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RIVERTWIN

A regional model for integrated water management in twinned river basins

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Dissemination level

PU	Public	X
PP	Restricted to other programme participants (including Commission Services)	
RE	Restricted to group specified by the consortium (including Commission Services)	
CO	Confidential, only for members of the consortium (including Commission Services)	

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1 Summary

The aim of the RIVERTWIN research programme is to develop tools for an integrated water management that can be applied for administrative purposes, especially within the context of the EU-Water Frame Directive (WFD) [2000].

This deliverable contributes to the integrated regional model MOSDEW (Model for Sustainable Development of Water Resources). It provides the interface of a decision support system as a GIS-based model framework of loose-coupled sub-models' results. The integration concept, set up here for the Neckar River basin serves at the same time as pioneer model concept for the subsequent river basins of the Ouémé (Benin) and the Chirchik (Uzbekistan).

Essential technical elements of the MOSDEW-interface are used in all three water basins: The meta-database as central information hub for primary data and model results, the CMS (Content management system) and the general hard- and software settings for the web query interface of MOSDEW.

The modelling frame, embracing the range and density of results is probably set much wider and more intensive for the Neckar River basin. This corresponds also to the good data availability. However, due to delays of delivery of some official basic data for some participants there is a significant delay of delivery of sub-model's results. The integration is concerned by that delay as it is at the „end of the pipe“. Thus, especially the final look and data output at the web interface is actually beyond expectations. Independent from missing content that will be completed during the next two months, concepts and architecture of the MOSDEW-interface Neckar is ready and described within this deliverable.

The special models' portfolio of Rivertwin in the Neckar basin shows significant strengths of model results for repercussions of land use changes (e.g. by EU agriculture policy) on diffuse pollution and their economic and ecological implication (taking fishes as indicators).

First coarse analysis showed relative hydrological robustness of systems with respect to the climate change (on basis of the 30 years scenarios), but relatively high sensitivity to economic and ecological impacts by EU policy or other land use changes.

The development of MOSDEW is constantly accompanied by meetings with the regional stakeholders and authorities responsible for political and technical implementation of the EU-WFD (Water Frame Directive). Final discussion with respect of possible implementation of MOSDEW-interface will be during 2006.

Within the first two years all available sub-models' results could be transferred into the integrated database. First results are represented and queries can be done via internet.

2 Introduction

Integrated water resources management is a very complex task that involves issues of disciplines with a great variety of professional languages, approaches and scales. For each discipline more or less mature models are available but tackle only relatively narrow fields of management requests. Additionally to these (important) single aspects, integrated resources management has to meet soft defined objectives like sustainability that include political or ethical values and it has to answer questions that may emerge by rapid changing and uncertain futures like 'global climate change' or fundamental socioeconomic changes. In that sense the integrated regional model MOSDEW (Model for Sustainable Development of Water Resources) is not only a sum of results of single (sub-)models but creates a new "integrated" quality.

RIVERTWIN is not about theoretical issues of integration or sustainability, the focus of RIVERTWIN is explicitly on application for very specific situations in specific water basins. According to the original layout of the project the idea to establish a general „integrated supermodel“ was not considered as an impossible option. But getting involved in the discussion of details this idea turned to be not the appropriate approach leading to the projects objectives. Constantly adapted and improved approaches for specific tasks and solutions lead to the model integration presented here as a result of two years optimising the best decision support system according to

- 1.) the availability of data,
- 2.) the modelling field and structure (characteristics of sub-models involved) and to
- 3.) the required administrative demands.

Within this triangle of integration determinants, an obligatory modelling framework for the RIVERTWIN consortium has been developed and MOSDEW grew into a configuration of a submodels' setting, their (internal) data interfaces and an (external) web-based interface for an integrated decision support system.

The well structured and adapted internal MOSDEW-data interface organises the communication between the modellers and technical data of their sub-models ("integrating by interfacing"). The external interface as an application addresses expert users/decision makers of the administrative context.

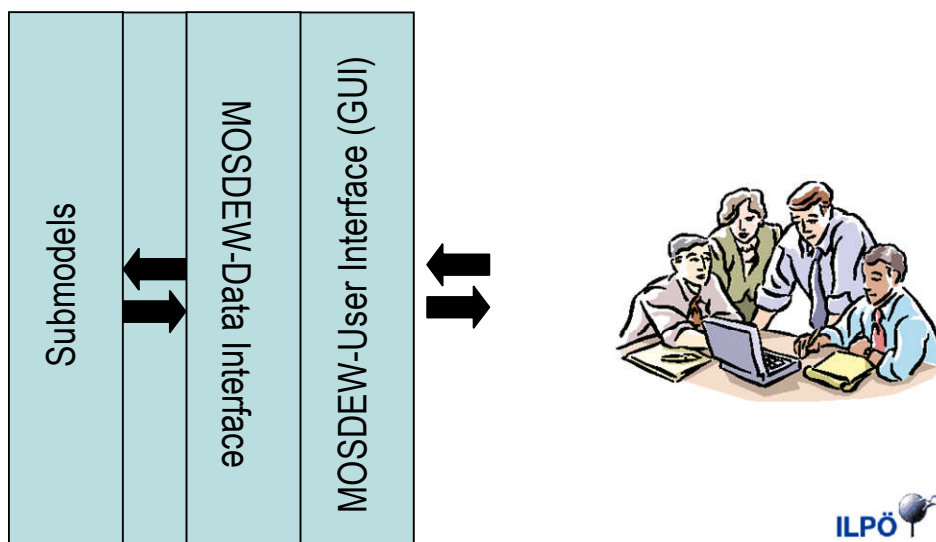


Fig.1: MOSDEW, a regional model with internal and external interfaces (data and user integration)

3 Integration concept

3.1 Aims

An integrated water resources management has to tackle four main task areas:

- 1.) hydrological functions
- 2.) Ecological functions and demands
- 3.) Water use (for withdrawal and recharge)
- 4.) Water use (water as carrier structure)

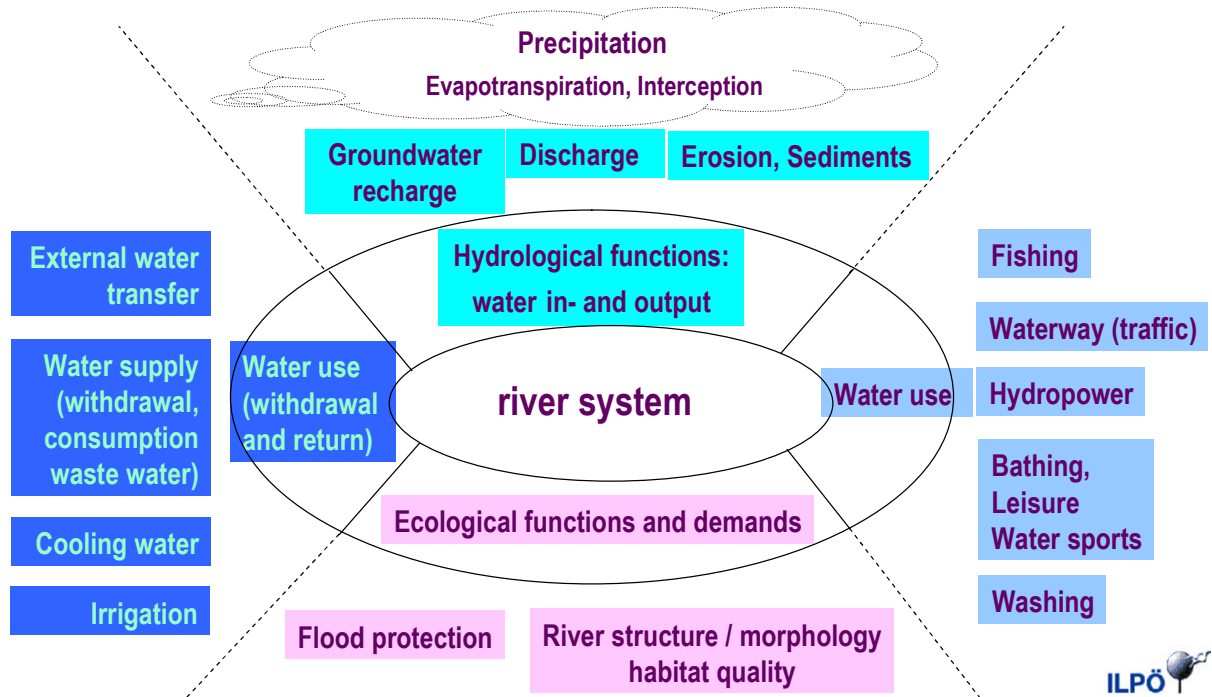


Fig.2: Integrated water basin management tasks and river basin functions

Figure 2 shows essential functions, an integrated river basin has to consider. The Rivertwin modelling framework covers strongly the hydrological functions, the water use (withdrawal and return) and ecological functions in the sense of morphological habitat quality. Additionally to the figure agro-economic aspects are covered while other economic aspects like water prices, fishing or tourist use are not simulated.

Flood protection could be an interesting issue but needs a very high temporal resolution beyond Rivertwin scales.

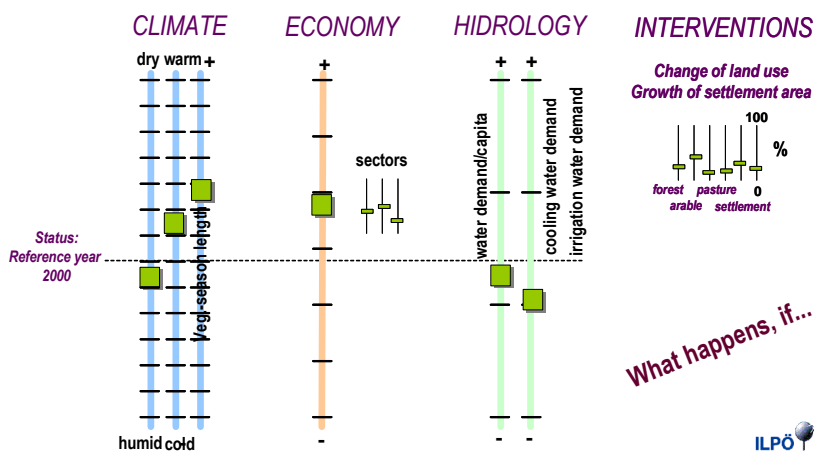


Fig.3: Control panel for planning simulations

Correlating land and water use management with site parameters the model aims to show the causal link between global climate and socioeconomic change, site potential, agricultural productivity, economic benefits and ecological, hydrological and economic

impacts.

The idea for MOSDEW as a decision support system is to have an instrument which enables decision makers to change most important parameters for answers to the variety of questions of the type- „what happens if...?“ Thus, MOSDEW can be a vital model for evaluating management strategies as required by the EU-WFD implementation of management plans. The range of results was given by the modelling frame according to defined scenario baseline conditions and climate change caused by „global climate change“ (s. Fig. 9). As models are not coupled dynamically in Rivertwin, only defined cases of the simulation range really can be assured (with a certain uncertainty). Uncertainty in modelling however is still high and for planning purposes ordinal information is often sufficient and truer than pseudo-cardinal information.

3.2 Approach

The Rivertwin integration concept is a GIS (Geographical Information System) based loose coupling strategy. The modelling framework couples 11 single models (sub-models). Most of these models are well recognised by science and administration since a long time. Even as they are considered as fully developed stand-alone models, they only contribute partial results for the integrated model.

That means, that all sub-models principally run their simulations autonomously, but defined conventions assure standardised inputs and outputs (spatial and temporal scales, interfaces and formats) throughout the whole modelling chain and direct them towards integrated output values. Another important element for that process is the common modelling frame. As models are not dynamically coupled, a defined framework of obligatory results (simulation cases) has to be set up. The potential output range has to meet an essential request coming from planning demands.

For the ancestor of MOSDEW, called MOSDEL (Printz, Lang, 2002), own modules had been implemented to fill gaps of missing data and sub-models' features within that research programme. It became clear during the cooperation process in Rivertwin, that no additional algorithms or modules were necessary to establish the intended decision support system. Results of the sub-models already were sufficient to reach a deep understanding for the system processes significant to the WFD needs. Moreover, a complex “meta-model” could even reduce the acceptance for stakeholders or possible applicants as it loses transparency or traceability.

Spatial integration

Integration in Rivertwin bases on a geographic information system (GIS) that means, all model results are challenged to meet minimum requirements to spatial scales and relationships. An important integration task was to identify gaps and deficits and finally to harmonise them either by sub-models' adaptations or by GIS algorithms e.g. by (dis-)aggregation.

Data and sub-model results are stored into defined information layers - common obligatory geometries or 'entities', such as shown in the figure 4. These geometries correspond to dimensions used in the EU-WFD such as water bodies, river segments etc.

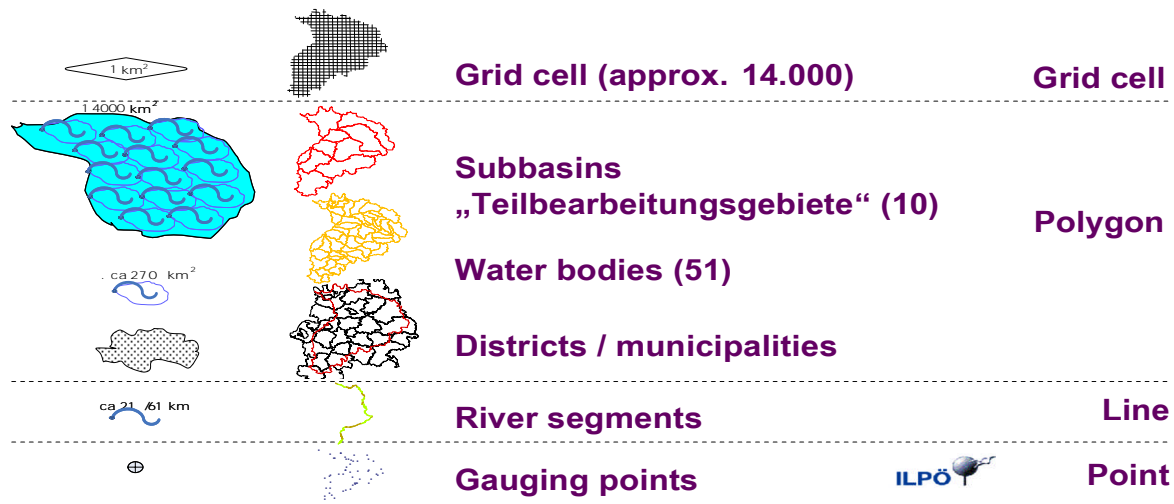


Figure 4: Rivertwin integration geometries / entities

The Neckar River basin embraces a total area of ~14,000km². 51 Water bodies of the Neckar River basin have a mean size of about 270 km², while a mean river segment of the main river stem Neckar has a length of 21km. The subbasins (10 “Teilbearbeitungsgebiete”) are nothing else than aggregations of the water bodies. Some models are calculating on basis of a grid. The respective resolution has been defined as 1km². Grid cells can easily be correlated to each water body.

The only data that was not possible to recalculate on water bodies/sub-basins was data for/from the agro-economic model as statistical input is only available on county level.

After homogenising information layers of data input and sub-models output results, these layers can be queried according defined criteria, such as sustainability indicators and thresholds. Thus, natural site parameters (including global climate change) on one hand side can be combined with land use and water use management on the other side. Impacts, that might result by scenario estimations or by any valid management options then can be assessed in an integrated way according to hydrological, ecological and agro-economic sustainability criteria or even as a synopsis of sustainability (in case this makes sense). And finally - results can be localized within the river basin.

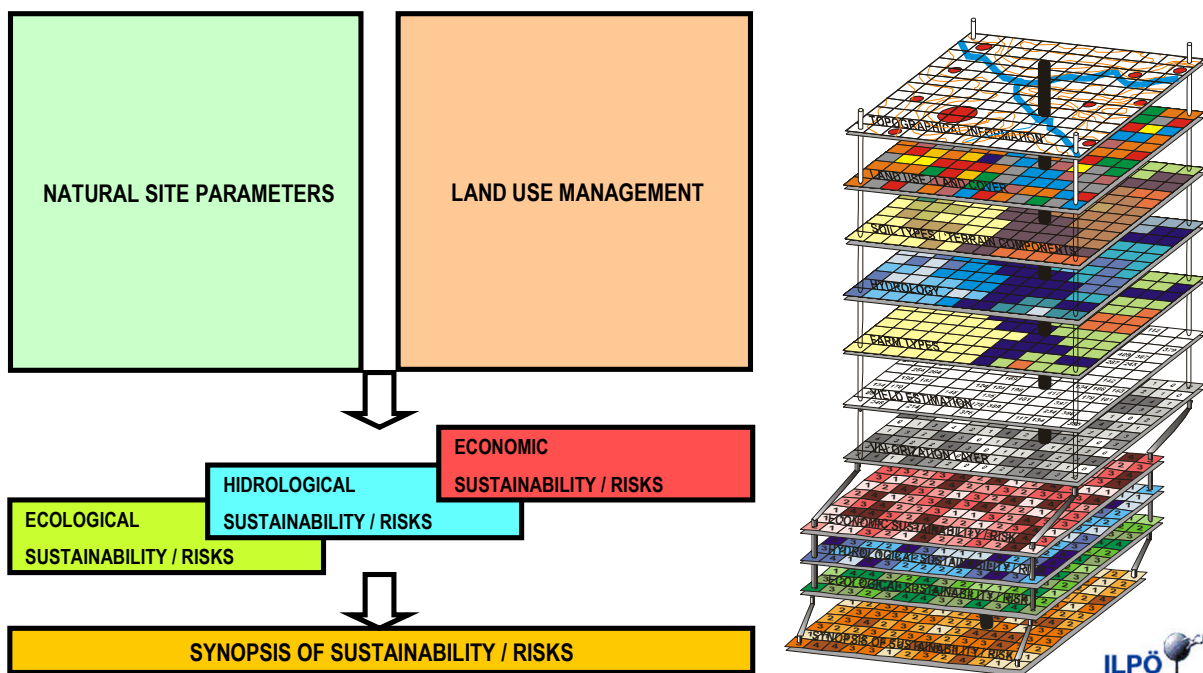


Fig. 5: Example of spatial integration of different working groups' results

Essential elements of MOSDEW as a decision support system is a data warehouse with a web based graphical user interface, while the data warehouse includes a solid spatial data base with basic (primary) data and strategic simulated/aggregated data as well as a set of valuation rules (s. fig. 6).

However, to feed the aggregated data base, a common idea of scenarios and characteristics of relevant strategic evaluations has to be developed in close cooperation with all sub-modellers and experts of stakeholders and authorities.

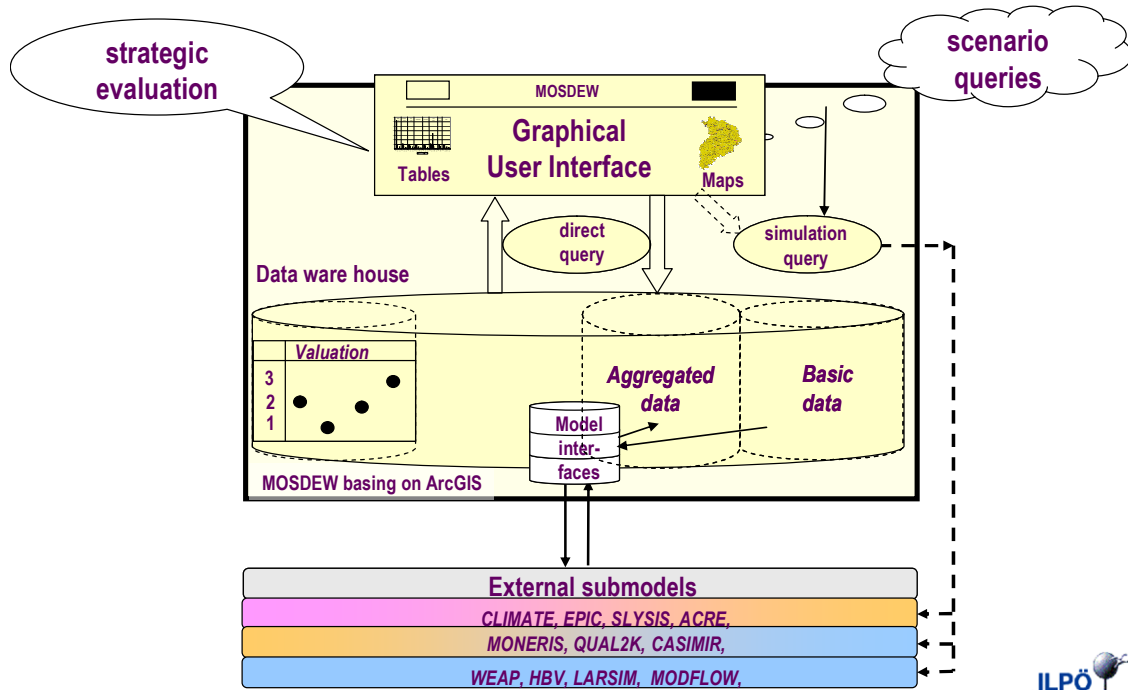


Fig. 6: Simulations steps and coupling

3.3 Modelling chain and definition of interfaces

In Rivertwin a total of 11 sub-models represent three main home domains: hydrology, ecology and (agro-)economy (s. fig. 7).

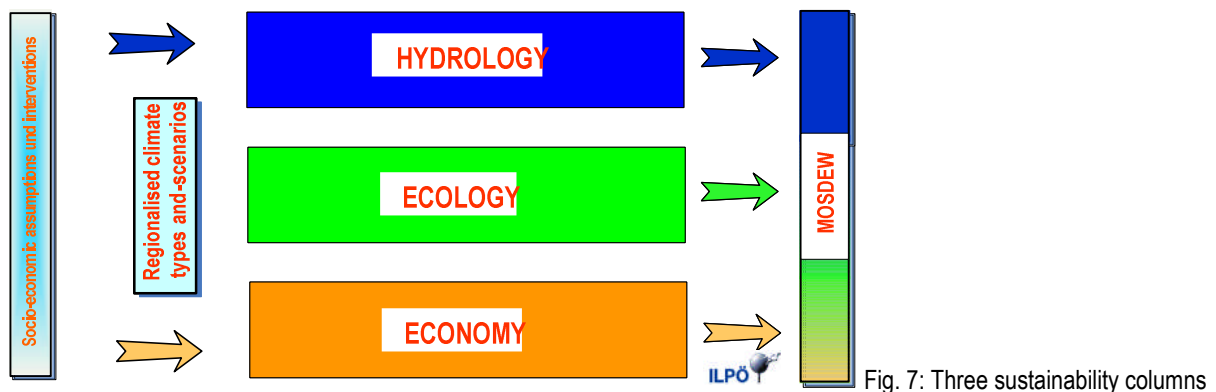


Fig. 7: Three sustainability columns

The second figure correlates the Rivertwin model family to the three model columns, and shows interrelationships between the models (fig. 8). Model interrelations are shown also more detailed at figures 13-15.

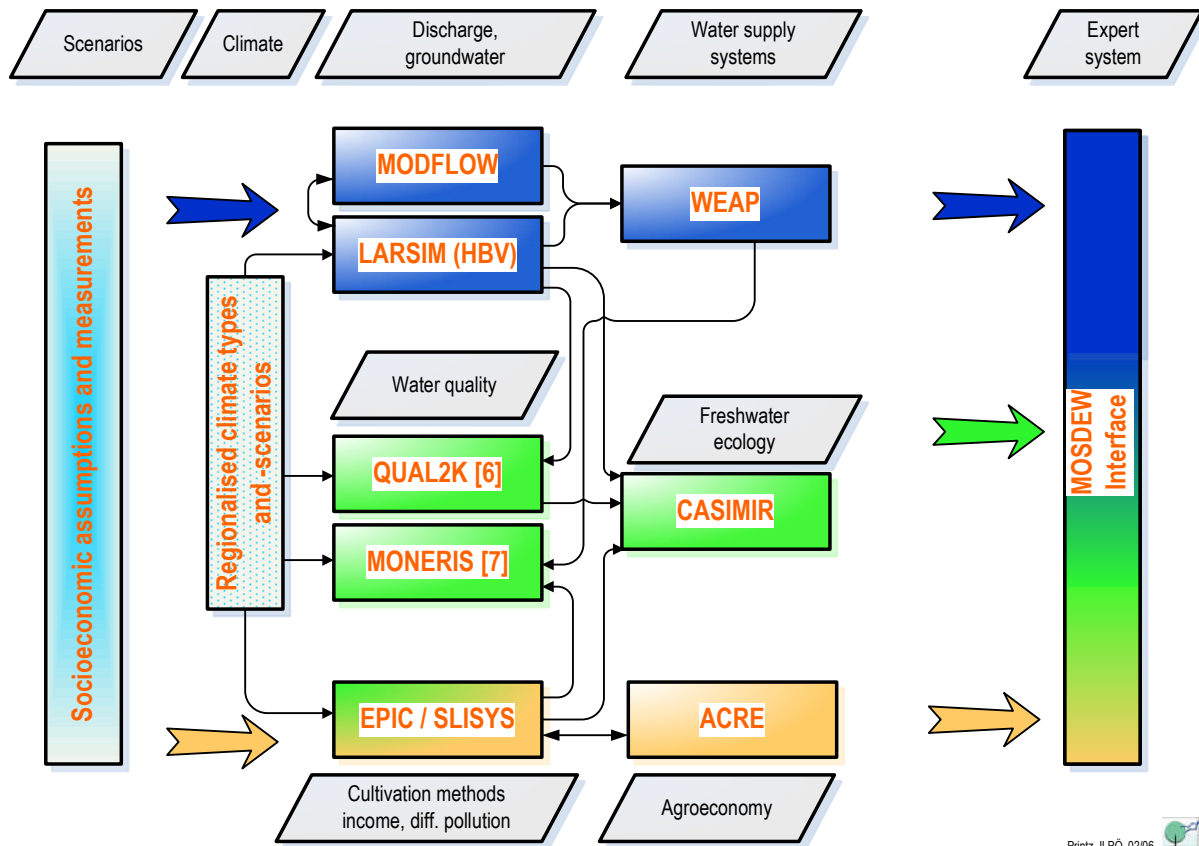


Fig. 8: Integrated coupling scheme Neckar River basin (simplified)

To organise the data exchange cascade during summer 2005 models had been synchronized as “pioneer”/first and a second modelling group in a chronological order. Climate regionalisation had to be ready at a very early beginning as it delivered basic data to all groups. The first group was built by LARSIM/HBV, MODFLOW, EPIC/SLISYS and WEAP. It is to consider, that even within this group are out-/input dependencies and thus temporal delays included. Generally, basic system conditions are first “sketched” by the hydrological and the “soil-land use” models before it is finally processed by the “ecological” models that depend much more from modelled input.

A series of four workshops has been initiated to define common interfaces as well as temporal and spatial scales. During all workshops a very active participation of the Neckar River basin working groups was noticed. As a major result, the interface tables could have been set up (s. annex). Details of data formats also have been made obligatory.

As a vital integration tool from the very beginning the platform for data exchange, the meta-database has been installed. It assures the use of the “official” version of primary data as well as for the models’ results including all necessary meta-information (ca. 30 description parameters).

As experienced from former projects, theoretically discussed and agreed interfaces often differ from real delivered results. That’s why we requested dummy model data already at the very beginning and pushed for results for the reference year (2000) at a very early stage. Thus, first ‘live’ exchange of data was initiated. Format adaptations were organised pragmatically according to the respective needs. E.g. it was noticed, that climate scenario years include only 360 days, while other models with daily data is calculating with 365. It was agreed to include 5 days with 0°C and without rainfall during the winter season for 365 days-models. Thus, format questions have been solved without further problems between the (mostly two) concerned data exchange partners.

Basic geometries (entities) like basic modelling grid, river basins etc. were provided by the integration group in ESRI^(TM) formats.

Modelling frame

Questions emerging by scenario queries and strategic evaluation lead to specific model simulation queries. These predefined queries (modelling frame) are simulated by all models and fed into the integrated database. Outputs are given in form of tables or maps and finally valuated concerning the degree of sustainability (hydrological, ecological and economic thresholds, s. annex).

As mentioned above, modelling exercise started with a reference year (2000) for testing the interfaces but also for calibration use. Four main levels for multiplying sub-models results have been additionally established:

- 1.) climate types and sequences (6 types plus 4 sequences with 30 years each)
- 2.) two socioeconomic scenarios (A1 and B2, referring to the IPCC global climate scenarios)
- 3.) interventions (four)
- 4.) intensities (s. scheme)

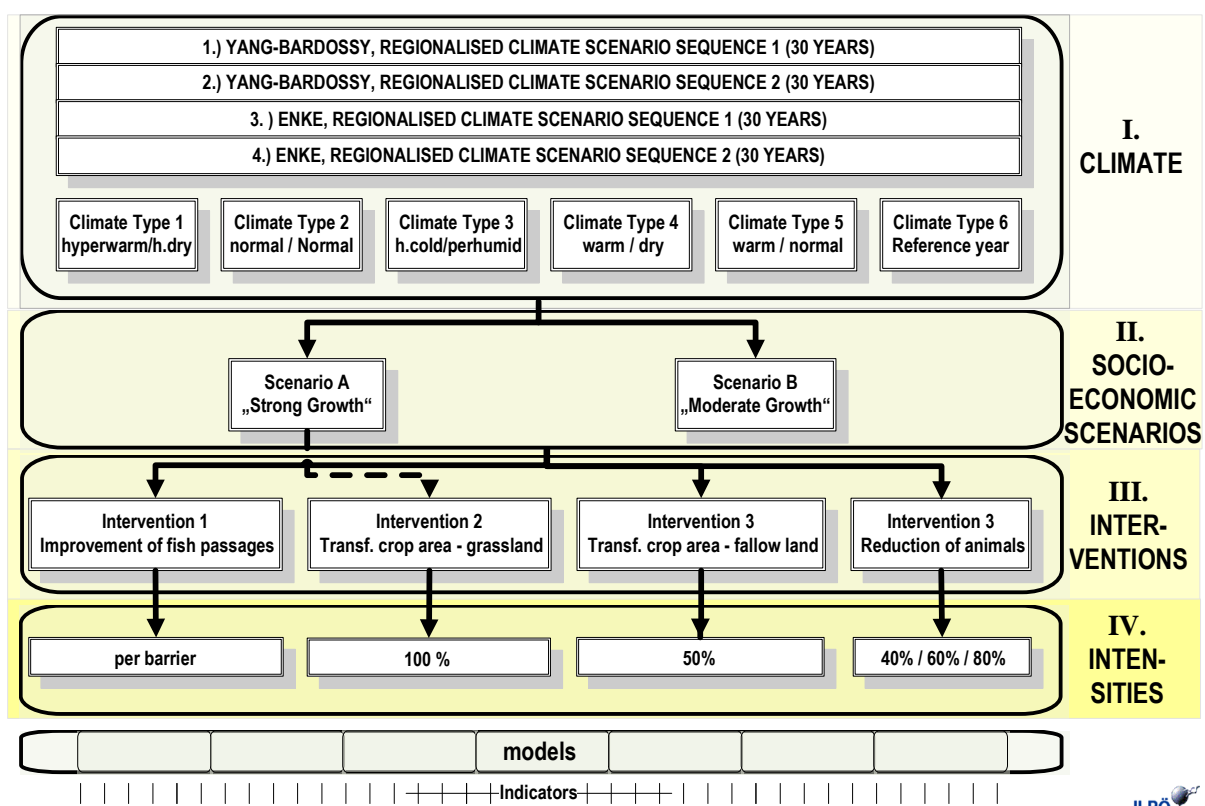


Fig. 9: Data result multiply layers

All possible combinations lead to a theoretical number of ~ 800 combinations/results for each model that should explore in an exemplary but exhausting way the range of possible future effects of climate and management changes. Of course, if sensitivity to certain input variables was low, simulation runs had been reduced for some cases/models (e.g. climate variations of the climate sequences for the agro-economic model ACRE).

The modelling frame has been adjusted in close cooperation with the stakeholders, especially with the LUBW Karlsruhe. Relatively “hard” data like climate scenarios there was still available (e.g. both ENKE climate sequences were totally inherited by the LUBW-agency to enable the comparison of their own modelling results) as LUBW initiated several studies on regional impacts of global climate change. In contrast the definition of socioeconomic frame conditions was mainly done as a pioneer work by the interdisciplinary RIVERTWIN working group (where ILPOE took a key role).

1.) *Climate types and sequences:*

Climate types had been selected by filtering historical data according to irregular (min/max) precipitation and temperature as well as typical mean values (Yang-Bardossy, UStutt-IWS). The filtered irregular years have been additionally compared with significant yield deviations and historical fish crisis situations. As global climate change models tend to calculate with relative mean values it was necessary to cover also extreme situations (e.g. as the hot and dry year 2003), especially as global climate change simulations give clear significance to the aggravation of extremities.

The four 30-years climate sequences all base on ECHAM 4 scenarios (2001-2030). ECHAM4 scenarios in general can be considered as relatively moderate as algorithms try to avoid extremities in favour to show long term trends of 100 years range. Thus, only in final periods of original 100 years sequences severe changes in global models are registered. The regionalised Yang-Bardossy (UStutt-IWS) sequences consider global A1 and B2 scenarios for 2001-2030 (synchronized with the time horizon of our socioeconomic scenarios), years with relatively moderate climate change potential.

Additionally two "ENKE" climate scenarios regionalised according a specific approach proposed by Enke (s. <http://ww.kliwa.de>) have been added. We included them after discussions with authorities and stakeholders: "ENKE-sequences" are actually regarded and discussed in Baden-Württemberg as 'official' regionalisation of global climate scenarios. In order of LUBW, Bureau Ludwig, Karlsruhe selected extreme sequences concerning discharge irregularities (Gerlinger, 2005). In compliance with LUBW, we selected the most significant extreme sequences (one min.= 'dry'/one max.= 'wet'). ENKE simulations start officially with 2021 climate data (considering from then three decades in total). We anticipated 20 years (2021 will be input year for 2001 and so on). This 20 years anticipation is another try to get a more extreme diversification in climate.

2.) *Socioeconomic scenarios:*

Two different socioeconomic baseline scenarios have been elaborated - a more (A1) and a less (B2) globalised scenario. Both originate in the IPCC study for global climate change and have thus the same background as the regionalised climate sequences A1 and B2. The global storylines for these two scenarios have also been regionalised for the Neckar basin-respective key variables - especially with concern of water use have been defined.

A special concern for the integration group was the GIS-based simulation of a changed land use. Basing on historical settlement growth per municipality, two growth rate options (moderate and strong) for the scenarios A and B have been calculated. Settlement area was designated according to neighbourhood criteria near to existing settlements replacing farm area. Output values were created for each 5 years with ha and km²-grid resolution respectively.

Inhabitants' growth estimation was based on the Deutschland 2020 study [Kröhnert et al. 2004] of the Berlin Institute (scenario B, moderate) and on official estimations of the official Statistical Bureau of Baden-Württemberg. Study estimations related to spatial unities above municipality level have been disaggregated considering historical municipal data. BIP and water use could then be calculated by capita with a spatially relatively high resolution.

3.) and 4.) *Interventions and intensities*

Interventions focus on

- Improvement of the fish passages according to the feasibility study that was performed by the Regional Commission (RP Stuttgart, Dr. Rainold Hoffmann study). The simulation of this intervention is limited to the CASIMIR model. CASIMIR principally can show effects of passage improvement for each weir but will also combine defined aggregated options like the ones of the Hoffmann study.
- 100% transformation of crop area into grassland

- 50% transformation of crop area into fallow (additionally to the area lost through increase of settlement areas)
- Reduction of animals. A sensitivity analysis will be performed by ACRE (80/60/40% basing on the reference year 2000) to define further calculations with interesting variations.

Interventions are principally calculated on base of the reference year and include all combinations of climate sequences and socioeconomic scenarios. However – only selected models will be sensitive to the respective interventions above. The last intervention will be checked by ACRE concerning to the significance of implications for the further modelling chain. After the check a decision of the number of variation will be taken.

3.4 Technical implementation

The technical implementation of MOSDEW has three determinants:

- 1.) MOSDEW is based on a geographic information system (GIS)
- 2.) Results should be retrievable via Internet
- 3.) Soft- and hardware resources demand should be small

According to this three demands, a series of hard and software decisions has to be taken.

In RIVERTWIN “raw” data of the sub-models are stored “as they are” at the meta-database. For final visualisation purposes data has to be transferred into a homogeneous database.

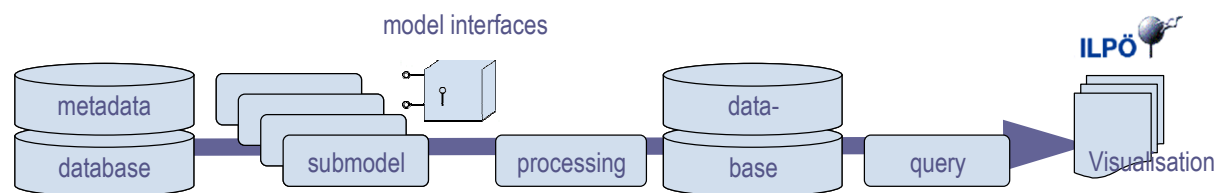


Fig. 10: Technical MOSDEW workflow

To have a productive workflow many applications are involved.

- 1.) MOSDEW is based on a GIS

Water basin oriented approaches are often recommended to be handled by a GIS, especially, if (e.g. administrative) data has to be related in a new way to this kind of basic geometries. On basis of these defined “entities” (water basins, river segments, administrative units) all results are projected. Data formats have to be transformed, results have to be (dis-)aggregated. Often, project partners need special formats or information, where sophisticated GIS application is needed. ILPOE offered this kind of GIS service for all participants where needed. The chosen Software for this pre-processing is ArcGIS, as it is actually one of the most powerful GIS-tools. It is also generally used by the stakeholders in the Neckar River water basin. The GIS is mainly used as backend for pre-processing of data and geometries. According to the pre-processing needs, other GIS software (than the expensive ArcGIS) could also be applicable as GIS-backend.

- 2.) Results should be retrievable via Internet

Internet-browser visualisation enables to involve various, decentralised institutions and authorities that might be spatially separated. It also makes complicated installation routines on different computer systems and environments dispensable.

A series of applications is needed to perform a GIS-based expert system on the web.

Database-Backend – Primary and raw sub-model data is stored in a specific data structure. The responsibility of this data is decentralized. The data formats are proprietary. The access of data (up-

and download) and meta-data is realized via MySQL-database and PHP-scripts. This is a classical example of an approved easy freeware and open-source application.

Transformed unified data is stored in a PostgreSQL-database. For the transformation, special (vba) scripts for each data format have been set up.

The PostgreSQL database is extended by PostGIS, an open source spatial extension, allowing it to be used as a spatial database backend. All relevant entities have been transformed to that format.

Applications

Specific forms and queries for the stored data finally result in the application of MOSDEW.

To come to a real decision support system, additional and explaining information should be available especially for new non-expert users. Therefore a content management system is put aside to the pure query form. Both applications are closely linked and can be kept in parallel windows.

Server

An apache webserver who runs exclusively the RIVERTWIN applications has been set up at ILPOE. With the same hardware additionally an UMN-Mapserver is running for drawing the basic geometries provided by PostGIS.

Clients

Applications can be queried via all internet browsers. However, applications are optimised for the use of Firefox 1.x or newer, Java Script enabled.

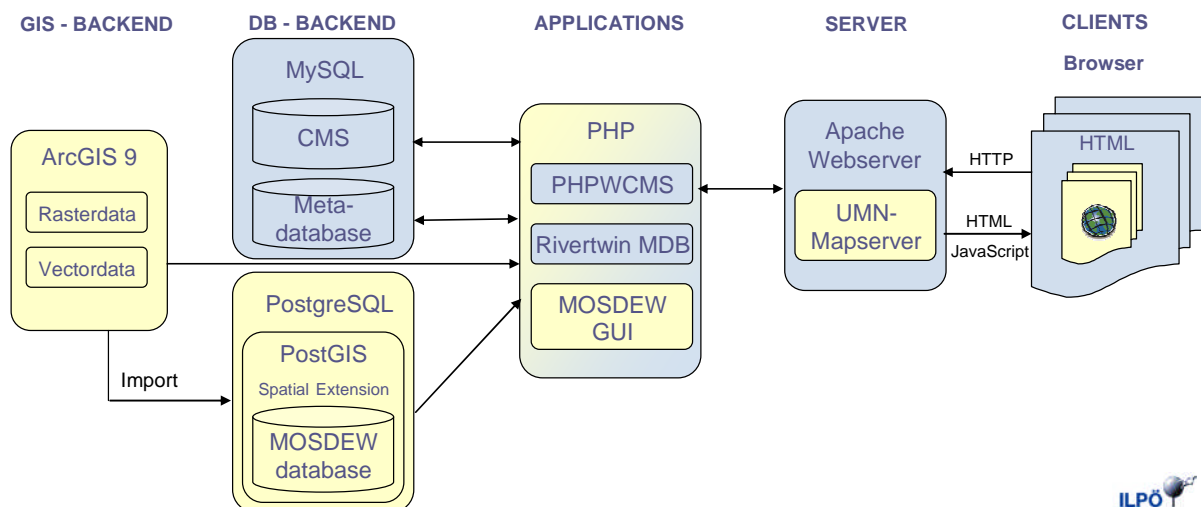


Fig. 11: Software applications for MOSDEW

3.) Soft- and hardware resources demand should be small

It was decided for the core elements of a web-based solution to implement only open-source products, mainly with respect to limited financial resources in developing countries. Open-source products are for free in this area and adaptations can be made by passionate local manpower. They seem to gain more and more performance and thus it was worth a challenge. Another important argument was the relative low implementation complexity. A good implementation of an oracle database would consume an excessive time proportion within respect to the given projects' time frame and necessities of the intended type of decision support system.

A special focus during the last year will be a possible transfer to applications, basing only on closed source programmes, as it is the case for the LUBW.

Meta-data base

Meta-data are data about data. The RIVERTWIN meta-database aims to facilitate the administration and easy access of primary base as well as for the project results. This is of vital importance for a project consortium, that is spread over Europe, Asia and Africa and that have relatively voluminous and sometimes decentralized stored data and user groups.

The RIVERTWIN meta-database is online since middle of June 2005:

(http://www.ilpoe.uni-stuttgart.de/projekte/rivertwin/metadata/md_login.php)

The Rivertwin meta-data catalogue bases on the standards of the FEDERAL GEOGRAPHIC DATA COMMITTEE (FGDC) (Ed.) 1998 and INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO) 2003. For the needs of 'Rivertwin' the FDGC/ISO catalogue was adapted: it was reduced pragmatically to preliminary 35 fields (see table), which include additional project specific elements, such as data interfaces of the models. Besides documentation of existing data the Rivertwin metadata catalogue can also serve as a data need catalogue to facilitate integrated modelling.

As database application was chosen 'MySQL' (open source software). Using PHP-functionality, query and visualization of data is possible for all project participants via internet browser (password protected).

For each river basin, responsibility for primary data has been divided within the project participants according to the contents and working discipline respectively. The first meta-data at the early beginning has been the data catalogue that has been elaborated during the spatial integration workshops. Responsible persons had to care for the availability and completeness of meta-data description of their defined area. Especially data acquisition in reality was left to the locals. Another problem in general is that data often is available only in the native language which enables only locals a further interpretation and deeper understanding of data (not only for meta-database uses).

Data can be queried by search terms as ID-number, responsible persons, themes, spatial and temporal extent, interface/model, and a full text search.

While at the beginning, only download functionality was needed, in the second project year, the upload function became more and more essential for the exchange of the models results.

For upload, data has to be categorized according to its spatial and temporal relation as well as to other characteristics. Separated options are given for primary and result data. Data thus can be uploaded and stored physically at the ILPOE server. A link to any other server would also be a valid option, but is rarely used in fact.

Database

Each model has its own data in- and output format. At the meta-database data is accepted as it is (responsibility is fully to the data owner/uploader).

To be able to use that heterogeneous data for an integrated model or expert system, data has to be transferred into a unified data base. The software used for the unified database is PostgreSQL with the PostGIS extension as this database software supports GIS applications.

4 Results

The Meta-Database has been set up 2004 and was followed up by the integrated database in 2005.

The definition of framework conditions has been finished in June 2005, completed by final definitions of interventions and intensities in December 2005.

A detailed timetable was set up in order to complete most of the Neckar modelling during summer '05 until autumn '05. However, due to the delay of major primary data input and justifiable modelling difficulties, extensive delays have been noticed for all models. As a consequence, integration of data into a unique database and furthermore as expert information system also delayed (important sub-models data is still "in the pipeline"), but expected for the next months.

Main parts of delivered results are already transferred to the integrated database and have roughly been checked.

The data and map server (hard and software) has been set up and can be accessed via CMS:

<http://www.ilpoe.uni-stuttgart.de/projekte/rivertwin/> (->MOSDEW results/Neckar).

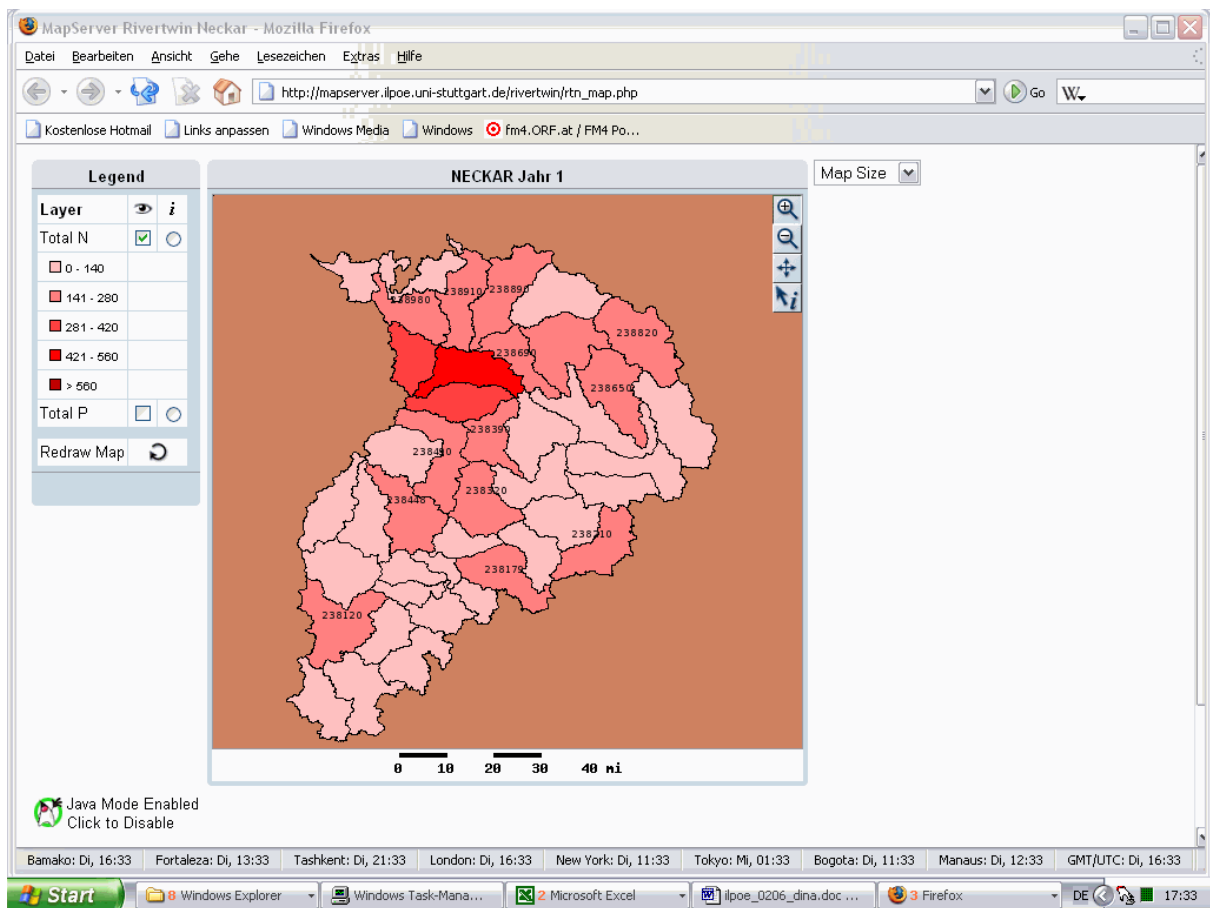


Fig. 12: screenshot of MOSDEW web-GUI prototype (year 01: total N input in rivers per water body; MONERIS result)

Data will be shown as result of the above mentioned combinations but also with respect to the thresholds. Therefore a list of hydrological and ecological indicators has been agreed with the LUBW.

Table 1 shows the status of result deliverables of the models (left column) with respect to the simulation levels (climate sequences/scenarios/intervention/intensities) at the middle of February 2006.

Situation is improving constantly, however-e.g. a general simulation mistake at an early beginning of modelling chain (e.g. in WEAP) causes a time consuming revision of subsequent models' results (e.g. in case of WEAP it would be MONERIS, QUAL2K and CASIMIR) including update of the integrated database.

Thus, concept and technical structure are fully implemented-the web-based interface and the “engine” behind are set up.

Deliverables	Y-B1	Y-B2	ENKE (1+2)	CLIMATE TYPES	SZENARIO_A	SZENARIO_B	INTER. + INTEN.
CLIMATE					-	-	-
LARSIM							
HBV							
MODFLOW							
WEAP	-	-	-	-			-
SLYSIS							
MONERIS							
QUAL2K							
CASIMIR							
ACRE	-	-	-				

Model Group 1	Status	delivered	partially delivered	-
Model Group 2	MDB 17.2.			no results needed

Tab. 1: Status of delivered result deliverance to the MDB (17.2.06)

During the next weeks the graphical user interface and query options will be completed and missing data will be fed in. For a better understanding background information and guiding expert knowledge will be offered via links to the content management system (CMS) at ILPOE (s. internet link above-work in progress). Constant progress can be observed “live” via internet.

With actual status an exhausting integrated analysis or interpretation is still not possible. Some preliminary results are sketched in the following.

It already can be stated, that in the Neckar River basin quantitative water problems are not likely to be very predominant. Comparing the total demand per year in the water basin with natural recharge rates of mean historical annual values and the reference year, annual demand is 2.9% and 2.6% of natural recharge respectively.

According to LARSIM data, hydrological sustainability of the Neckar River is relatively high. Changes of monthly discharge rates even in dry months and including land use changes are below uncertainty percentage for that model. The threshold of 1/3 MNQ was not reached.

In a first sketch, concerning EU-CAP effects (mainly induced by omission of subsidies) land use change was calculated by ACRE, cultivation area of winter wheat, winter barley, winter rape and sunflowers will reduce, partially significantly, while clover and fallow land proportion will rise. Livestock will be reduced, partially significantly. Related to that subsidy changes, cross margin in counties with “classical” cultivation mix will sink partially drastically, whereas in some counties with a naturally high greenland proportion, income could even rise (in small quantities). The repercussions of these EU-CAP reform induced effects on water quality simulated by the modelling chain (via EPIC-SLISYS-MONERIS-QUAL2K) will be of higher importance.

The presentation of modelled change in ecological quality will be one of the main tasks in the near future as soon as final results therefore will be available.

As soon as all results/data will be available a sensitivity analysis will be done with respect to the sustainability thresholds.

5 Discussion and conclusion

In general it can be stated that the RIVERTWIN research programme compiled a pretty good integration configuration. The given modelling frame corresponds very well to the simulation feasibility of the models. While the models and the responsible modellers can handle in general (and partially with delays) the prospected simulation demands within the given project time, the number and quality of simulations provides sufficient potential strategic planning decision situations, even if not necessarily all of the models had to calculate each single potential situation (as shown in Fig. 9).

The models design of the RIVERTWIN model family fits mostly quite well in terms of spatial and temporal resolution and data demand. Some problems have been registered e.g. concerning ACRE and QUAL2K.

The spatial resolution of ACRE is at the county level (as administrative unit which is usually larger than and also usually separating water basins). These problems could be solved by area proportional interpolation. Moreover it was agreed, that ACRE does not deliver results for all climate sequences, as it is not so much sensitive on the differences of the sequences. Thus it was sufficient to concentrate on the five basic climate types and especially on the different socioeconomic scenario assumptions, especially as ACRE is at the beginning of the data chain.

In the course of the project it also became clear, that it was not possible to get the full range of results by the Qual2K model. This model is Excel/VBA based and needs about 25 input parameters. For each simulation situation, most of parameters have to be typed in by hand. As an automated input option was not possible to implement during the given project time, we agreed with the responsible modeller on a feasible series of 144 simulation situations. As the temporal resolution of QUAL2K is per day, we dispose finally 144 different days as results. Most of these simulation situations (days) have been defined to be from middle to extreme situations, hoping to match best the challenge of established thresholds. This gives already precious information - however, as the temporal resolution of QUAL2K is per day, it is still rather erratic. To cope with planning needs, a decision maker would surely prefer to know more systematically, in which situation thresholds are likely to be broken. Concerning resolution and input demands, it is finally an open question, if other models than QUAL2K would have been fit better to the rest of the RIVERTWIN modelling chain. A concentration of main parameters and maybe coarser resolution but complete result list would also be more helpful to the following members of the data chain.

Key problems in the Neckar basin concerning EU-WFD are water quality and improvement of fish habitat quality. To both issues the Rivertwin consortium contributes via MOSDEW substantial strategic planning information. Within a changing environment e.g. by 'global climate change' or by political reforms like CAP, possible implications can be evaluated in an integrative way. It will even be used for purposes beyond WFD, as e.g. in the case of negotiations about the reduction of N-load amounts to the Northern Sea by OSPAR treaty.

Therefore we are convinced to really match with MOSDEW the needs for creating strategic long term planning and management instruments as they are required by EU-WFD for integrated management plans in water basins. An important expected finding will be e.g. the check of ecological robustness of the Neckar basin. Also the agro-economic 'costs' for further improvement of water quality will be a very interesting issue.

Right from the beginning or even before a series of meetings with stakeholders and authorities (representatives of the Ministry of Environment, LUBW/Agency for Environment Baden-Württemberg and the Regional Commission Stuttgart) has been initiated in order to clear the institutional, administrative frame, where possible applications could play a major role and what specific planning tool

necessities emerge out of the Water Frame Directive in general but also very precisely in the situation of the Neckar River basin in Baden-Württemberg. Throughout the whole modelling process there were stakeholder meetings on a regular basis. At the beginning of the project, the administration apparently was deeply involved in completing the status report for the WFD. This changed apparently during 2005. Without fail, awareness for the implementation of that kind of tools grew throughout the project time at the authorities and the constant cooperation led meanwhile to the application of Rivertwin scenario assumptions at the authorities.

Concerning a possible implementation of MOSDEW the foreseen meetings in 2006 with authorities and stakeholders as well as public presentations will be crucial. The transferability of technical architecture and possible interfaces for optionally adding existing tools of the administrative and technical structure will be of high relevance.

For further developments it is to remind that the software architecture is open to implement additional model features. Thus, e.g. by the introduction of a sophisticated thermal output model for power plants could add a better estimation of the water heating problem in the Neckar River. Also adaptations or exchange of models is possible although a respective programming of the respective interfaces is necessary.

A greater challenge in a future project would be the direct coupling of models, at least partially. A very helpful task could e.g. be the programming of Excel/VBA based applications like MONERIS or QUAL2K. However, there is always a certain risk doing direct coupling. A lot of energy is put into "technical" interfacing, while the professional supervision of output plausibility and 'state of scientific art' is in danger to get lost.

6 Annexes

6.1 Acronyms

CAP - Common Agricultural Policy

CMS – Content management system (modular built information system that can be easily updated)

EU – European Union

GIS – Geographic Information System

GUI – Graphical User Interface

ILPOE - Institute for Landscape Planning and Ecology/University of Stuttgart

KLIWA – Klimaveränderung und Wasserwirtschaft (Climate change and consequences for water management),
<http://www.kliwa.de>

LfU – Landesanstalt für Umweltschutz (transferred to LUBW since 1-1-06)

LUBW – Landesanstalt für Umwelt, Messungen und Naturschutz Baden-Württemberg (Agency for Environment,
 measurements and nature protection Baden-Württemberg) former LfU (until 31-12-05)

MOSDEL – Model for Sustainable Development of Land Use

MOSDEW – Model Interface for Sustainable Development of Water Resources

OSPAR – Oslo and Paris Commission for the Protection for the Marine Environment in the North-East Atlantic
<http://www.ospar.org/>

UStutt – University of Stuttgart

WAVES - Water Availability and Vulnerability of Ecosystems and Society in Northeastern Brazil)

WFD – Water Frame Directive

WP – Work package

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6.5 Interface tables

Content	in-entity of interest	out-entity of interest	temporal resolution	spatial resolution	unit	geographical format	from model	to model
NECKAR BASIN								
Within water Block								
Groundwater recharge	water body	aquifer	daily	1km ²	m ³ /s	Grid	HBV	MODFLOW
Discharge GW to surface water	aquifer	river segment	daily / 10 days	1km ²	m ³ /s	Point	MODFLOW	HBV
River discharge	water body	river segment	daily	approx. every 35km	m ³ /s	Point, Node	HBV	CASIMIR, MONERIS
Water level	river segment	river segment	daily	approx. every 35km	height above sea level (m)	Line	CASIMIR	MODFLOW
Surface Water temperature	river segment ²	river segment ²		every 200-1000m	°C	Line	QUAL2K	CASIMIR
Surface Water oxygen concentration	river segment ²	river segment ²		every 200-1000m		Line	QUAL2K	CASIMIR
Surface Water nitrate concentration and other pollutants	river segment ²	river segment ²		every 200-1000m		Line	QUAL2K	CASIMIR
Groundwater Withdrawal from wells	point	aquifer	monthly	Point data / municipality level	m ³ /s	Point/well	WEAP	MODFLOW
Depth to Groundwater	aquifer	river segment	average / year	1km ²	m	Grid	MODFLOW	MONERIS
Hydrogeology Types	aquifer	river segment	none	km ² / subcatchment	description	Grid (Area)	MODFLOW	MONERIS

Content	in-entiy of interest	out-entiy of interest	temporal resolution	spatial resolution	unit	geographical format	from model	to model
<u>Between Land use and Water Block</u>								
soil information	soil unit	soil unit	irrelevant	1 km ² area weighted mean	Perm. Wilting point, Field Capacity, oil depth,	Grid (Area)	SLISYS	HBV, MONERIS
soil information	soil unit	soil unit	irrelevant	1 km ² area weighted mean	Depth to groundwater, total nitrogen content in topsoil, clay content	Grid (Area)	SLISYS	MONERIS
Surface water sediment load	soil unit	river segment	Monthly	water body/ MONERIS area	t / a	Grid (Area)	SLISYS	MONERIS
Surface water nitrate load	soil unit	river segment	Monthly	water body/ MONERIS area	kg / a	Grid (Area)	SLISYS	MONERIS
Surface water phosphate load	soil unit	river segment	Monthly	water body/ MONERIS area	kg / a	Grid (Area)	SLISYS	MONERIS
Surface water pesticide load	soil unit	river segment	Monthly	water body/ MONERIS area	g / a	Grid (Area)	SLISYS	MONERIS
Nitrate load to groundwater	soil unit	aquifer	Monthly	water body/ MONERIS area	kg / a	Grid (Area)	SLISYS	MONERIS
River gauge flow	river node	river node	Daily	river nodes	m ³ /s	Point	HBV	WEAP

Content	in-entity of interest	out-entity of interest	temporal resolution	spatial resolution	unit	geographical format	from model	to model
Ground water storage	aquifer	water body	Monthly	1km ²	To be discussed between SEI - USTUTT IWS-GW	Grid	MODFLOW	WEAP
Pollutant concentration in surface water	river segment, reservoirs, lakes	river segment, reservoirs, lakes	Monthly	water body/ MONERIS area		Line (Point)	MONERIS	WEAP
Waste water reflux to river	outlet pipes	river segment	Monthly	water body/ MONERIS area	m ³	Line (Point)	WEAP	HBV

Content	in-entiy of interest	out-entiy of interest	temporal resolution	spatial resolution	unit	geographical format	from model	to model
Within Land use Block								
Water use by agriculture for animals, sprayer	farm area	district/municipality	Year	district	m ³	Grid (Area)	GAMS	WEAP
Mean yield per crop ³	farm area	district/municipality	Year	district	(kg/ha)	Grid (Area)	SLISYS	GAMS
soil, climate	farm area	soil unit	Daily	1km ²		Grid	SLISYS	EPIC
Crop yield, water consumption, nutrient and pesticide transport	soil unit	farm area	Year	farm area (km ²)		Grid (Area)	EPIC	SLISYS
Crop distribution	farm area	farm area	Year (reference year and scenario years)	district		Grid (Area)	GAMS	SLISYS
Fertilizer use (inorganic)	farm area	farm area	Year	district		Grid (Area)	GAMS	SLISYS
Fertilizer use (organic)	farm area	farm area	Year	district		Grid (Area)	GAMS	SLISYS
Water demand by for power production (cooling water)	power plant	river segment	Year (Month?)	water body/ MONERIS area		Line	from scenario variables	WEAP
Water demand by industry	district/municipality	river segment, aquifer	Year (Month?)	Municipality / district ?		Grid (Area)	from scenario variables	WEAP
Water demand by households	district/municipality	river segment, aquifer	Year (Month?)	Municipality / district ?		Grid (Area)	from scenario variables	WEAP

Table 2: Interface tables

6.6 Detailed coupling schemes

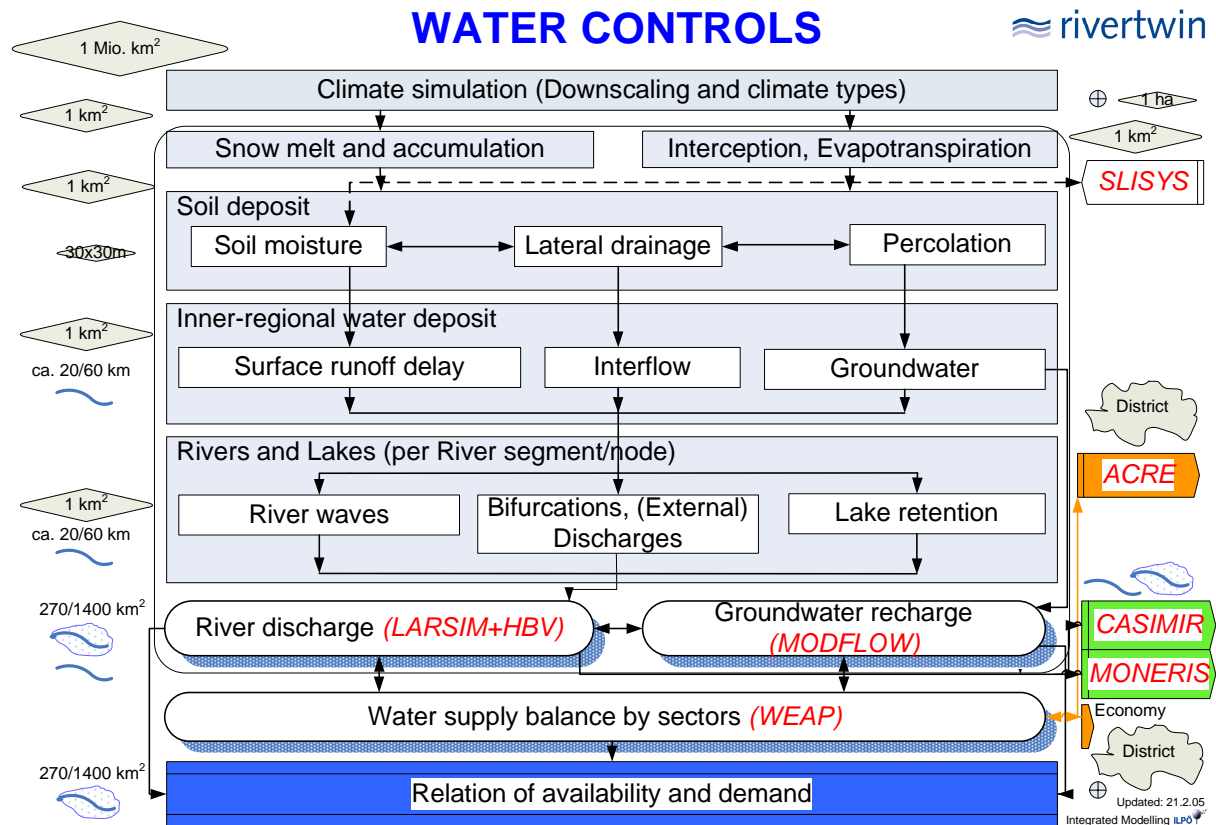


Fig.13: Integrated coupling scheme Neckar River basin: water controls

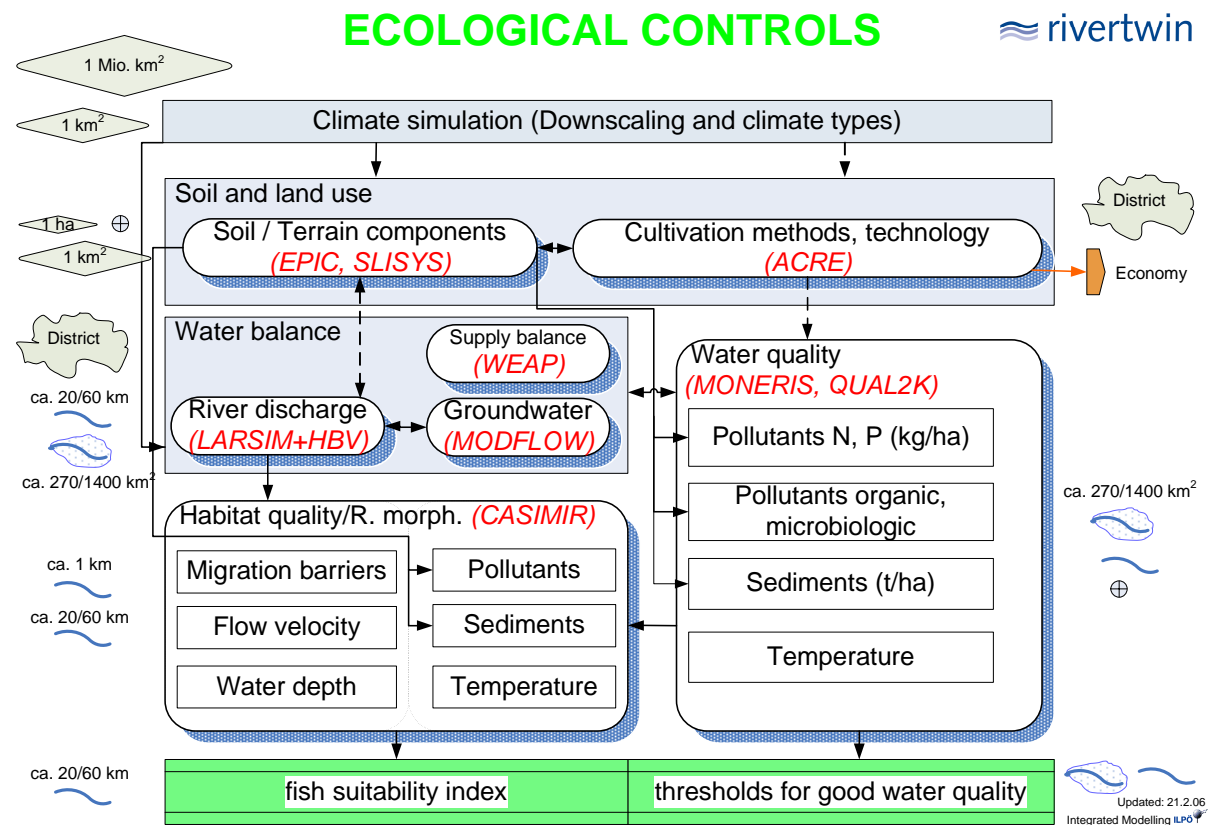


Fig.14: Integrated coupling scheme Neckar River basin: ecological controls

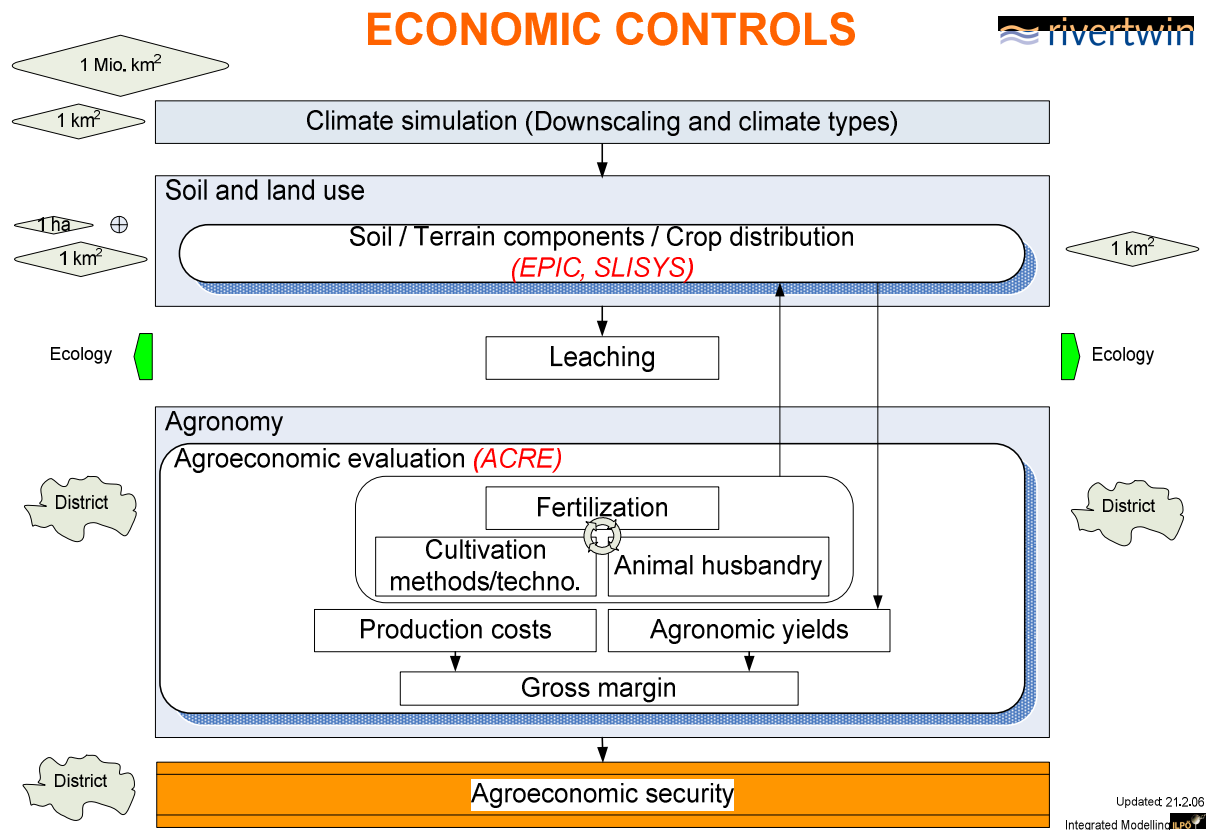


Fig.15: Integrated coupling scheme Neckar River basin: economic controls

6.7 Interchange formats

Model	Programming language	Output format	Spatial output entity	Temporal resolution	Output Parameter
Climate regionalisation	fortran	Ascii	1km grid and climate stations	Daily (360 days/a for sequences)	Mean/min/max temperature (°C), precipitation (mm)
LARSIM	proprietary	Ascii	Water basin	Daily	Discharge
HBV	fortran	Ascii	Water basin	Daily	Discharge
MODFLOW	proprietary	Grid/Ascii	1km grid	Monthly	m ³ water; distance (m) to surface
WEAP	proprietary	CSV	Subbasin	Year	m ³ water demand and waste water by sector
MONERIS	vba	Excel	Subbasin	Yearly (5 years)	N, P-input for each pollution path
QUAL2K	vba	Excel	River segment (~1km)	Daily (only 144 selected days)	Q, H, U, t _{travel} ; Min./Max. temperature °C, Min./Max./mean concentration of total N/P, suspended solids, NH ₃ , %saturation, SOD, BOD, total organic carbon
CASIMIR	avenue	Shapefiles	River segment (~20km)	Yearly	Habitat suitability for Barbel
EPIC	proprietary	Ascii	M ² /ha	Daily	Crop yields kg
SLISYS	proprietary/GIS	Ascii/Excel	Water basin	Annual	Crop yields t N/P emission from farmland (t)
ACRE	proprietary	Ascii	County	Annual	EUR

Tab. 3: Interchange formats

6.8 List of WFD-relevant thresholds agreed with LUBW

	Water management goal	Indicator	MIN. THRESHOLD	MIDDLE THRESHOLD Orientation value	MAX. THRESHOLD	Spatial relation	MORE INFORMATION
HYDROLOG. INDICATORS	Sustainable water availability	Minimum discharge		1/3 MNQ	1/6 MNQ (lower limit)	Reach after withdrawal	Water power-plants directive BW
		Water withdrawal		> 1/3 MNQ	complete withdrawal individual regulations	Reach after withdrawal	BW-administration
		Relation withdrawal/groundwater recharge					

Tab. 4: Hydrological threshold values

	<i>Water management goal</i>	<i>Indicator</i>	<i>MIN. THRESH-OLD</i>	<i>MIDDLE THRESH-OLD Orientation value</i>	<i>MAX. THRESHOLD</i>	<i>Spatial relation</i>	<i>MORE INFORMATION</i>
ECON. IND.	Agroeconomic security	Gross margin income/ha	< 200EUR/ha	200-600EUR/ha	> 600EUR/ha	County	Hints by MLR

Tab. 5: Economic threshold values (without LUBW agreement)

	<i>Water management goal</i>	<i>Indicator</i>	<i>MIN. THRESH-OLD</i>	<i>MIDDLE THRESH-OLD Orientation value</i>	<i>MAX. THRESHOLD</i>	<i>Spatial relation</i>	<i>MORE INFORMATION</i>	
ECOLOG. INDICATORS	Physical water quality	Sedimentation				River water bodies		
		Water temperatur at outlets of power plants			28°C	River water bodies	EU/German fish law	
	Biological water quality	Water quality (-classes)		I-II	II	F-WK (> 70% der Strecken)	LAWA	
		O ₂ Concentration		Salmonides: 6 mg/l Cyprinides: 4 mg/l		River water bodies	LAWA	
		CBOD - Salmonides waters		3mg/l		River water bodies	German fish law	
		CBOD - Cyprinides waters		6mg/l		River water bodies	German fish law	
		CBOD - other waters		6mg/l		R. water bodies	German fish law	
		Habitat suitability for fish species/communities					no general numbers possible	
	Chemical water quality	N-conc./river				6mgN/l	River water bodies	LAWA
		Nitrate-concentration /groundwater				50mg/l	water body	EG-Nitrate directive
		T _w >10°	NH ₄ / River			1 mg/l	R. water bodies	
		T _w <10°	NH ₄ / River			3 mg/l	R. water bodies	
			NO ₃ / River			0,1 mg/l	R. water bodies	

	Phosphorus conc. / River			0,2mgP/l	R. water bodies	LAWA
	PSM-Eintrag			sum 0,5 µg/l	R.-WB/WB	
	Single parameter PSM-input			0,1 µg/l	R.-WB/WB	LAWA/List 38a
	CBOD - Salmonides waters		3mg/l		R. water bodies	German fish law
	CBOD - Cyprinides waters		6mg/l		R. water bodies	German fish law
	CBOD - other waters		6mg/l		R. water bodies	German fish law
	Salt-Chlorides		200 mg/l		R.-WB/WB	
	Heavy metals(Sediment)				R.-WB (> 70% of segm. length)	
	Copper			160 mg/kg		
	Chromium			640 mg/kg		
	Zinc			800 mg/kg		
	Cadmium			2,4 mg/kg		
	Mercury			1,6 mg/kg		
	Nickel			800 mg/kg		
	Lead			200 mg/kg		

Tab. 6: Ecological threshold values

6.9 Scenario assumptions

	Current situation		Scenario	Scenario
	acc. own calculations	according WFD-report*	A	B
	2000/2001		2030	
Demography				
Population (nb-BaWü) 2000	5 292 120			
Population (nb-BaWü) 2001?	5 331 590	5 500 000		
Area Neckar-basin (BaWü)	13 618	13 644		
Total area (BaWü incl. States of Bavaria and Hessen)	13 709	13 958		
Population Neckar-basin (nb-BaWü)	5 331 590		6 332 411	5 366 270
Mean annual pop-growth rate 2000 - 2030			0,59%	0,02%
Population density Neckar-basin (nb-BaWü)	391		464	393
Urban Population (Municipalities > 10.000 Inhabitants)2000/2030	69,13%		73,21%	68,92%
Rural Population (Municipalities < 10.000 Inhabitants)2000/2030	30,87%		26,79%	31,08%
Economy				
GDP Neckar basin (Mio. EUR)		146 437	265 250	197 375
GDP sector 'services' (Mio. EUR)		88 645	160 562	119 476
GDP sector 'industry' (Mio. EUR)		56 785	102 858	76 538
GDP sector 'Agriculture and forestry' (Mio. EUR)		968	1 753	1 305
Annual GDP growth (2000-2030)			2,0%	1,0%
Water use				
Water consumption (1.000m3, year 2001, Housholds, small enterprises)	236 126		277 360	176 282
Water consumption liters/capita/day (2001, Housholds, small enterprises)	121	121	120	90
water use in industry (1.000m3/year, 2001)		88 062	76 419	28 836
water use in industry (m3/month, 2001)	7 338 500		6 368 250	2 403 028
water use for energy production (1.000m3/year, 2001)		3 887 511	3 544 292	126 739
water use for energy production (m3/month, 2001)	323 959 250		295357 641 807	10561 557 292
water use in service sector (m3/month, 2001)		nodata	nodata	nodata
water use in agriculture (1.000m3/year, 2001)		29 907	calc. by GAMS	calc. by GAMS
water use in agriculture (m3/month, 2001)	2 492 250		calc. by GAMS	calc. by GAMS
industrial technology level & water awareness (low/medium/high)	high		medium	high
Wastewater				
technological level (low/medium/high)	high		high	high
total amount (Mio. m3/year, 2001)		4 922	4 304	286
total amount (m3/month, 2001)	410 166 667		358 690 975	23 831 702
public sewage plants (Mio. m3/year, 2001)		1 013	753	154
public sewage plants (m3/month, 2001)	84 416 667		62 760 288	12 819 894
Cooling water from power plants (Mio. m3/year, 2001)		3 887	3 544	127
Cooling water from power plants (m3/month, 2001)	323 916 667		295 357 642	10 561 557
Industry (no information about treatment, Mio. m3/year, 2001)		22	7	5
Industry (no information about treatment, m3/month, 2001)	1 833 333		593 223	450 251
Land Use (on base of km2-Grid)				
	2000	%own calc.	%own calc.	%own calc.
Forest (km2)	5 311	36,74%	36,53%	36,73%
Agriculture (km2)	4 865	33,66%	32,68%	33,56%
Pasture (km2)	3 086	21,35%	20,76%	21,25%
Settlement (km2)	1 191	8,24%	10,02%	8,45%
Water (km2)	1	0,01%	0,01%	0,01%
Sum		100%	100%	100%

Tab. 7: Socioeconomic scenario assumptions