

Impacts of global change on ecosystem services in Hesse

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Background: Global change describes the human impacts on the Earth System and includes processes of global dimension that have regional effects. The anthropogenic climate change and changes in use of the land surface as a result of complex interactions of political, cultural, social and economic factors are considered central aspects. Both processes have impacts on the functionality of terrestrial ecosystems and thus lead to changes in the provisioning of ecosystem services (ESS).

Objectives: The aim of the project was to combine methods from environmental science and environmental psychology in order to conduct an interdisciplinary analysis of the inventory (supply) and demand of ecosystem services in the state of Hesse. This includes the evaluation of the current situation as well as future changes due to processes of global change. In this context, adaptation measures in the areas of land use and agriculture were then outlined.

Methods: Starting point of the environmental psychology section of the study was an evaluation of the current level of knowledge of the Hessian population on the subject ESS using guiding questions interviews. Based on the results, a survey using standardized questionnaires was conducted to analyze the appreciation of ESS by the population and the acceptance of future changes. The outcome of the survey was analyzed according to human lifestyles and spatially explicit located in Hesse, using the Sinus Milieu approach.

The environmental science section of the project included the construction of a spatial inventory of the current supply of ESS using a Geographic Information System (GIS) as well as different environmental models and assessment methods. The following ESSs were considered: (1) food and bio-energy (yields of major crop types), (2) CO₂ regulation (biological carbon sequestration in soils and vegetation), (3) regulation of nutrient/water quality (nutrient retention), (4) habitat function (natural habitats, land use), (5) aesthetic information (land use) and (6) leisure (land use). For each of these ESSs an indicator has been defined (in brackets). Crop yields for wheat, rapeseed, potato, and silage corn have been calculated with the process-based simulation model DNDC while the GIS-based model INVEST has been used for the determination of biological carbon sequestration and nutrient retention. For the assessment of habitats, as well as the aesthetics of the landscape and leisure, the concept of landscape capacity was adopted and further refined. Starting from this inventory, scenarios of land-use change and anthropogenic climate change were investigated with regard to their effects on ESS. The simulation of land-use change was done with the land-use model LandSHIFT. Different climate projections based on the SRES A1B scenario were used to assess the effects of climate change on crop yields and the nutrient retention. A merge of both study sections was done exemplarily for the ESS leisure by combination of maps of its supply and demand.

Results and discussion: The analysis has two major findings regarding the level of knowledge of the Hessian population to ESS and their respective importance. For one, it becomes clear that the interviewed persons generally know little about most of the ESSs. Therefore for most of them only few answers were given. This can be explained so that the vast number of these ESSs is not directly

visible. In contrast, for directly visible services such as food and raw materials more answers were given. On the other hand it showed that when the interviewed persons were specifically asked at the importance of individual EESs many of them were classified as important or very important with no distinction between visible and non-visible services. A mapping of the demand for ESSs at the district level was exemplary conducted for the ESSs "Aesthetic information", "habitat function" and "leisure". Here, differences between the Hessian regions show up very well, but the general demand is on a very high level.

The simulated changes of crop yields under climate change show large differences between the examined climate projections. For example for rapeseed yield both increases and reductions were calculated with various climate model inputs. In total, two robust trends could be identified. First an approximation of the crop yields between southern and northern Hesse showed up in the simulations to the end of the 21st century. While crop yields in southern Hesse tend to stagnate or even to decline, yield increases can be found in northern Hesse. In addition, a strong effect of the changing seasonality of temperature and precipitation showed up for winter wheat, which is typically sown in autumn. The investigated climate scenarios were characterized by warmer and wetter winters until the year 2100 which favors plant growth during the winter months due to higher temperatures and higher precipitation. Adaptation measures to stabilize and to improve the yield situation in particular in southern Hesse include the cultivation of more climate-adapted crop varieties, as well as the adjustment of sowing and harvest dates. Due to earlier harvest dates it might also become possible to grow a second crop in the year, which can generate additional income to the farmer and/or contribute to the fixation of nitrogen.

Three scenarios of land use were specified and analyzed with regard to their effects on the supply of ecosystem services. The business as usual (BAU) scenario assumes that the current production of field crops remains constant. The bioenergy-scenario assumes an expansion of biomass production in Hesse for energy conversion, while the third scenario takes into account a strong expansion of organic farming. The scenarios differ significantly from each other with regard to the provisioning of the different ESSs. In the BAU and eco farming scenarios the supply of the ESS "food and bioenergy" is the same since in both scenarios the quantity of crop production is equal and the main difference is the type of agricultural management. In contrast, the supply of the ESS "food and bioenergy" in the bioenergy scenario is significantly higher e.g. in response to an increasing domestic demand for biofuels as well as to an increasing global demand for food products. However, this increased supply means that at the same time the supply of other services is decreasing. Regarding the ESS "CO₂ regulation", the bioenergy scenario that is characterized by the complete conversion of set-aside area to arable land performs worse compared to the scenarios that assume an alternative use of set-aside land (grassland, KUP, afforestation). The same applies to the supply of the ESS "habitat function" as well as the ESSs "aesthetics information" and "leisure". Through the use of the surplus land for agricultural production, there is no space available for increasing the other ESSs. In addition, as the bioenergy scenario is characterized by higher nitrogen application in agriculture there is a stronger demand for the ESS "nutrient retention".

Based on the results of the study, the authors see great potential to take advantage of the ESS concept to sensitize the Hessian population of the need for climate and environmental protection, as well as for sustainable land use. Moreover, the results can make valuable contribution for the planning of measures targeted at an increase of the supply of ecosystem services in order to better meet the existing demands.