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НОВЫЕ МЕТОДЫ И РЕЗУЛЬТАТЫ ИССЛЕДОВАНИЙ ЛАНДШАФТОВ В ЕВРОПЕ, ЦЕНТРАЛЬНОЙ АЗИИ И СИБИРИ

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This monograph shall inform you about up to date methodologies and recent results in landscape research. It is intended as a guide for researchers, teachers, students, decision makers, stakeholders interested in the topic of landscape science and related disciplines. It provides information basis for decision makers at various levels, from local up to international decision bodies, representing the top level of landscape science in a very short form.

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Chapter III/54: LandCaRe-DSS: A DECISION SUPPORT SYSTEM FOR PROJECTION OF CLIMATE CHANGE IMPACTS ON AGRO-ECOSYSTEMS AND CROP PRODUCTION

Глава III/54: LandCaRe-DSS: система поддержки принятия решений для учета влияния изменения климата на агроэкосистемы и производство сельскохозяйственных культур

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ABSTRACT. Decision support for developing practicable, resilient climate change adaptation strategies for the sustainable use of agro-landscapes encompasses a wide range of options and issues. The model-based interactive spatial information and decision support system LandCaRe-DSS available to farmers, regional planners and other stakeholders supports decision-making processes in this direction. This system does not only support interactive scenario simulations and multi-ensemble and multi-model simulations at the regional level by providing information about the complex long-term impacts of climate change. It also helps to find suitable, sustainable agricultural adaptation strategies to climate change (crop rotation, soil tillage, fertilization, irrigation, price and cost changes…) at the farm level. LandCaRe-DSS uses different ecological impact models, including for crop yield, erosion risk, regional evapotranspiration, total water flow-out and irrigation water demand. At the local level, a farm economy model is directly coupled with both the biophysical-based agro-ecosystem model MONICA and the statistical-based crop yield model YIELDSTAT to simulate the economic consequences of regional climate change and of proposed agricultural adaptation strategies. The interactive LandCaRe-DSS prototype offers a wide range of data analysis and visualization tools and an information system for climate adaptation in agriculture. Selected examples demonstrate the versatility of LandCaRe-DSS applications.

Резюме. Поддержка принятия решений в целях разработки практически осуществимых, устойчивых стратегий адаптации к изменению климата для устойчивого использования агроландшафтов охватывает широкий круг вариантов и вопросов. Основанная на моделях интерактивная пространственная информационная система поддержки принятия решений LandCaRe-DSS, доступная фермерам, специалистам по региональному планированию и другим заинтересованным пользователям, поддерживает процессы принятия решений в данном направлении. Эта система не только поддерживает интерактивное моделирование сценариев и многопрофильного и много модульное моделирование на региональном уровне, но и предоставляет информацию о сложных долгосрочных последствиях изменения климата. Она также помогает найти соответствующие устойчивые стратегии адаптации сельского хозяйства к этим изменениям (сезонное, обработка почвы, внесение удобрений, орошение, изменение соотношения цен и затрат...) для фермерского хозяйства. Система LandCaRe-DSS использует различные экологические модели, в том числе - модели для прогнозирования урожайности сельскохозяйственных культур, для оценки риска развития процесса эрозии почвы, а также для расчета региональной эвapotranspiration, потребностей в оросительной воде и общего расхода водных ресурсов. На локальном уровне модель фермерского хозяйства непосредственно связана с динамической моделью MONICA, которая описывает биофизические процессы в агрозистеме, а также со статистической моделью YIELDSTAT, разработанной для моделирования экономических последствий регионального изменения климата и предлагаемых стратегий адаптации сельского хозяйства. Интерактивный прототип LandCaRe-DSS предлагает широкий инструментарий анализа и визуализации данных, а также - информационную поддержку адаптации сельского хозяйства к изменениям климата. Приведен ряд примеров для демонстрации универсальности применения системы LandCaRe-DSS.

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KEYWORDS: Decision support system, Productivity of arable land, Climate change, Regional impact assessment, Simulation models, Agricultural adaptation strategies

INTRODUCTION

One of today’s and tomorrow’s fundamental task for mankind is to evaluate the productivity of agricultural landscapes and develop sustainable regional land management strategies for the production of feed, fodder and energy. It is also important that we preserve landscape and biodiversity, conserving soil and water resources. Agricultural land use is a key aspect of this task. However, it is not easy to identify sustainable concepts for agriculture. A sustainable land management for food production is a fundamental human activity, supporting the existence of mankind. Across the globe, agricultural production is primarily dependent on the weather, the general patterns of which are determined by annual fluctuations. Agricultural production is also dependent on future climate change.

To date, most discussions about climate change have focused on mitigation measures. Only little attention has been given to the adaptation to climate change, which will be critical for many countries on all continents, including several regions of Europe, such as the eastern part of Russia up to the Urals. The effects of climate change on agriculture may be positive or negative, depending on the variability of weather conditions, site quality, land use and management. Adaptation must take account of sustainability with regard to high plant production without losing ecosystem services.

Because of recent developments in modelling existing models are capable of identifying the potential of agricultural landscapes and the environmental constraints surrounding crop production at the regional and national level depending on expected climate change. In addition, these models can be integrated in interactive usable decision support systems (DSS), helping farmers and other stakeholders to determine the best regional management practices for adjusting agriculture to climate change. At the same time, these DSS must meet users’ demand for transparency, interactivity and user-friendliness without any loss of information [1]. Until now, only a few suitable spatial DSSs and analogous tools have been available such as ADSS [2] or GFARM [3], which were developed for specific regions only and are not available to the general public. To close this gap, LandCaRe-DSS was developed by the Institute of Landscape Systems Analysis of the Leibniz-Centre for Agricultural Landscape Research (ZALF) Müncheberg, Germany, as a real-time response system using mainly regional models of intermediate complexity [4] but also dynamic process-based agro-ecosystem models at field plot or farm level such as MONICA [5].

This paper presents the conceptual framework, the basic structure and functionality of LandCaRe-DSS, exemplarily two results of LandCaRe-DSS scenario studies, and ways in which the system can be adapted for other regions or countries.

AIM OF THE METHOD

The decision support system LandCaRe-DSS was developed to close the methodical gap in the field of getting a model-based decision support for finding cost-effective adaptation strategies of agriculture to climate change at regional as well as at field level as basis for a better economic survival of farmers and regional stakeholders under changing conditions. For the usage of LandCaRe-DSS by farmers, regional planners and other administration stakeholders a simple user interface and a convenient handling is required.

PRINCIPLE AND PROCEDURE

The LandCaRe-DSS system consists of an information and advisory system related to climate and climate change, a number of databases, various statistical as well as expert- and process-based simulation models for different spatial scales (regional and farm scale) and a zooming user interface that connects all system levels and modules. The conceptual framework of LandCaRe-DSS is presented in Figure 1. The central databases of LandCaRe-DSS contain historical climate data, different regionalized future climate projections for different regions, parameters for different agricultural crops, detailed management and economic data for 188 different cropping procedures as well as geo-referenced data concerning land use, topography, hydrology and soil characteristics. The system’s modular structure also enables regionalized climate data from different emission scenarios of other global climate models as well as other management and economic parameters to be linked with little effort. For different climate values such as temperature, precipitation, climatic water balance, heating and cooling days, start and end of vegetation, the
thermocline and the chill sum can be undertook a trend analysis, an inner-yearly analysis (daily and monthly), and a frequency analysis.

Figure 1 – Conceptual framework and levels of integration of different modules in LandCaRe-DSS (modified from [1])

Currently LandCaRe-DSS includes a range of simulation and impact models and algorithms for calculating climate and landscape indicators: the model BAGLUVA for calculating the long-term averages of regional actual evapotranspiration and total flow-out; the model EROSION for potential soil erosion risk estimation, statistical grassland model GL-PROD for grassland yield and forage quality calculation; the statistical model ONTO for ontogenesis of major agricultural crops; the model PHAENO for the typical phenological phases of different wild plants; the model VEGPER for the vegetation period calculation; the statistical-based model YIELDSTAT for estimation of crop yield, biomass and carbon fixation for more than 15 agricultural crops; the model BERBEDUE for identifying irrigation poverty; the empirical model ZUWABE for calculating site- and crop-specific irrigation water demand; the model LANUDIS for stochastic distribution of agricultural crops on arable land based on given cropping ratios; the process-based dynamic agro-ecosystem model MONICA for calculation of different ecosystem values including crop yield; the farm economy model FEM for calculating farm-level cost accountancy items. Using the FEM model in combination with other models it is possible to simulate the economic consequences of regional climate change and proposed adaptation strategies.

LandCaRe-DSS supports long-term and ensemble simulations on a spatial resolution of 100m x 100m, using coupled climate and agro-economic scenarios. The temporal resolution of models is no lower than 1 day, while the results of climate scenarios are typically evaluated for time periods of 30 years, providing robust information on the variability of the selected variables.

Unlike other decision support systems, LandCaRe-DSS offers interactivity, dynamics, variable spatial dimensions, scenario simulations, web-usability, extendibility and adaptability [1]. The whole system is easy to adapt to other regions or countries taking into account country-specific geo-data, other static and/or dynamic impact models incorporated, special parameterized and validated, other climate and/or emission scenarios and country-specific interface communication languages. A detailed description of LandCaRe-DSS, including the models and databases it contains and initial applications, is given in [1], [9] and [10].

TEST RESULTS
Exemplarily only one example of using the LandCaRe-DSS is presented here: the influence of enriched energy cropping, of non-tillage and of irrigation on crop yields under climate change.
For the time period 2005-2075 for the Uckermark region (dry lowlands of the Federal State of Brandenburg, 2600 km²) and the Weisseritz region (humid mountainous area of the Free State of Saxony, 400 km²) an investigation was carried out into how the regional productivity of crops would change taking into account the climate scenario WETTREG A1B if farmers were urged to grow energy plants, causing the cropping ratio to change in favour of silage maize in these regions. For the same period additional an analysis was made of how the irrigation of economically important crops or a change from conventional to non-tillage methods for winter rape and winter cereals would impact the regional productivity. The simulation results are shown in Figure 2.

**APPLICATION**

The LandCaRe-DSS prototype was parameterized and validated for the two Eastern German regions above-mentioned. LandCaRe-DSS is constantly being developed, updated and adapted in a number of research projects such as REGKLAM (http://www.regklam.de) for the Dresden region (Free State of Saxony, ca. 4500 km²) and CARBIOCLIM (http://www.uni-goettingen.de/de/211024.html) for the whole Mato Grosso and Pará states of Brazil. LandCaRe-DSS also has been used in practical climate scenario studies for assessing the impact of climate change on agricultural productivity and irrigation water demand up to 2050 for three federal states of Germany: Saxony [6], Brandenburg [7] and Thuringia [8]. LandCaRe-DSS was converted into an operative web-based version as a basis for wider distribution (http://www.landcare-dss.de).

Thanks to the modular structure of LandCaRe-DSS, little effort is required to adapt the system to geo-data bases valid for other regions or countries; incorporate other static or dynamic impact models; switch to other climate and emission scenario data; and implement other interface communication languages.

**CONCLUSIONS**

The LandCaRe-DSS system

1. offers historical and predicted climate data for region or climate station and visualizes trends,
2. allows for considering different regionalized climate scenarios (new ones can be integrated),
3. provides background information on climate change and on potential management strategies for agriculture to arrange with climate change,
4. enables an ecological impact assessment of possible climate and land-use changes at regional level,
5. offers integrated bio-economic analysis of potential agricultural adaptation strategies to climate change at farm level, taking different scenarios of price and cost dynamics into account,
6. is characterized by unrestricted choice of the spatial level and by interactive scenario simulation runs based on the advances in modern information technology,
7. supports policy-makers and administrative bodies in strategic planning for integrated water and land management, as well as farmers and agricultural advisory agencies identifying optimal agricultural adaptation strategies to climate change and
8. has potential for application and adaptation to regions in Russia and Central Asia.
REFERENCES


