

The 'Dream Valley' ABM: From reproducing macroeconomic indicators to participatory exercises

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Advanced Systems Analysis program

The 'Dream Valley' model

Overview. Purpose

The model is used for studying dynamics of the Finnish economy in the cases of external or internal shocks (e.g. sudden export drop, migration crisis etc.)

The aim of the model is not to be predictive and it does not provide the users with accurate forecasts.

The ways the model is applied are fourfold:

- 1) Experimenting with different scenarios: if this event happens or a policy is implemented, what is the outcome.
- 2) Decision maker toolkit: a decision maker can change parameters during simulation and see what happens (observation of the dynamics of the system change).
- 3) Increasing resilience: define a shock scenario and plan policy actions to repair the system in a crisis, then test the response.
- 4) *Pattern identification: run a large number of different scenarios and identify some typical reaction patterns (and anomalies).*

The 'Dream Valley' model

Overview. Purpose

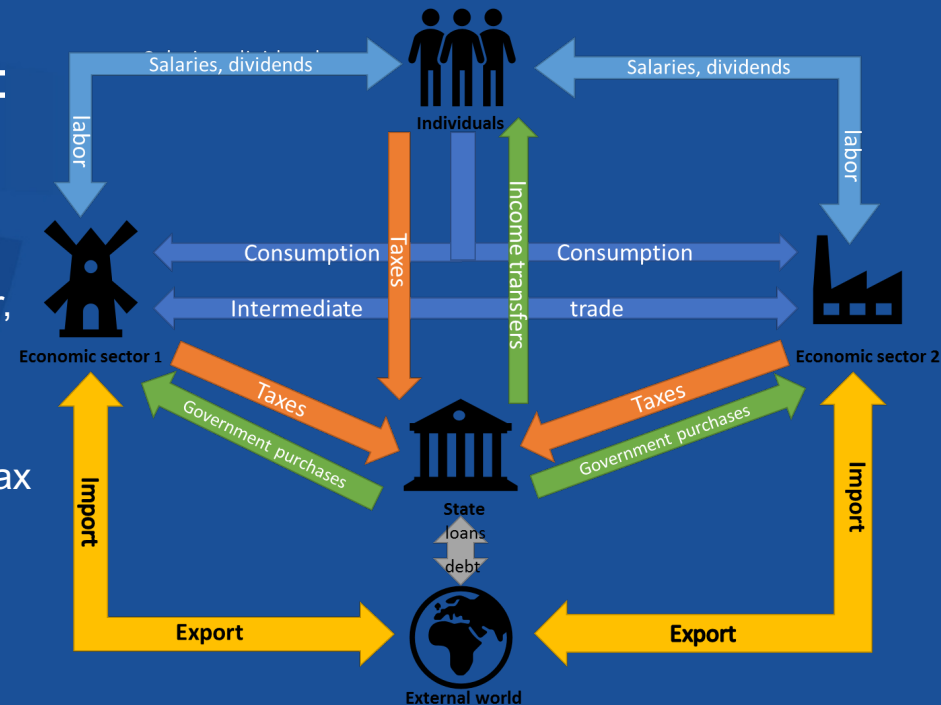
- Research questions
 - Economic
 - **Sectors in trouble** – export volume decreases dramatically (i.e. Russian counter-sanctions)
 - **Transition from manufacturing to services** (i.e. paper plants)
 - Sovereign debt is increasing and the government is cutting its purchases
 - Social
 - **Ageing of population – high dependency rate**
 - Failure to attract highly skilled foreigners
 - **Employment shift to public sector**
 - High personal debt and low savings rate
- Qualitative to quantitative scenarios

The 'Dream Valley' model

Overview. Entities, state variables, and scales

DV contains three types of agents:

- **individuals (people)** [age, gender, education level, income, consumption structure, saving, willingness to work etc.]
- **economic sectors*** [demand, labor, input-output data, taxes paid, labor intensity etc.],
- **the government** [budget structure, tax rates for individuals and economic sectors, unemployment benefit etc.]



The model environment consists of the Main class ('Model' or 'Observer') and external world which exports and imports good to the model economy and acts as a source of immigration to the model and destination of emigration from the model.

The 'Dream Valley' model

Process overview and schedule

- Time-step is one month
- Each time-step total demand for each sector is calculated (export + government purchases + domestic demand + intermediate consumption – import)
- Sectors estimate required amount of labor; labor is hired/fired
- Sectors distribute the revenue as salaries and dividends
- Individuals make decisions on consumption and labor market activity
- Government collects taxes and pays social transfers and purchases from the sectors
- Macrodata (GDP, unemployment, population structure etc.) is recorded in datasets

The 'Dream Valley' model

Model-specific features

- No pricing mechanisms, model is demand-driven; Finland has an open economy
- No explicit monetary institutions (i.e. banks)
- All stocks and flows are monetary
- The model is Implemented in AnyLogic software (Java-based, proprietary; supports ABM, system dynamics and discrete-event modeling)

Case-studies

- First versions of the 'Dream Valley' modeled an artificial region
- Then it was customized for three Finnish regions (Joensuu, Pori and Oulu); Korea and, now, Finland – involving advisors to relevant decision makers
- The thorough validation process is now in progress

Agent-based Modeling for Korean Strategic Foresight

This project jointly run by STEPI (Science and Technology Policy Institute, Seoul, Korea) and ASA, IIASA aims to provide foresight into possible consequences of several major shocks which may hit the economy of South Korea.



Overview

The current foresight methods are mainly based on descriptive scenario building which provide decision-makers with a set of narratives of the end states of the alternative futures. Contrary to this, this project focuses on the transition process to those end states.

Practically, the ambition of this project two-fold. Firstly, it aims to produce a computer interactive tool that provides decision-makers with a better understanding on the dynamics of potential futures. The focus of the study is, therefore, on how futures are unfolding, in

addition to what may have happened.

Secondly, the project will assist policy planning in testing potential impacts of the different policy options.

IIASA Research

The research is a part of the ASA exploratory studies of uncertainty.

This project is based on the previously developed economic Agent-Based Model (ABM) called Dream Valley (DV). The model has been designed to simulate the regional dynamics in case of global (external) shocks of different sort. The primary use of the model is to analyze of the disruptive changes and for testing different policy options used for mitigating the shock impact. The previous case-study was carried out within the project [Structural Change of the Finnish Economy – a Systems Approach](#).

Structural Change of the Finnish Economy – a Systems Approach

The research initiative aims at increasing the systemic understanding about the impact of global trends and unforeseeable shocks on the Finnish national economy and regional economies as well as producing science-based tools for practical policy planning, which will support sustainable regional growth in the volatile global environment; such planning that minimizes the need for the special corrective actions in the future and that maximizes the sustainability of regions.



Overview

The typical annual GDP growth rate (on average 2.7% in 1975-2010) may not be reachable due the asymmetric development of the global economic system; simultaneously some of the traditionally strong exporting industries (such as forest and electronics industries) are focusing their investments on abroad. The new growing sectors such as the IT sector and various components of the service sector have not shown to be able to replace the loss of exports of the manufacturing sectors. Besides, regions abandoned by large employers do not become attractive sites for the new service industries. Decision makers are facing tough decisions; hence they need better understanding on the dynamics of the transition phase as well as science-based tools for supporting decisions.

IIASA Research

Economic network representing intermediate good flows between economic sectors export and import flows for three Finnish regions – Pori, Joensuu and Oulu are studied. It is found that in all three regions the most effective policy intervention to stimulate local production is increasing the state subsidies to unemployed and the state demand.

Three approaches are used to model economy of the regions: *network analysis, multipliers and agent-based modelling*.

Dream Valley simulator (DV) is an agent-based model of a regional development covering several features, such as heterogeneity and bounded rationality of agents, stochasticity in implementing the decisions, interactions of agents and their adaptation and learning. Agents are individuals, companies and the government acting in the physical environment. Using the Dream Valley simulator allows for experimenting different policy options and their impact on the regional economics and its population, in other words the Dream Valley simulator is an artificial laboratory for experimenting with regional economies. The region specific customized Dream Valley will be validated by historical data and expert estimates. It tests the vulnerability of the regions to a number of shock scenarios where economic shocks are exogenous to the regions.

A policy report to the Ministry of Employment and Economy summarizes policy recommendations; three papers presenting the models, simulation results and conclusions are being prepared.

The 'Dream Valley' verification

- Documentation – a beta-version of ODD protocol is available (for Korean version of the model)
- Programmatic testing
 - Unit testing – most functions tested, manual testing (see [challenges](#))
 - Code walkthroughs – the most complex functions tested
 - Debugging walkthroughs – was not yet performed
- Test cases and scenarios
 - Corner cases – partially; some interactions of the model were “frozen”; submodels were run in a static mode (e.g. data inputs only for one time-step, no evolution, but the model was run for a long time)
 - Specific scenarios – business as usual and some shock scenarios were identified on participatory workshops
 - Relative value testing – partially; verified qualitatively by observing patterns

The 'Dream Valley' validation

- Micro-face validation – using existing (sub)models, literature analysis, [participatory modeling](#)
- Macro-face validation – model outputs pattern analysis using the dashboard (part of model's GUI), reporting to experts ([see Case-Studies](#))
- Empirical [input validation](#) – data taken from open and reliable sources such as Statistics Finland and Eurostat. The number of technical parameters is minimized; substance-based parameters are based on expert assessments
- **Empirical output validation – real-world data validation – reproduction of past time series**

The 'Dream Valley' validation

Example of a participatory workshop setting

Procedure

- Sorting participants into teams
- Session 1: each team forms a government with specific goals
 - Select values for the parameters on the control panel
 - Make prediction for output variable trends in the DV model
 - Assessment of the outcomes by the Expert Panel
- Session 2: looking for extremes
 - Select values for the parameters on the control panel that may collapse the valley
 - Make prediction for output variable trends in the DV model
 - Assessment of the outcomes by the Expert Panel

Key input data used

Sources: Eurostat and Statistics Finland

- **Input-output tables** (coefficients and initial monetary values) and inverse matrices for economic sectors
- **Labour force** distribution across the sectors, numbers of unemployed and economically inactive (pensioners, students, children etc.) population
- **Probabilities of changing labor state** (employed/unemployed/inactive)
- **Population data** (age- and gender-specific numbers of individuals)
- **Families structure** and marriage age data for both genders (*to be used in the further model versions*)
- Individuals **consumption structure** by economic sector

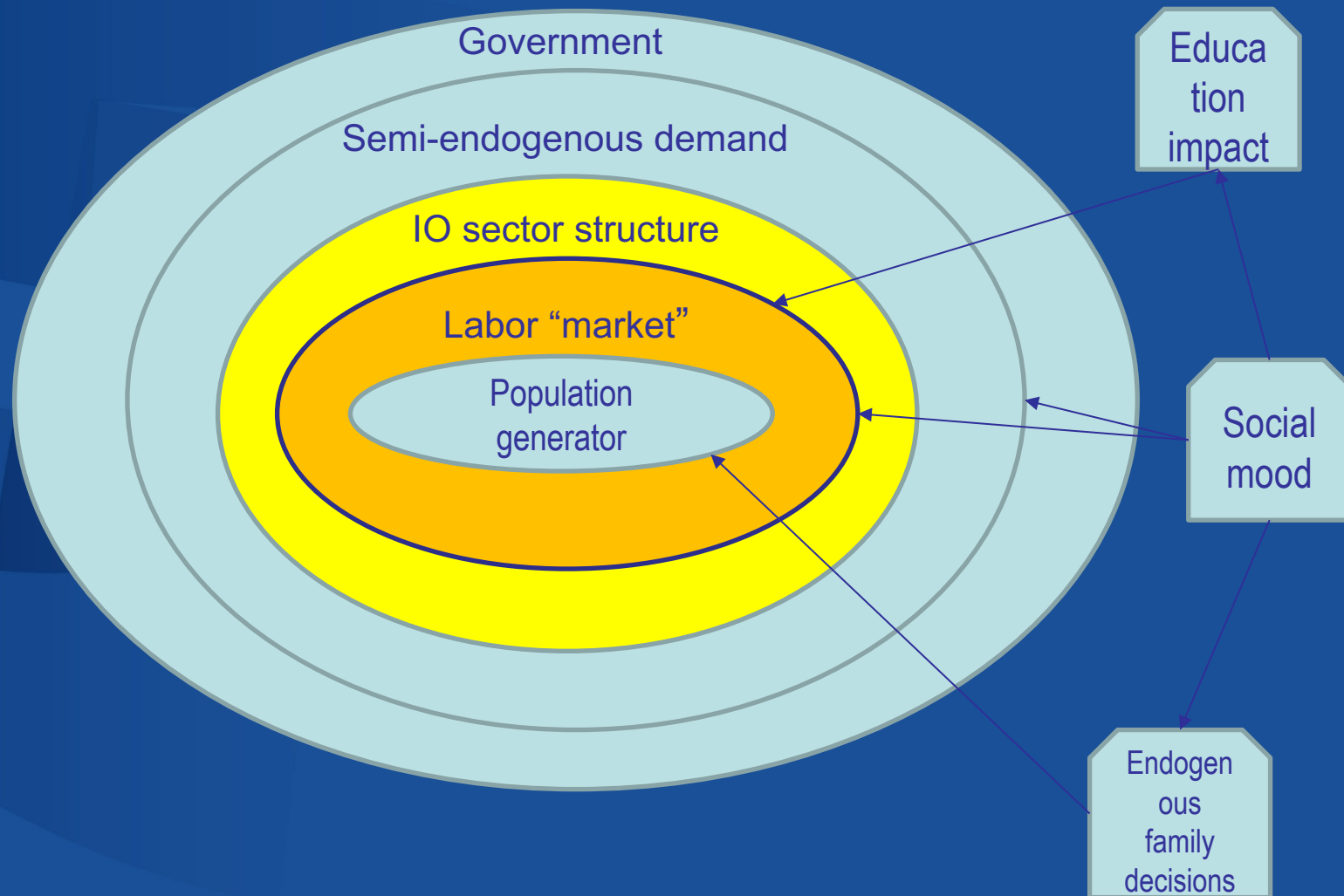
Real-world data validation

Reproduction of past time series

- Main indicators
 - GDP
 - Unemployment rate
 - Population
- Secondary indicators
 - Employment and activity rates
 - Total output and labor sizes for economic sectors
 - Income and consumption distributions
 - Taxes collected; government spending
 - Some others (mainly used for validation)
- Simple analysis of outputs in Excel

Dream Valley submodels

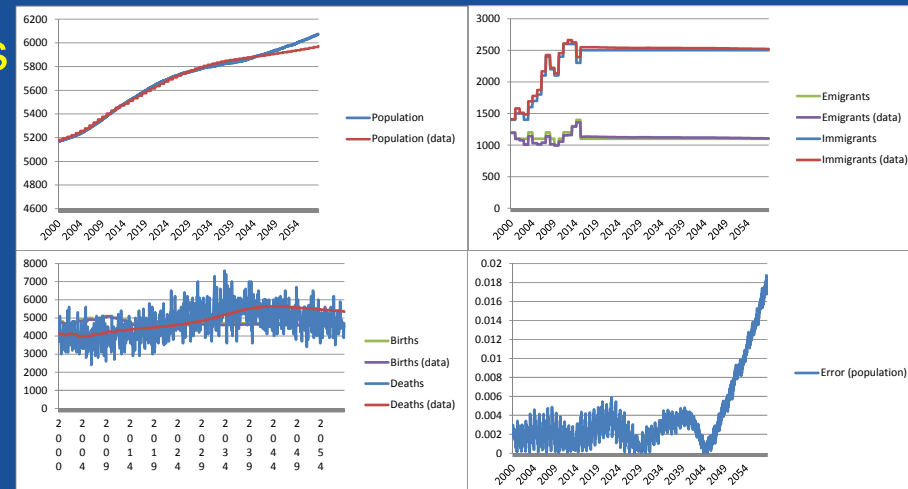
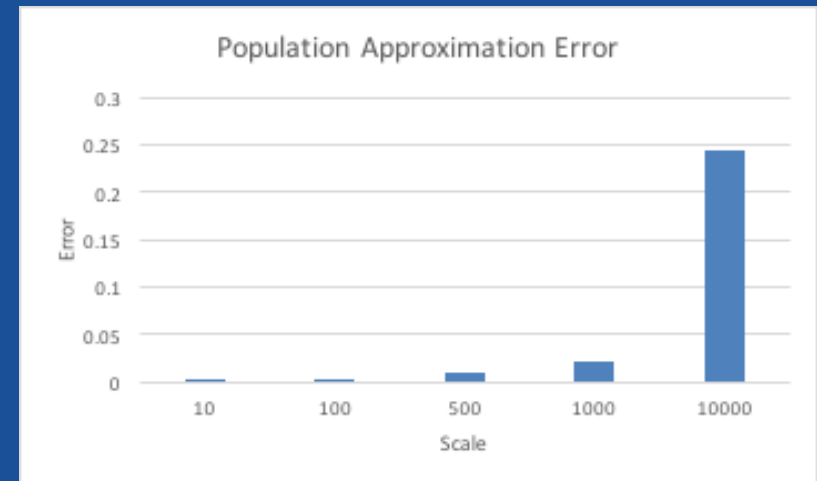
Multi-layer framework + additional modules



Population generator submodel

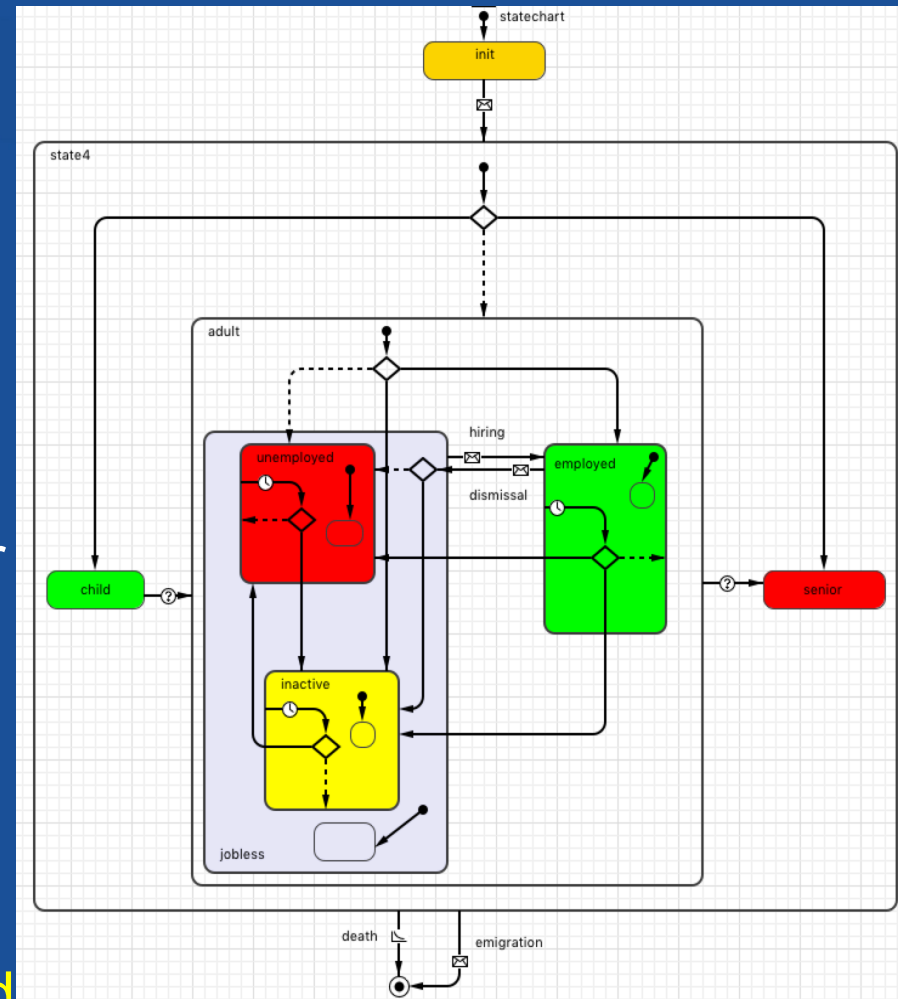
Generates artificial population of human agents

- Uses birth rates, age-gender-specific death probabilities, immigration and emigration rates from the past data and projections (available up to 2060)
- Scaling factor from 1:10 to 1:1000
- **Validation – reproducing population, age-gender structure and deaths rates past time series with minimal possible error**
- No additional parameters used!
- Special demographic models exists and maybe employed (i.e. “The Wedding Ring”)



Labor “market” submodel

- Labor as a production factor
- No labor prices, demand-driven recruiting
- Labor intensity (individuals required to produce 1M Eur. goods/services) is taken from data
- Probabilities of changing labor state are taken from data
- **Validation – stock-flow consistency of employed, unemployed and inactive individuals on each time step; total labor amount should yield data**



Labor “market” submodel

Results

Input-output economic structure submodel

- Well-established approach; gives a more realistic representation of the macroeconomy
- Allows testing resilience of various economic sectors under shocks of different nature
- Detailed data available for Finland for years 2000-2015 – labor sizes, labor intensity, input coefficients (compensation of employees, capital formation etc.) and input values (in EUR)
- **Validation – macro indicators (total output, labor-related rates) should yield to a one-sector model (previous layer). Sector-specific outputs (output and labor size) should yield the data**

031	Sum	0.778
032	Net taxes on product(Less subs	0.005
033	Scrap	- 0.001
034	Total intermediate input	0.781
035	Compensation of employees	0.104
036	Operating surplus	0.089
037	Depreciation of fixed capital	0.025
038	Other net taxes on production	0.001
039	Total value added	0.219
040	Total input	1.000

Semi-endogenous demand submodel

- Final demand consists of
 - Export
 - Government purchases
 - Domestic consumption
 - Intermediate consumption
- Domestic consumption is generated by individuals consuming part of their income – salaries, dividends, state transfers
- **Validation – final demand should yield previous model layers; income and consumption structures should yield data (challenging!)**

Government submodel

- The government (state) collects taxes from individuals and economic sectors
- It allocates budget for purchases from the sectors and transfers to individuals (pensions, unemployment benefits etc.)
- The model user can control the government using the dashboard
- An “autonomous” government is possible
- **This submodel has not been validated yet**

Complete 'Dream Valley' real data validation

Possibly the obtained results will be added to the final presentation

Verification and validation challenges

- AnyLogic is a proprietary software
 - Some unpredictable behavior of the model occurred due to implementation features, which are not documented
 - Automated unit testing is more complicated (though a debugger is available)
- High sensitivity to input data and model parameters
- High precision goals – e.g. even 1% error in unemployment rate maybe not satisfactory
- Availability of certain input data (e.g. transitions of labor available only from 2007 on), regional IO tables available only for 2002 etc.
- Definitions of certain input data – e.g. if an employed person is inactive on the next step – is it possible, if (s)he retired due to age?; unemployment and activity rates (Eurostat definition) are counted for ages 15-74.
- Balance between model extension (more complicated, detailed-“realistic” agents’ properties and interactions) and its tractability

Further steps

- Thorough documentation of the modeling and experimenting process using TRACE
- Increased stochasticity in the model (decisions of the agents; scenarios) – need for massive runs and output distribution analysis
- More advanced methods of model output analysis (statistical tests, regressions)
- Formal sensitivity and robustness analysis (using AnyLogic Professional featured experiments)
- Employment of "serious games" for calibrating certain features of the model
- Design of detailed modules for answering concrete "narrow" research questions
- Running the 'Dream Valley' on an HPC – this, of course, requires full validation beforehand 😊

DREAM VALLEY II

Validating an Agent-based World



Speakers:
Elena Rovenskaya ASA, IIASA
Arkady Kryazhimskiy ASA, IIASA
Brian Fath ASA, IIASA
Alexey Voinov ITC, Netherlands
Hans Liljenström SLU, Sweden
Michael Thompson, RPV, IIASA
Nikita Strelkovsky, MSU, Russia

Thanks for your attention!

Further questions?
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