# LAND USE CHANGE AND AGRICULTURE PROGRAM

*The research efforts of the LUC Program are geared toward making a difference both in combating global hunger and poverty and in the preservation of global natural resources.* 

## Mission

The strategic goal of the Land Use Change and Agriculture (LUC) Program is to support policymakers in developing rational, science-based and realistic national, regional and global strategies for the production of food, feed, fiber and bio-energy and other services to achieve long-term sustainability of land and water resources while promoting rural development.

To achieve this goal, the LUC Program aims to advance applied science with a focus on the following strategic research objectives:



- Develop new and improved tools and databases in order to provide a spatially detailed understanding of alternative land and rural development options and strategies, against the background of global change.
- Analyze synergies and trade-offs of alternative uses of agro-resources (land, water, technology) for producing food and energy, while preserving environmental quality.
- Identify hot spots of significant environmental and rural social risks, and clarify their relation to global change.
- Verify methodologies and tools in applications for regional/national case studies needed to improve global scenarios and links with region-specific conditions, issues, and policy options.

Three areas of research, outlined below, are identified for the period 2006–2010. These cover key issues of importance for understanding the interactions between society, land use, agriculture, and climate over the coming decades.

### **Research Areas**

The first area provides a common thread for the program's global research through a "Food and Agriculture to 2100" project that unifies the themes of climate and anthropogenic impacts on soil and water resources, adaptation and mitigation strategies, and rural development. The second area analyzes subsets of these issues in regional case studies in Europe, China, South Asia, sub-Saharan Africa, and Latin America. The third area includes activities aimed at developing new methodologies that advance our ability to derive and manipulate spatially explicit data and provide better integration of socio-economic and bio-physical analyses.

### Global level research:

- Food and Agriculture to 2100;
- Climate change, impacts, mitigation, and adaptation;
- Water and agriculture;
- Bio-fuel production and land competition.

### Policy support for sustainable development of regional agricultural and rural sectors:

- Agriculture and rural development in transition economies;
- Multi-functionality of land and sustainable socioeconomic and environmental development;
- Environmental impacts of agriculture;
- Regional bio-fuel roadmap.

### Methodology development:

- Sequential rebalancing methods for spatial allocation and downscaling;
- Framework for spatial ecological-economic analysis;
- Methodologies for spatial global and regional land cover change scenarios.

The LUC Program builds on established close interactions with relevant international organizations, ensuring that deliverables are of high policy relevance. International collaborations with leading climate change research institutions strengthen the Program's ability to deliver products with high scientific standards.

Changes in land use and land cover are central to the study of global environmental change. Not only do they have profound regional implications that can be felt during the life span of current generations, but they also exhibit cumulative long-term global dimensions. Important issues needing to be addressed include loss of biodiversity, diminished land productivity, land degradation, water contamination, and receding groundwater tables. In addition, land management and land use changes greatly affect emissions and the sequestration potential of major greenhouse gases. Future decisions concerning land use clearly play a major role in strategies for mitigation and adaptation to climate change.

# Agriculture in the 21st Century

IIASA's integrated modeling framework comprises a global spatial agro-ecological zone (AEZ) model and a regionalized general equilibrium model of the world food economy. The two models form the basis of scenario evaluation and policy analysis of food and agriculture in the 21st century at the national, regional, and global levels. The study includes analyses related to future demographic and economic development pathways and of the potential impacts of climate change on, for example, natural resources and the environment, agricultural science and technology research priorities, food and agricultural systems, population and demographic changes and consumption, international agricultural trade reforms and globalization, and assessment of the scale and location of risks of hunger and malnutrition.



## Food Security and Bio-energy Production

The role of bio-energy has been strongly enhanced by its inclusion in the climate change debate, as well as through the opportunities it may create for rural development and improved energy security. Land use competition with food and feed production is considered a potential key barrier to exploiting the regional and global bio-energy production potential. LUC activities aim to assess the potential role of bio-fuel production under different scenarios of projected food and feed demand, severity of land use restrictions, yields of food crops and bio-energy feedstocks, and availability of bio-fuel conversion technologies. In this area of research the following activities and projects are currently under way:

*Global Assessment of Bio-energy Potentials:* This activity comprises a spatially detailed global estimation of agro-bioenergy potentials and, building on this spatially detailed understanding of agro-bio-energy sources, an assessment of development options, synergies, and land use competition among food and bio-energy plants.

*Renewable Fuels for a Sustainable Europe (REFUEL):* The REFUEL project is designed to encourage a greater market penetration of bio-fuels. To help achieve this goal, the project is developing a bio-fuels road map, consistent with European Union (EU) bio-fuel policies and supported by stakeholders involved in the bio-fuels field. The two-year project involves seven renowned European partners. REFUEL is being financed by the European Commission under the "Intelligent Energy – Europe" programme.

*Effective and Low-disturbing Bio-fuel Policies (ELOBIO):* This project seeks to identify sets of policy measures that are suitable for both the promotion of bio-fuels, while at the same time avoiding or minimizing negative effects on other EU policy goals and markets. LUC's role in ELOBIO is to model impacts of increased demand for bio-fuel feedstocks on food and feed commodity markets and to assess the effects of different policies and measures aiming to reduce this disturbance. ELOBIO research and recommendations are serving the Intelligent Energy Executive Agency of the European Commission.



## Water and Agriculture

Water is a key driver of agricultural production. The area under irrigation has expanded to over 270 million ha worldwide, about 18% of total cultivated land. Agriculture is the largest user of water of all human activities: irrigation water withdrawals represent 70% of the total anthropogenic use of renewable water resources. This has brought agriculture into competition with other water users and has impacted negatively on the environment. The research in this thematic cluster undertakes a comprehensive, spatially detailed quantification of water needs for agriculture based on the integrated ecological–economic evaluation of food system changes against the background of future global change.

*Water and Global Change (WATCH):* This EU Integrated Project brings together 25 partner institutions in the hydrological, water resources, and climate communities to analyze, quantify, and predict the components of the current and future states of the global water cycles and related water resources, to evaluate their uncertainties, and to clarify the overall vulnerability of global water resources related to the main societal and economic sectors. LUC provides global spatial data on key components of the water cycle from 1900 to 2100 regarding agricultural, industrial, and domestic uses. This involves scenario projections of agriculture development and land use change as well as providing modeling techniques and methodologies for scaling and analyzing the data.



*Water Scenarios for Europe and for Neighboring States (SCENES):* SCENES is a four-year EU Integrated Project with 23 partner institutions that includes stakeholders in the development and analysis of a set of comprehensive scenarios of Europe's freshwater futures up to 2025.

### Land Resources and Agro-ecological Zoning

The Food and Agriculture Organization of the United Nations (FAO), with the collaboration of IIASA, has developed a spatial analysis system that enables rational land-use planning on the basis of an inventory of land resources and evaluation of biophysical limitations and production potentials of land. This is referred to as the Agro-ecological Zones (AEZ) methodology. The AEZ methodology follows an environmental approach; it provides a standardized framework for the characterization of climate, soil, and terrain conditions for analyzing synergies and trade-offs of alternative uses of agroresources (land, water, technology) for producing food and energy while preserving environmental quality.

*Global Agro-ecological Zones Assessment (GAEZ 2007):* This FAO-sponsored agro-ecological zones project includes practical applications and a novel methodology for spatial downscaling of agricultural production statistics to produce a detailed global gridded inventory of year 2000 agricultural yields and production. Using this information in conjunction with estimated attainable yield potentials, yield gaps are estimated and production opportunities worldwide are quantified. Examples of applications are: (i) quantification of land productivity; (ii) estimation of extents of land with quantified rain-fed or irrigated cultivation potential for respectively food, feed, fiber, and bio-energy production; (iii) occurrences of environmental constraints to agricultural production, and (iv) identification of potential hot spots of agricultural conversion and the possible geographical shifts of agricultural land potentials as a result of changing climate.

*Harmonized World Soil Database (HWSD):* In the context of GAEZ 2007, separately co-funded by the FAO, an up-to-date harmonized global soil resources database is being compiled by LUC, in close collaboration with the FAO, the Chinese Academy of Sciences (CAS), the International Soil Reference and Information Centre (ISRIC), and the Joint Research Centre (JRC) of the European Commission. The HWSD has superior spatial representation and attribute information compared to the Digital Soil Map of the World of 1995, published by the FAO, or any other currently available global soil data product. The soil units that occur in individual mapping units are linked to standardized soil attribute databases that provide soil characteristics for both top-soil and sub-soil.

*Exploiting Information on Global Environmental Risks—Agriculture (EIGER-Agri):* The objective of this project is to enhance available knowledge and data on yield and land suitability of key agricultural crops under climate change conditions. Improved spatially referenced datasets of crop yield and land use for different climate change scenarios will be complied and integrated in order to assist decision making and environmental risk assessments. An important component is the development of crop damage modules (pest/disease, thermal damage, ozone) for use in global/regional agro-ecological

assessments. EIGER-Agri is a joint effort of the LUC Program at IIASA, the Plant Production System Group at Wageningen University (PPS-WU), and the Sustainable Agriculture Research Division of Unilever.

# Policy Support for Sustainable Development of Agriculture and Rural Sectors:

In support of and complementing the global studies, LUC has been conducting or initiating a number of regional projects, for example: in Ukraine on agriculture and rural transformation in transition economies; in Europe on land use issues related to sustainability and bio-fuel production; and in China on water scarcity and agro-environmental impacts in the context of rapid growth, globalization, and global change. These projects consider a time horizon of 25 to 50 years and are carried out at the regional/national scales in close collaboration with local research partners. The studies address critical policy issues of land stewardship, based on spatially detailed assessments of policy alternatives with specific consideration of social development in rural areas and implications for the resource base and ecosystems.

*China Agricultural Transition:* Social and Environmental Impacts (CATSEI): This EU-funded project, implemented by six prominent European, Chinese and US-based partners, investigates the impact of China's rapid economic transition on its agricultural economy with special reference to the consequences of trade liberalization and to changing trade flows. The research focuses on three themes: trade, social conditions, and environment.

*Sustainable Livestock Production in China:* LUC is developing an integrated model for spatio-temporal analyses of livestock and crop production under alternative economic and demographic projections. The model evaluates alternative strategies to achieve robust production allocation and intensification with regard to factors such as demand concentration in urban agglomerates, environmental hazards and impacts, nutrient balances and GHG emissions, and risks of disease outbreaks.

Agro-Ecological Zones Assessment for the Transition of the Agricultural Sector in Ukraine: This activity aims to gain a better understanding of land use change and its effects on the transition of the agricultural sector of Ukraine, estimate the agricultural potential of Ukraine's natural resources, and assess the impacts of climate change on crop suitability and yields in Ukraine.

## Highlights of Recently Completed Major Projects:

### Policy Decision Support for Sustainable Adaptation of China's Agriculture to Globalization (CHINAGRO)

Following the accession of China to the World Trade Organization, Chinese policymakers have been facing the challenge of defining transition strategies that maintain a socially sustainable level of rural income and employment, meet the need of rapidly growing urban populations, are environmentally sustainable, and meet international commitments. The CHINAGRO project (2003–2005) addressed a range of questions that are at the core of the ongoing debate on trade liberalization and globalization.

### Modeling Opportunities and Limits for Restructuring Europe Towards Sustainability (MOSUS)

The MOSUS project (2003–2006) aimed to integrate three major themes of European policies within a macroeconomic, multi-sectoral framework representing the interrelation of the economic, social, and environmental domains. These policy themes are: sustainable development, competitiveness and social cohesion in the knowledge-based society, and globalization and international trade.

For more information on IIASA's Land Use Change and Agriculture Program, please contact:

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IIASA is an international, interdisciplinary scientific institute sponsored by a consortium of scientific organizations in Africa, the Americas, Asia, and Europe. At IIASA, leading scientists research the critical issues of global environmental, economic, technological, and social change that we face in the twenty-first century. IIASA's studies provide timely and relevant insights for the scientific community, policymakers, and the public.