial instruments in integrated catastrophic flood management. Multinational Finance Journal, 7(3&4):207-230.

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[13] Messner S., Golodnikov A., Gritsevskyi, A. (1996). A stochastic version of the dynamic linear programming model MESSAGE III. Energy - The International Journal, 21(9):775-784.

Other relevant joint publications:

Ermoliev, Y., Makowski, M., Marti, K. (Eds.) (2012). Managing safety of heterogenious systems: Decisions under uncertainties and risks. Springer-Verlag, Heidelberg, Germany.

Ermoliev, Y., Ermolieva, T., Fischer, G., Makowski, M., Nilsson, S., Obersteiner, M. (2008). Discounting, catastrophic risks management and vulnerability modeling. Mathematics and Computers in Simulation, 79(4):917-924.

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