

Estimating the effects of the EU Common Agricultural Policy on ground and surface water quality: A case study in the Neckar basin

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ABSTRACT

The RIVERTWIN project (www.rivertwin.org) supports the goals of the EU Global Water Initiative (www.euwi.org) and the EU Water Framework Directive by adjusting, testing and implementing the integrated regional model MOSDEW for the strategic planning of water resources management in three river basins in Europe, Central Asia and West Africa. This paper focuses on the estimation of the effects of the new EU agricultural policy on the quality of ground and surface waters in the Neckar basin (South Germany) based on the linkage between the agricultural sector model ACRE-Neckar, the soil and land resources information system SLISYS and the water quality models MONERIS and QUAL2K.

The Agro-economic Production model at Regional level-Neckar (ACRE-Neckar) represents the agricultural production in the Neckar river basin. The model optimizes agricultural production by maximizing the farm income using the Positive Mathematical Programming (PMP) method. ACRE-Neckar is based on the 'regional farm approach'. ACRE-Neckar calculates the production of food and fodder crops as well as livestock under the political scenario of the European Common Agricultural Policy reform 2003 (CAP reform 2003). Simulation of the CAP reform scenario results in less intensive

production systems, which are associated with a reduction of nitrogen input. The data of land use and nitrogen input calculated by ACRE-Neckar at regional level were delivered to SLISYS-Neckar, which distributed the data at lower scale level.

The land resources information system SLISYS-Neckar contains a spatially distributed model for the estimation of nitrate leaching and nutrient loads in surface runoff with high spatial ($< 1 \text{ km}^2$) and temporal (1 day) resolution. On the arable land sixteen crops are distinguished considering crop specific management with respect to operation scheduling, fertilization and tillage. Information about the crop distribution on the arable land was obtained from the agricultural census of the Statistical Bureau for the state of Baden-Württemberg (reference year 2003) or from the sector model ACRE-Neckar (CAP scenario). The simulation results show that the EU common agricultural policy will cause a decrease in the pollutant loads to groundwater in the range of 9 %. According to the results of the surface water quality models, this trend can be also observed for surface water, through reduced loads in the baseflow and less surface runoff, if population density remains constant. In this case the total nitrogen concentration in the Neckar river may be reduced by the CAP reform by more than 14 %. However, when economic growth rate is higher and population density increases, then it is most likely that the beneficial environmental effects of the CAP reform will be offset by an increasing nitrogen input from waste water.

Keywords: economic-ecological modelling, water quality, agricultural policy

1 INTRODUCTION

Water resources in the European Community, as well as in developing countries, are under increasing pressure from the continuous growing demand for sufficient quantities of good quality water for all purposes. Consequently, in 2003 the European Commission launched the “EU Global Water Initiative”, which proposes to apply the principles of the European Water Framework Directive (WFD) to other continents. The RIVERTWIN project (www.rivertwin.org) has been carried out in order to support the goals of the EU Global Water Initiative (www.euwi.org) and the EU WFD by adjusting, testing and implementing the integrated regional model MOSDEW (Model for Sustainable Development of Water Resources) for the strategic planning of water resources management at the basin scale in three river basins in Europe, Central Asia and West Africa (Mueller et al. 2005, Gaiser et al. 2007).

Integrated modelling is a novel approach to couple knowledge and models from different disciplines and research fields. The coupling may be soft (data coupling) or rigid (dynamic model coupling). At the global scale, research activities in integrated regional modelling have led to the development of prototypes of so called Earth System Models like the IMAGE model (Alcamo 1994, Leemans et al. 1998), which are now being improved and upgraded to be used in forecasting of global climate change effects on ecosystems and society. At the regional scale, most of the integrating modelling approaches in the last decade have focused on the description of the interaction between atmospheric and hydrological processes integrating disciplines from natural sciences (Rode et al. 2002, Horak and Owsinski 2004). Scenario studies combining socio-

economic and biophysical models have been successfully carried out for East Anglia (Loveland 2001), North-East of Brazil (Printz and Lang 2003), the Aral Sea Basin (De Groen et al. 2002, Dukhovny 2002) and at local scale (Dabbert et al. 1999). However, only very few approaches like the MULINO DSS (Giupponi et al 2004) integrate features of water quality modelling that are important for implementation of the WFD, in particular biological water quality, or do consider the impact of economic and social drivers on water quality.

Hence, the regional model MOSDEW has been developed in the Neckar basin (SW Germany) to assist planning authorities and decision makers to assess the impacts of economic and demographic development, and the effects of global climate and land use changes on the long-term availability and quality of water bodies.

The reform of the Common Agricultural Policy (CAP) has been adopted on 26 June 2003 by the European Union (EU). The CAP reform marks a fundamental change of the Common Agricultural Policy, which determines the EU support to the farm sector (EC 2003). Three key elements of the CAP reform 2003 which are significant for agricultural production are: (1) Decoupling of payments, (2) Cross-Compliance and (3) Modulation. Decoupling of payments means that a single farm payment is paid to EU farmers according to the Single Payment Scheme, which is independent from production. Cross-Compliance implies that the decoupled payments are linked to environmental, food safety, plant health and animal welfare standards, as well as the requirement to keep all farmland in good agricultural and environmental condition. Modulation includes a reduction in direct payments for larger farms to finance the new rural development policy

(EC 2003). It is expected that the CAP reform will have strong effects on the land use patterns and cropping intensity, which will in turn drive in water quality.

This paper focuses on the ex-ante estimation of the effects of the new EU agricultural policy in combination with two economic scenarios on the quality of ground and surface waters in the Neckar basin (South Germany) using the model integration approach of MOSDEW.

2 MATERIAL AND METHODS

Model Structure

In the Neckar basin, MOSDEW integrates a model cascade of nine sub-models that are “loose-coupled” through the MOSDEW interface (Fig. 2-1). A statistical model for downscaling of climate scenario outputs from GCM runs is at the head of the cascade (Bárdossy and Plate 1992, Stehlík and Bárdossy 2002). In parallel, the agro-economic sector model ACRE-Neckar (Henseler et al. 2005) is calculating the distribution of agricultural land use types and crops. ACRE-Neckar simulates changes of the European Common Agricultural Policy (CAP) according to the current reform "CAP reform 2003" at a regional scale (NUTS 3). The outputs of the two models feed into a large scale hydrological model HBV (Bergström 1995, Göttinger and Bárdossy 2005) which calculates river discharge and ground water recharge at daily resolution. The hydrological model is coupled with the MODFLOW ground water flow model to estimate ground water levels and base flow to the river (Harbaugh et al. 2000). On the other side, the

outputs of the climate downscaling model and the agro-economic sector model ACRE-Neckar supply data input to the Soil and Land Resources Information System SLISYS (Gaiser et al. 2005) which produces estimates on diffuse pollution from various land use types. The output is handed over to the water quality model MONERIS (Behrendt et al. 2000) which receives additionally estimates on emissions from point sources (waste water treatment, urban systems, industrial sites) from the Water Evaluation and Assessment Planning system (WEAP) (Yates et al. 2005). All emissions collected by MONERIS together with the daily discharge values provided by the hydrological model feed into the surface water quality model QUAL2K, which assesses parameters that characterize the surface water status like pH, temperature, electrical conductivity, suspended solids, nitrogen and phosphorus forms. Finally, output from QUAL2K together with the HBV discharges is collected by the CASIMIR, the mesoscale version of an ecohydraulic model to describe the biological status of surface water bodies (Eisner et al. 2005).

This paper focuses on the estimation of the effects of the new EU agricultural policy on the quality of ground and surface waters in the Neckar basin (South Germany) based on the linkage between the agricultural sector model ACRE-Neckar and the soil and land resources information system SLISYS (Fig. 2-2). The **A**gro-**e**Co**n**omic **p**Ro**d**uction model at **r**Egional level for the Neckar basin (ACRE-Neckar) represents the agricultural production in the Neckar river basin. The model optimises agricultural production by maximizing the farm income using the Positive Mathematical Programming (PMP) method. ACRE-Neckar is based on the 'regional farm approach' i.e. that agricultural

production is represented at regional level (NUTS 3) by one single farm. ACRE-Neckar was calibrated with statistical data for the year 1999 (Henseler et al. 2006). It calculates the production of food and fodder crops as well as livestock under the political scenario of the European Common Agricultural Policy reform 2003 (see below).

The land resources information system SLISYS-Neckar contains a spatially distributed model for the estimation of nitrate leaching and nutrient loads in surface runoff with high spatial ($< 1\text{km}^2$) and temporal (1 day) resolution. The estimation of diffuse pollutant loads from all land use types is based on simulations with the agroecosystem model EPIC (Erosion Productivity Impact Calculator, Williams 1995). The basin has been subdivided into hydrological response units (LUSAC: Land Use-Soil Association-Climate unit) which are quasi-homogenous with respect to land use, soil and climate. EPIC calculates the target variables for each LUSAC unit. The definition of the LUSAC units is based on the soil association map of the state of Baden-Württemberg (1:200.000) (LGRB 1995), geological information (LfU 2005), climate information from 90 meteorological stations as well as a land cover map derived from a LANDSAT TM interpretation of the year 2000 (LfU 2002). On the arable land sixteen crops are distinguished considering crop specific management with respect to operation scheduling, fertilization and tillage. Crop management including the intervals and rates of nitrogen application and fertilizer types was defined in accordance with the recommended guidelines (KTBL 2005). Information about the crop distribution on the arable land was obtained from the agricultural census of the Statistical Bureau for the state of Baden-Württemberg (StaLa 2000) (reference year 2000) or from the sector model ACRE-Neckar (CAP scenarios). The crop acreages

were distributed accordingly by a restricted random distribution within each district. The simulation results of SLISYS at the level of the LUSAC units were aggregated to the water body or basin scale according to the area coverage of each LUSAC.

Due to different spatial and temporal resolutions of the applied models in the model cascade, model interfaces were defined rigorously allowing a smooth data exchange between the models (Table 2-1).

The MONERIS (Modeling Nutrient Emissions in River Systems) model is a conceptual, quasi-static model developed to estimate annual emissions of nitrogen and phosphorus from various sources on a subcatchment scale and the resulting loads at the subcatchment outlet (Behrendt et al. 2000). The model estimates annual loads from seven different pathways, which derive from point (direct and WWTPs) and diffuse sources (atmosphere, agriculture and urban areas). MONERIS depends on statistical data (i.e. inhabitants, nutrient surplus, information on sewer systems), geographical data stored and analysed in a Geographical Information System (GIS) and within the model integration framework from output of the models SLISYS-Neckar and WEAP.

The surface water quality model QUAL2K assesses parameters that characterize the surface water status like pH, temperature, electrical conductivity, suspended solids, nitrogen and phosphorus forms. The conceptual representation of the Neckar river used in the QUAL2K model is that of a segment that is divided into a number of unequally spaced reaches or computational steps equivalent to finite difference elements. For each computational element, a hydrologic balance in terms of flow, a heat balance in terms of temperature, and a mass balance in terms of constituents concentration is formulated. The

model presently simulates the main stem of the Neckar river. In addition, multiple loadings and abstractions can be introduced for any reach. Tributaries are not modelled explicitly, but are represented as point sources

CAP Reform and Economic Growth Scenarios

In order to estimate future agricultural production under the CAP reform 2003 until 2013 it was necessary to implement selected agro-political measures of the CAP reform 2003 in the agro-economic sector model ACRE-Neckar.

The three key elements of the CAP reform 2003 are decoupling of payments, cross-compliance and modulation. The decoupling of premiums within the CAP reform 2003 is represented in ACRE-Neckar by payments which are linked to hectares of farm area, differentiated into grassland, arable land and fallow land. Additional to land related payments a so called "top-up" per hectare arable land and grassland is paid in the districts. These payments are calculated from the reference premium amount of animal products, which is based on the average livestock number in the years 2000 to 2002. It is assumed that both, the farm area related payments and the "top-up" will change with time until 2013 according to Table 2-2. In Table 2-3 the coupled premiums in the reference year according to Agenda 2000 are compared with the decoupled premiums which are received according to the CAP reform 2003. It becomes evident that due to the CAP reform 2003 premiums for crops remain at the same level or decrease while premiums for grassland increase significantly.

From the catalogue of Cross-Compliance regulations (BMVEL 2005) four measures were selected for the Neckar basin to be implemented for scenario calculations within ACRE-Neckar. Fertilizer applications are based on the Fertilizing Regulation of the "EU Nitrates Directive" (EG Nitratrichtlinie), which is a measure of the "statutory management requirements" prescribed by Cross-Compliance. The regulation of keeping farm area in "good agricultural and environmental condition" is represented by a restriction for avoiding soil erosion. This restriction ensures that 40 % of arable land is covered with cover crops in winter time. Also, fallow land has to be covered. The regulation for "maintenance of grassland" is represented by a restriction that allows only to convert 10 % of the grassland area in the reference year 2000 into arable land.

Modulation is not taken into account in the scenario calculations because presently the exact rate of the reduction of the payments cannot be estimated.

Besides the EU agricultural policy, rapid growth of settlements and industrial areas is observed in the Neckar basin causing severe surface sealing. Therefore, the influence of economic growth, demographic changes and expansion of settlement area has been defined as additional scenario settings for SLISYS-Neckar and QUAL2K. In the last two decades the daily increase of sealed surfaces was between 10.6 and 12.0 ha per day (StaLa 2004). The areas covered by settlements or industrial sites increased between 1981 and 2004 from 3941 to 4879 km² and the proportion compared to the total basin area increased from 11.0 to 13.6% (StaLa 2004). The major driver for this process is economic growth. Therefore, expected land use changes through the CAP reform 2003 derived from ACRE-Neckar were combined with two assumptions for future economic

growth. On one hand, an economic scenario was defined with an optimistic assumption of 2% increase of GDP per year (“optimistic” scenario) which is associated with a population growth that will increase the population density from 391 to 464 inhabitants per km² by the year 2030. On the other hand, it is assumed that with an annual growth rate of 1% of the GDP the population density will remain constant (“pessimistic” scenario). These assumptions for economic growth were translated into growth rates of the sealed area in the Neckar basin of 4.2 ha per day (“pessimistic”) and 5.5 ha per day (“optimistic”) and used as input variable in SLISYS-Neckar and QUAL2K.

Climate Scenarios

In the model integration framework four types of climate scenarios are available: (1) downscaled climate scenarios provided by the state agency for environmental protection (= "ENKE-scenarios") and (2) output of climate scenarios A2 and B2 produced by the global circulation model ECHAM (Version 4), downscaled by Bardossy and Yang (2005).

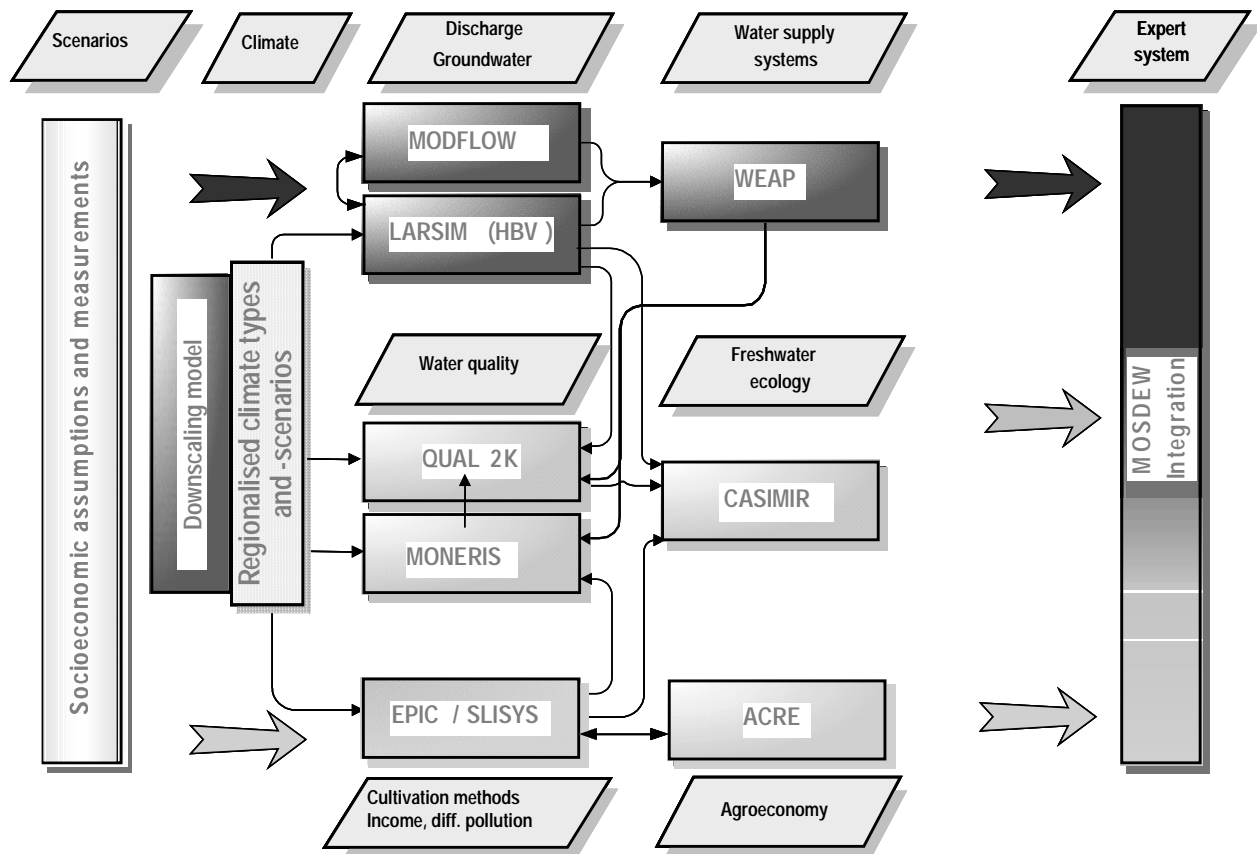


Figure 2-1: Integration structure of the submodels in the Neckar basin

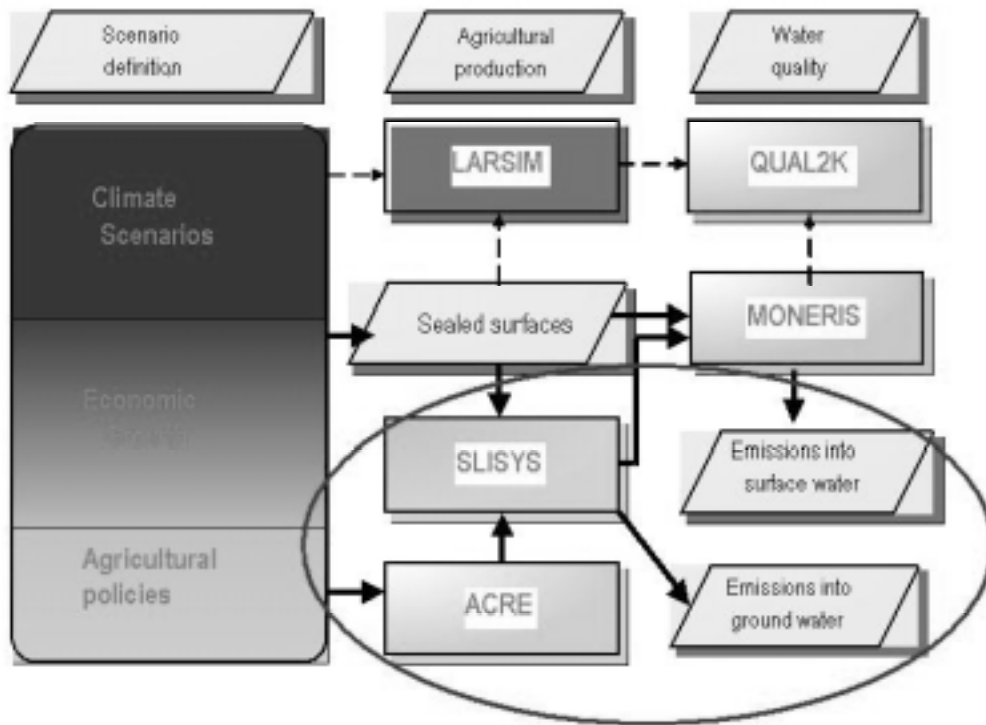


Figure 2-2: Workflow of scenario simulations for evaluating emissions into surface and ground water bodies

3 RESULTS AND DISCUSSION

Effects Of the CAP Reform 2003 On Land Use

Simulation of the Common Agricultural Policy (CAP) reform 2003 scenario results in changes of land use and of nitrogen input in the Neckar river basin.

The main driving forces for changes in agricultural land use and nitrogen input are changing political conditions, while modelling results of climate change scenarios in the next 30 years show a very small effect on agricultural yields. Therefore the changes in agricultural production due to climate changes until 2030 are marginal. However, the CAP reform affected agricultural production in the ACRE-Neckar simulations by reducing the area with maize production (mainly silage maize) which was replaced by an increase of clover grass and fallow land. The area for cereal production in the Neckar river basin and its administrative units (districts) do not change significantly in CAP because premiums for cereals in 2000 and after the CAP reform are equal (302 EUR/ha). The total reduction in arable land was estimated to be 6% until the year 2015 (Figure 3-1).

The mean agricultural income over the entire Neckar river basin, represented by the total gross margin, increases in CAP negligibly by 3 % (Figure 3-2). At district level changes in total gross margin vary. This depends on the share of grassland within a certain district. The larger the share of grassland on the utilised agricultural area the more the gross margin increases and vice versa. Deviations of TGM compared to the reference year 2000 were in the range from 96 % to 115 %. For most districts it can be concluded

that the CAP reform 2003 will lead to a negligible decrease or to a small increase of TGM (Henseler et al. 2006).

An important parameter for water quality is the input of nitrogen fertilizer (Figure 3-2). If the CAP reform is implemented, it is expected that the input of nitrogen decreases in nearly all districts due to the reduction of intensive fodder production (e.g. silage maize).

In summary, under the assumption of the CAP reform, crop production tends to change to less intensive production systems, which is associated with a reduction of nitrogen input.

Changes In Nitrate Leaching And Ground Water Quality

The data regarding land use changes calculated by ACRE-Neckar at regional level were delivered to SLISYS-Neckar, which distributed the data at a lower scale level.

The model was calibrated to produce accurate crop yields at field and district level (Abdel-Razek, 2006, Sereke et al. 2006). Calibration for nitrate leaching at the regional scale is impossible due to the lack of data. However, the simulated nitrate concentrations of the deep percolating water can be compared to the measured nitrate concentrations in the groundwater. The simulated values for the LUSACs in a water body were averaged to obtain an average leachate concentration, which corresponds to the concentration of the draining water when it leaves the root zone. The leachate concentrations were related to the mean nitrate concentrations of all ground water monitoring points in each water body (LfU 2003). The mean simulated leachate concentrations are positively correlated with mean measured nitrate concentrations of the forty-two water bodies defined in the basin,

which proves that the calculated nitrate loads are a good approximation for the nitrate loads in the ground water aquifers at the basin level (Figure 3-3). The concentrations in the leachate are generally higher than those in the groundwater. The difference is attributed to the process of denitrification in the saturated zone.

Figure 3-4 indicates a close relationship between the mean nitrate concentration in the leachate of the water bodies and the proportion of arable land within the water bodies. The distance of points from the regression line helps to identify water bodies with relatively high nitrate concentrations compared to other water bodies with similar proportions of arable land. These points are areas where specific measures to reduce nitrate concentration may be most efficient. Thus, the results may help to identify hot spots of nitrate leaching with highest priority for action.

SLISYS simulations of nitrate leaching over a period of thirty years (2001 to 2030) show a considerable inter-annual variability of the nitrate leaching over the basin from 15600 to 47900 Mg a⁻¹ of nitrate (Figure 3-5). This temporal fluctuation is attributed to the temporal variability of the amount and intensity of precipitation within individual years. Under the expected changes in land use through the CAP reform 2003, the nitrate loads seem to decrease compared to the land use in the year 2000. The decrease is also variable between years and ranges from 713 to 4768 tons per year. The mean annual decrease of nitrate loads amounts to 9 % compared to the land use in the year 2000 regardless of the evolution of other socio-economic indicators like population growth, economic development and urbanization (“optimistic” and “pessimistic” economic scenario in Figure 3-6). The increased settlement area in the optimistic and pessimistic scenarios had

no effect on nitrate leaching. A sensitivity analysis shows that the complete conversion of cropland to grass fallow has the potential to decrease the nitrate leaching by as much as 63% (Figure 3-6).

Figure 3-7 shows the output of climate scenario calculations with SLISYS-Neckar using the output of the global circulation model ECHAM4 with its effects on nitrate leaching at the basin scale. In spite of the slightly increased groundwater recharge in the ECHAM A2 scenario as calculated by SLISYS and the hydrological model LARSIM (data not shown), the nitrate leaching into the groundwater seems to decrease. However, the trend is not statistically significant on the observed time scale.

3.3. Changes in surface water quality

The validation of the model cascade with respect to the effects of land use changes on surface water quality included the comparison of simulated and measured values for river discharges and total nitrogen loads. Ten tributaries of the Neckar river with regular measurements of discharge (daily) and water quality (monthly) at the junction with the Neckar river were selected. In addition, observations at the outflow of the Neckar river into the Rhine were included. In general, the simulated discharge corresponded well with the measured discharges, except for the three tributaries Enz, Jagst and Kocher (data not shown). Large parts of these three tributaries are located in limestone areas with losses of water from the river bottom into the karst aquifers. Since the model cascade is not able to take into account these losses in detail, the discharge was slightly overestimated. As the discharges were slightly overestimated in the Enz, Jagst and Kocher catchments, the total discharge of N was also overestimated in these catchment areas. However, for the Kocher

and Jagst catchment, the differences were in the range of the standard deviations of the measurements. Overestimations were also observed in catchments smaller than 500 km² (Aich, Lauter and Elsenz). The overestimations for the catchments were in the range of 3.5 % (Kocher) to 143 % (Lauter) (Figure 3-8). In the Upper Enz and the Rems catchment the N load was underestimated by 14 and 17 % respectively. In general, the differences between the water bodies were well described by the simulation results, with the highest loads in the Enz and Kocher catchments and the smallest loads in the Aich, Lauter and Elsenz catchment. For the Neckar river, the difference between measured and simulated loads was 4.5 % and within the standard deviation of the measurements.

The impacts of land use changes combined with climate scenarios had been evaluated by the surface water quality model QUAL2K and the ecohydraulic model MesoCASIMIR using input from the models SLISYS and MONERIS. The model output of QUAL2K shows that the CAP reform 2003 has an impact on nitrogen concentration in the Neckar river in the range of -15 % and -18 %, if the economic growth rate is low (pessimistic scenario) and the population density remains more or less constant (Figure 3-9). This is explained by the lower nitrate input from groundwater, reduced volumes of surface run-off and lower concentrations of N in the surface run-off due to the increase of fallow land and the substitution of silage maize by clover grass. Clover grass and grass fallow are perennial crops which cover the soil for long periods and require less nitrogen fertilizer as compared to silage maize. However, when the economic growth rate is high and in consequence population density will increase, then the additional amount of N from waste water of the urban and industrial sites may offset the beneficial impact of the CAP

reform. This implies that additional population growth requires either a reduction in the volume of waste waters or in the N concentrations therein, which means a higher efficiency of the treatment plants or separation of waste water into grey and black water and individual treatment techniques for both water categories.

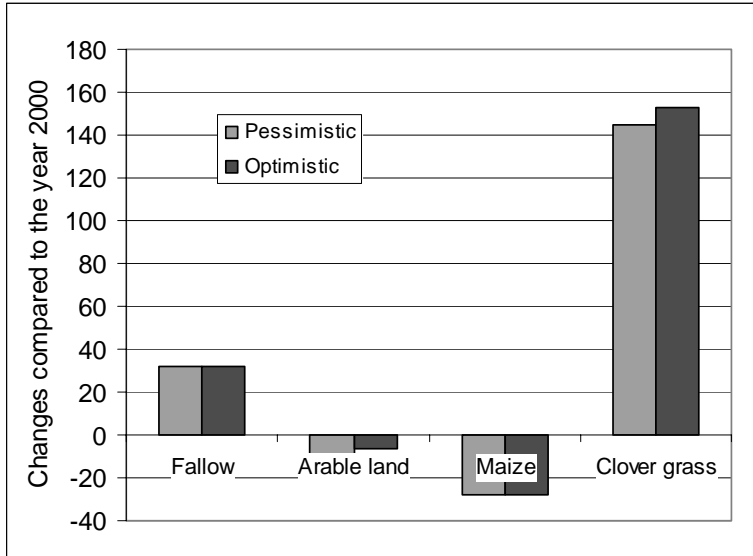


Figure 3-1: Expected changes in 2015 for fallow and arable land as well as maize and clover grass within the arable land due to the implementation of the CAP reform

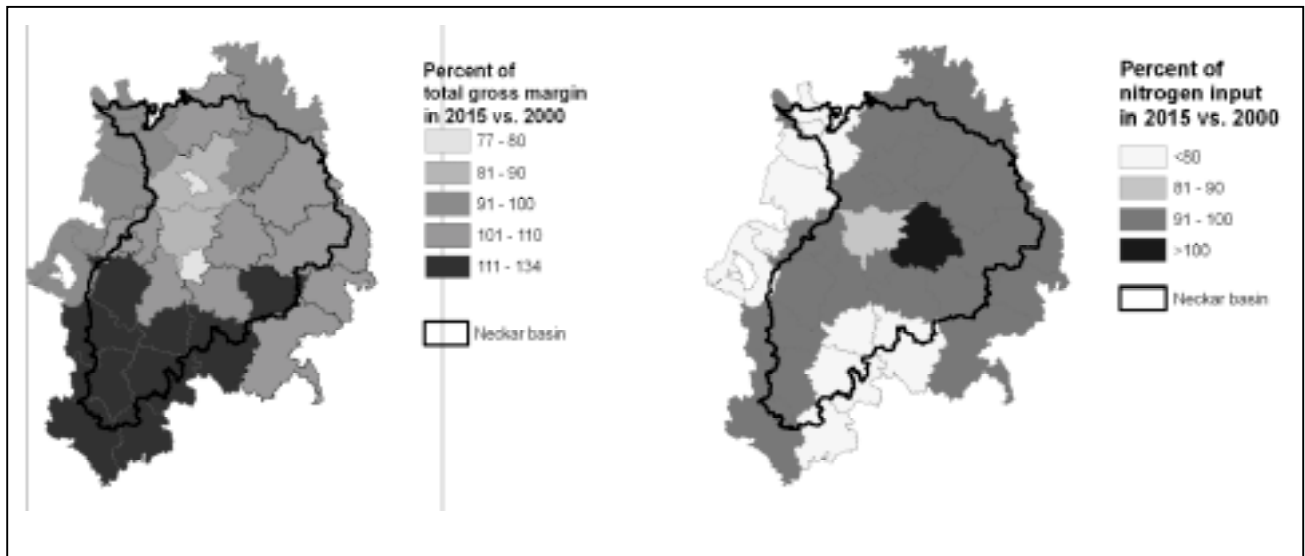


Figure 3-2: Estimated change in total gross margin and nitrogen input by the CAP reform in the year 2015 compared to 2000 in the administrative units within the Neckar basin

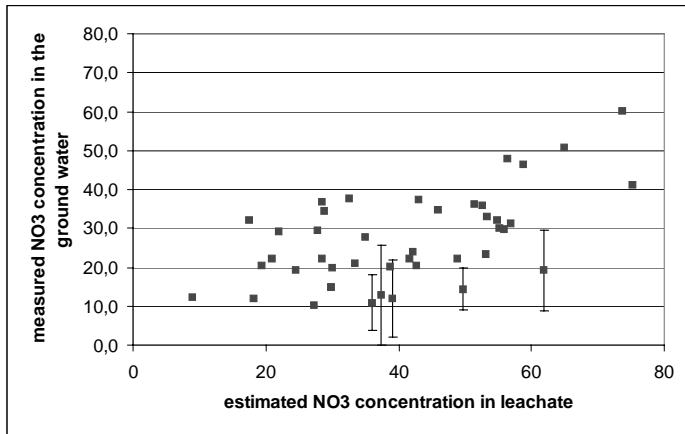


Figure 3-3: Relationship between mean simulated nitrate concentrations in the leachate and mean measured nitrate concentrations (in mg l^{-1}) for all water bodies in the Neckar basin

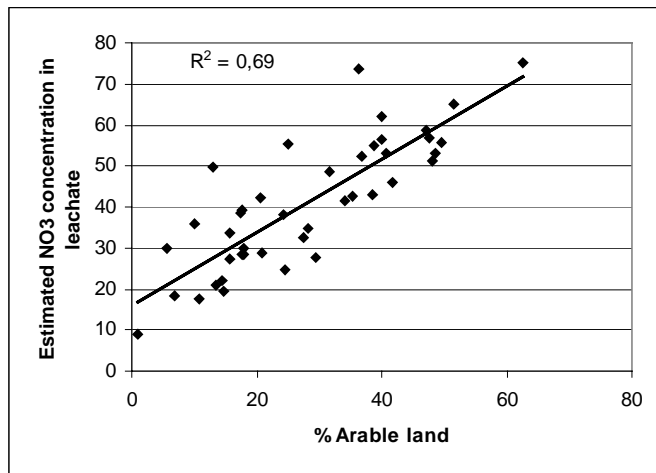


Figure 3-4. Estimated nitrate concentration over a ten years period in the leachate below the root zone in relation to the proportion of arable land within 42 water bodies

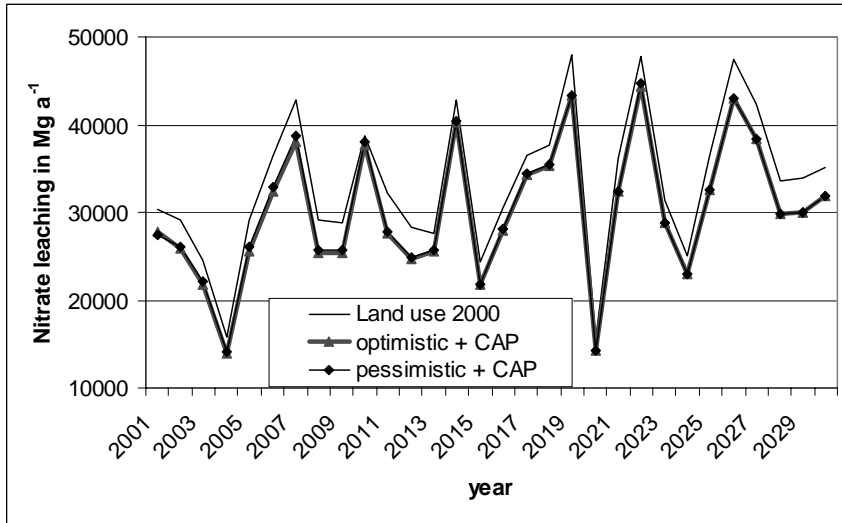


Figure 3-5: Changes in annual nitrate leaching over the entire Neckar basin due to the reform of the Common Agricultural Policy (CAP) combined with optimistic and pessimistic scenarios of economic development

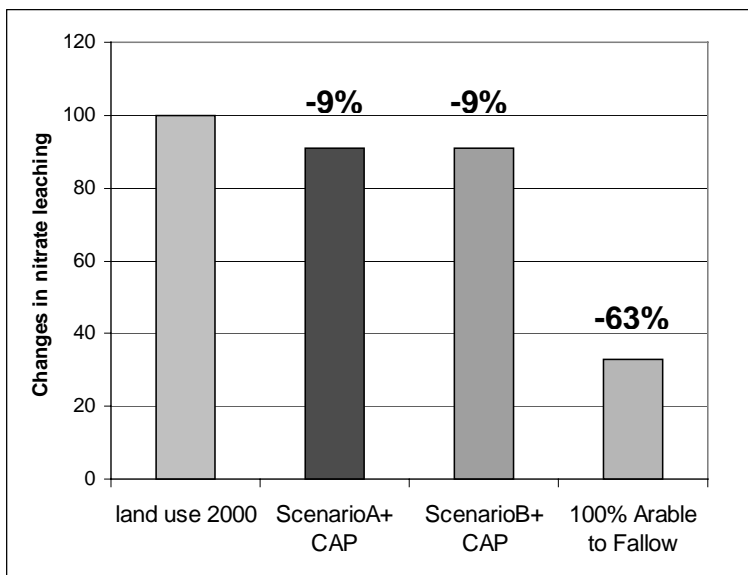


Figure 3-6: Changes in annual nitrate leaching over the entire basin due to land use changes (period 2005-2030 compared to simulations with historical time series 1980-2003)

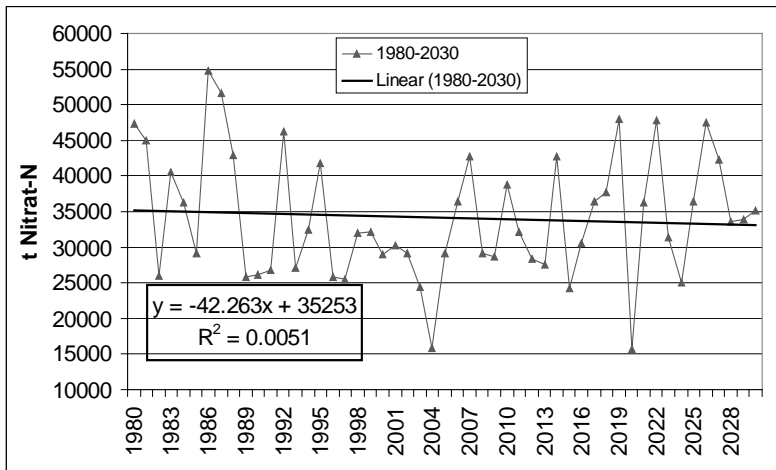


Figure 3-7: Nitrate loads to the ground water over the Neckar basin in the past and in the climate scenario A2 (downscaled ECHAM4 output for SRES scenario A2) with land use as in the year 2000

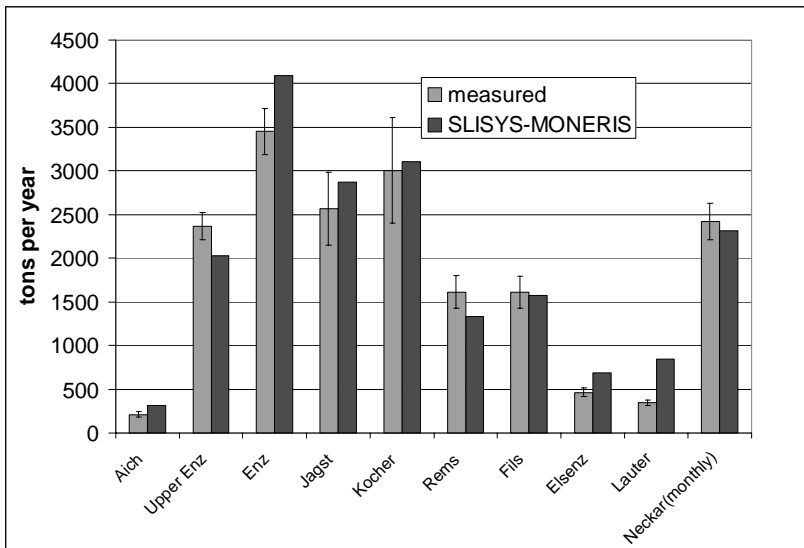


Figure 3-8. Comparison of estimated and measured annual nitrogen loads into the Neckar river and some selected tributaries

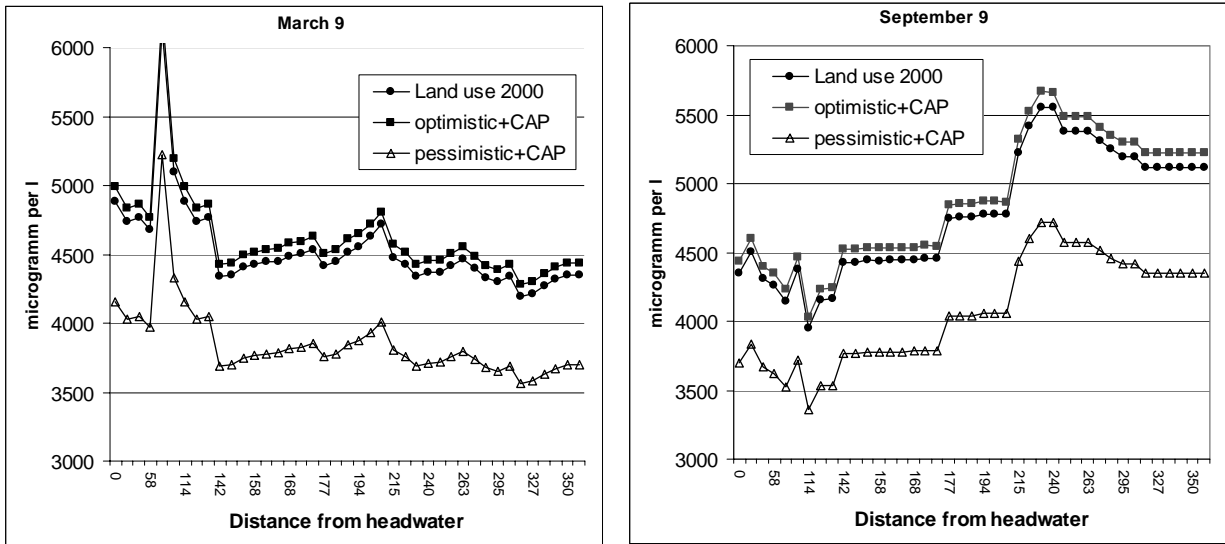


Figure 3-9: Changes of total N concentrations ($\mu\text{g l}^{-1}$) along the Neckar river due to changes in land use and economic growth scenarios (optimistic/pessimistic). Accepted threshold for total nitrogen concentration in rivers is $6000 \mu\text{g N l}^{-1}$

4 CONCLUSIONS

The MOSDEW model integration approach links agro-economic, crop growth and water quality models into one common framework for the evaluation of potential impacts of land use and climate change on water resources. The model cascade ACRE-SLISYS-MONERIS-QUAL2K was validated in the Neckar basin against historic data on land use, crop yields, river discharge and nitrogen concentrations in ground and surface waters. Then, scenario simulations were run over a period of 30 years with assumptions on economic and demographic growth combined with measures proposed by the reform of the Common Agricultural Policy in 2003. The simulation results suggest a trend in the agricultural sector towards more extensive farming with less nitrogen input and improved soil cover due to the CAP reform. This trend is likely to translate into a mean decrease in nitrate leaching over the entire basin by about 9% regardless of other socio-economic assumptions. In addition, in the case of a low economic growth, the measures of the CAP reform 2003 may cause a reduction of the total nitrogen concentration in the Neckar river by 14 to 18%. However, if the economic growth rate is high and consequently population density increases, then the positive effect of less intensive farming on nitrogen loads in the Neckar river will be offset by the higher nitrogen inputs from waste water inflows.

Since about three years, an increase in energy crops has been observed in the Neckar basin. In future simulation runs, the effect of an increasing share of energy crops within the arable land and the conversion of fallow land into land for energy crop production should be evaluated in order to quantify the impact on water quality in the Neckar basin. The results demonstrate that the linkage of economic and biophysical models has the potential to improve the qualitative assessment of the effect of policy measures on the environment and to come to a more quantitative evaluation of policy effects on the sustainable use of natural resources.

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Table 2-1: Example of model interface definitions between Climate downscaling model, SLISYS, ACRE and MONERIS

Content / Interface	out-entity of interest	in-entity of interest	temporal resolution	spatial resolution	unit	geometry	from model	to model
Precipitation, Max. / Min Temperature	climate station	climate station	daily	station	mm/°C	Point	Downscaling model	SLISYS
Crop distribution	district	district	annual	district	%	Polygon	ACRE	SLISYS
Crop yield	LUSAC	district	annual	district	Mg/ha	Polygon	SLISYS	ACRE
Nitrate leaching	LUSAC	water body	annual	water body	Mg/ sub- basin	Polygon	SLISYS	MONERIS
Total N load from waste water discharge	sub-basin	water body	annual	annual	m ³ / water body	Polygon	WEAP	MONERIS
Total N load from water bodies	outflow of water body	outflow of water body	daily	outflow of water body	Mg l ⁻¹	Point	MONERIS	QUAL2K

Table2-2: Assumed development of premiums according to CAP reform (BMVEL 2005)

	2000	2005	2010	2015^a
		EUR / ha		
Grassland	Coupled premiums according to Agenda 2000	56 + (top-up * 100%)	83.3 + (top-up * 90%)	302 + (top-up * 0%)
Arable land	and payments received from agro-environmental program	317 + (top-up * 100%)	315.5 + (top-up * 90%)	302+ (top-up * 0%)
Fallow land		317	315.5	302

^a The premiums in the year 2015 were modelled in ACRE-Neckar according to CAP reform scenario year 2013.

Table2-3: Premiums for the most relevant products in the 2000 and 2015

	Coupled Premiums in reference year according to Agenda 2000	Premiums according to CAP reform in scenario year 2015 for arable land and grassland	Percentage deviation (Premiums in 2015 of premiums in reference situation)
	EUR/ha		%
Cereals	302	302	0
Grain maize	427	302	71
Winter rape	499	302	61
Intensive grassland	30	302	1007
Extensive grassland	50	302	604
Permanent crops	0	0	0