Comparative model analysis of various sparing measures intended to crop production long-term sustainability by «APEX-AGROTOOL» integrated simulation system

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Abstract

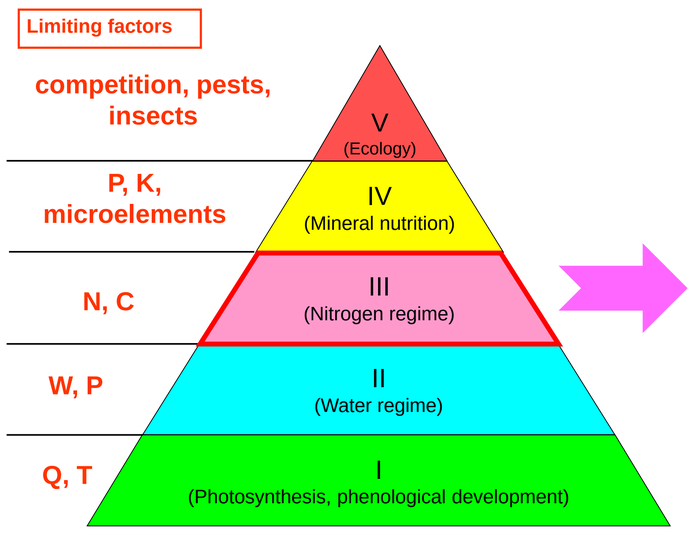
Maintaining or even increasing the fertility and sustainability of agricultural landscapes during their active agricultural use is one of the most important scientific problems in theoretical agricultural science. Contribution presents authors efforts to develop and improve the integrated system of crop simulation for analysis and investigation of various sparing measures intended to crop production sustainability. The system consists of two main components: a) «AGROTOOL» is a process-based crop model and b) «APEX» is a framework for multivariate analysis of arbitrary dynamic crop models. They both have been significantly modified for the stated purposes. The imitation system «APEX-AGROTOOL» was used to perform a series of computer experiments in order to estimate the relative effectiveness of different measures of prolonged action, which are aimed to improving the ecological stability of agricultural landscapes and conservation of soil fertility, taking into account the possible climate change.

Challenges

- Application of a dynamic crop model with daily time step for a long-term analysis in land use
- Climate change impact on crop productivity and agro-landscape sustainability
- Consideration of different sparing measures and agro-technologies in frames of any crop rotation scheme
- Model-oriented analysis of organic farming managements (green manure, catch crops, effective use of plant residues)
- Multivariate case study of the problems by means of full-factorial computer experiments

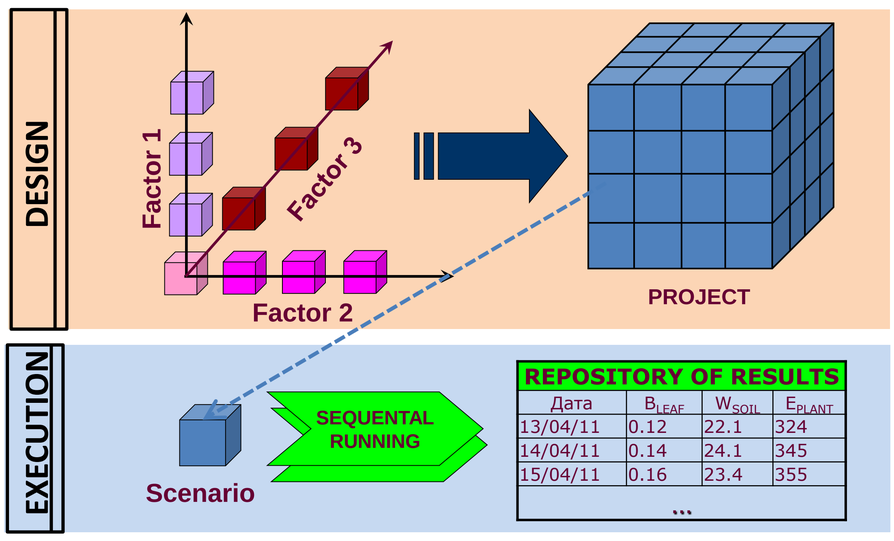
Materials

Dynamic Crop Model AGROTOOL v. 3.6



Modeling domain	Approach
LAI & Light Interception	**Monsi-Saeki**
Photosynthesis	**Original**
Light Utilization	**P - R**
Assimilate Partitioning	**Adaptive**
Yield Formation	**Y(P,R,T)**
Crop Phenology	***f*(T,W)**
Root Distribution over Depth	**EXP**
Stresses Involved	**W, N**
Soil Water Dynamics	**Richards**
Evapo(transpiration)	**FAO56**
Soil CN-model	**CN, P(5)**
Biological Nitrogen Fixation	**Adaptive**

Framework APEX (Automation of Polivariant EXperiments)



Predefined (project forming) factors:

- Soil
- Culture/Variety
- Weather
- Technology
- Location
- Initial State

Add-ons:

- Factor coupling
- «Virtual» factors in post-processing

Principal Modifications for Project Purposes:

AGROTOOL	APEX
✓ **Wintering:** Continuous calculation throughout the whole year. Improved algorithms of snow melting and soil thermal regimes.	✓ **Crop rotation**: special plug-in for planning incomplete factorial experiments and performing appropriate complex serial-parallel schemes of scenario computation
✓ **Predecessor:** Transformation of litter and root residues in the module of carbon-nitrogen transfer in soil	✓ **Looping**: transfer of the results from the previous run to the initial state of subsequent run
✓ **Fixation:** Adaptive sub-model of a biological nitrogen fixation by legumes	✓ **Forecasting**: Built-in stochastic generator of daily weather data that takes into account possible climate changes

Methods

- **Location:** Men'kovo Experimental Station (ARI), Leningrad Region, Russia (59°25'N,30°02'E)
- **Soil:** Experimental Field AES-01, Sod-podzolic sandy loam, well-cultivated
- **Cultures:** Spring Wheat (W), Barley (B), Winter Rye (W), Canola Seeds (C), Potato (P)
- **Weather:** 8 Synthetic weather scenarios generated by stochastic weather generator. Climate parameters identified from 30-year actual weather datasets for the nearest weather station «Belogorka» and modified according to IPCC-provided data: (**2050**, GCM – **HadCM3**, Emission Scenario – **A2**)
- **Base Technology:** No Irrigation, No Mineral Fertilizing

PLAN OF THE COMPUTER EXPERIMENT:

TESTED SPARING MEASURES:

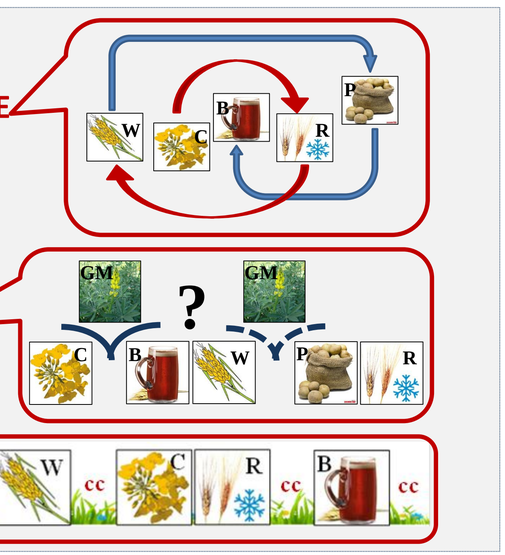
A) BEST CROP SEQUENCE IN THE ROTATION SCHEME

B) «SPARING» HARVESTING (STRAW REMAINS IN THE FIELD)

C) LEGUME AS GREEN MANURE CROP (LUPINE)

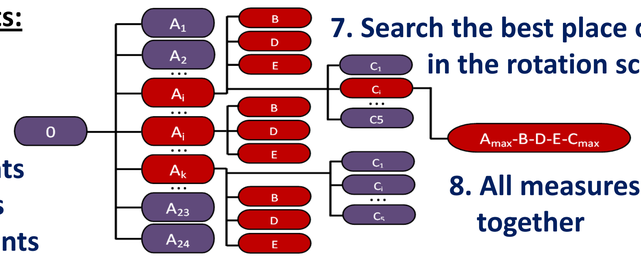
D) ORGANIC FERTILIZER (CATTLE MANURE)

E) WINTER CATCH CROP (RAPE)



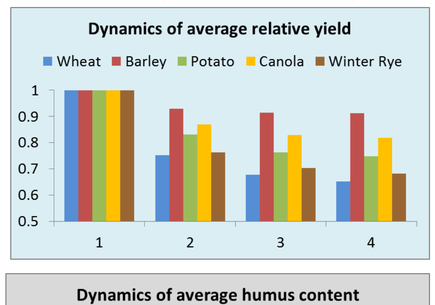
Scheme of numerical experiments:

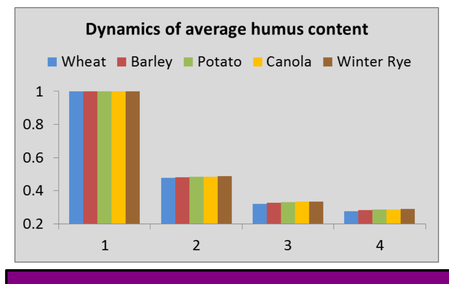
1. Base (no management)
2. Sequence. 4!=24 investigated variants
3. Choice 5 best variants of sequence.
4. Sparing harvesting for 5 selected variants
5. Winter catch crop before summer crops
6. Organic fertilization for 5 selected variants
7. Search the best place of lea in the rotation scheme
8. All measures together



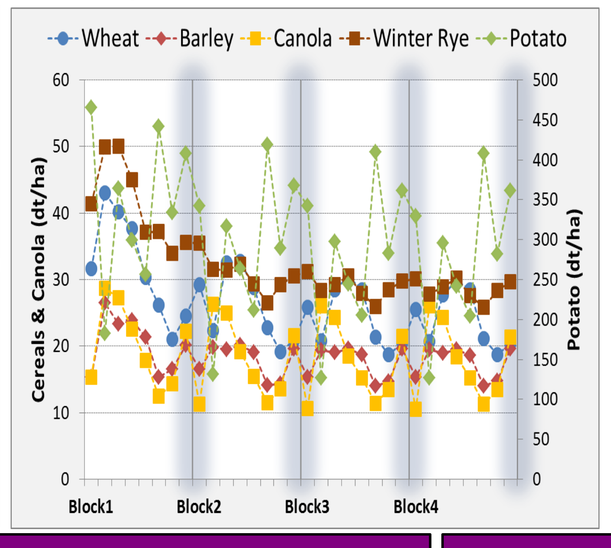
Results

Base (no measures)

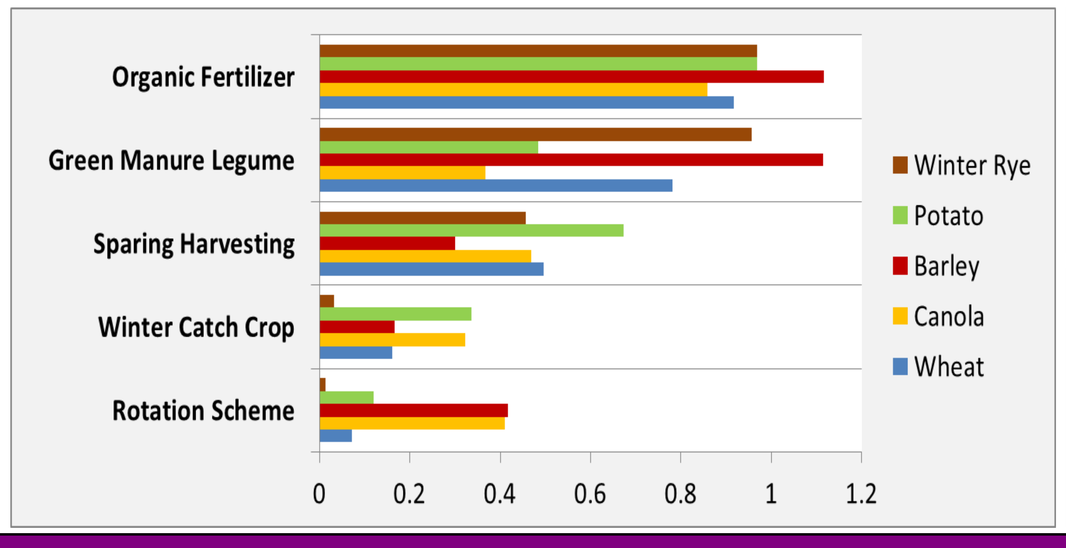




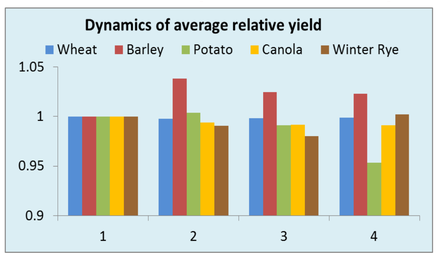
Yield dynamics in continuous rotation

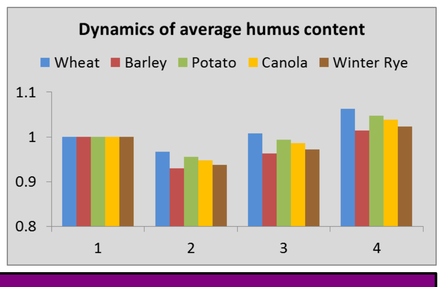


Comparative efficiency of tested measures (partial benefit / total benefit)



Full variant (all measures)





Conclusions

The results obtained prove that total abilities of developed integrated environment «APEX-AGROTOOL» cover completely the challenges of mid-term forecasting of agro-landscape sustainability and, therefore, it can be effectively used as a tool of model-oriented long/mid-term analysis of different crop rotation practices in land use.

Links & References

AGROTOOL Community Site : http://agrotool.ru (software is available)

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