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Summary

SLISYS is a soil and land resources information system that was created to provide information about soils, climate and terrain conditions in the Neckar basin. In addition, it contains models for estimating crop yield and diffuse emissions of nitrogen, phosphorous and agricultural chemicals from various kinds of land use. The report summarizes the data structure and spatial layers of SLISYS and presents results for the reference year 2000, validated against observation data. The annexes contain a user manual and additional data explanations for data input and simulation procedures of SLISYS.

1. Objectives

SLISYS is a soil and land resources information system that was created to provide information about soils, climate and terrain conditions in the Neckar basin. In addition, it contains models to estimate crop yield and diffuse emissions of nitrogen, phosphorous and agricultural chemicals from various kinds of land use. It is composed of a data domain and a model domain. The data domain contains soil, climate and terrain information as well as model specific data on crop management.

2. Data structure

The data domain of SLISYS is called NECKAR, which refers to regional extend of the data base (Neckar basin). The data are stored according to the data model SOTER which was proposed by the FAO (Food and Agricultural Organisation of the UN) for National Soil and Terrain Digital Data Bases (ISRIC 1993).

a. Climate data

The data structure for the climate data is derived from the SOTER data structure (ISRIC 1993). The data is stored in a relational database containing the tables STATION, DATA_SET, MON_DATA and DAY_VAL (Table A1 in the Annex). In SLISYS all climate relevant tables are stored in the table space (subdirectory) SOT_CLIM.

b. Soil and Terrain data

The data structure for the soil and terrain data is also derived from the SOTER data structure. The data is stored in a relational database containing the tables TERRAIN, TERRAIN_COMPONENT, SOILCOMPONENT, PROFILSET, PROFIL and HORIZON (Tables A2, A3 and A4). In SLISYS all soil and terrain relevant tables are stored in the table space (subdirectory) SOTER.

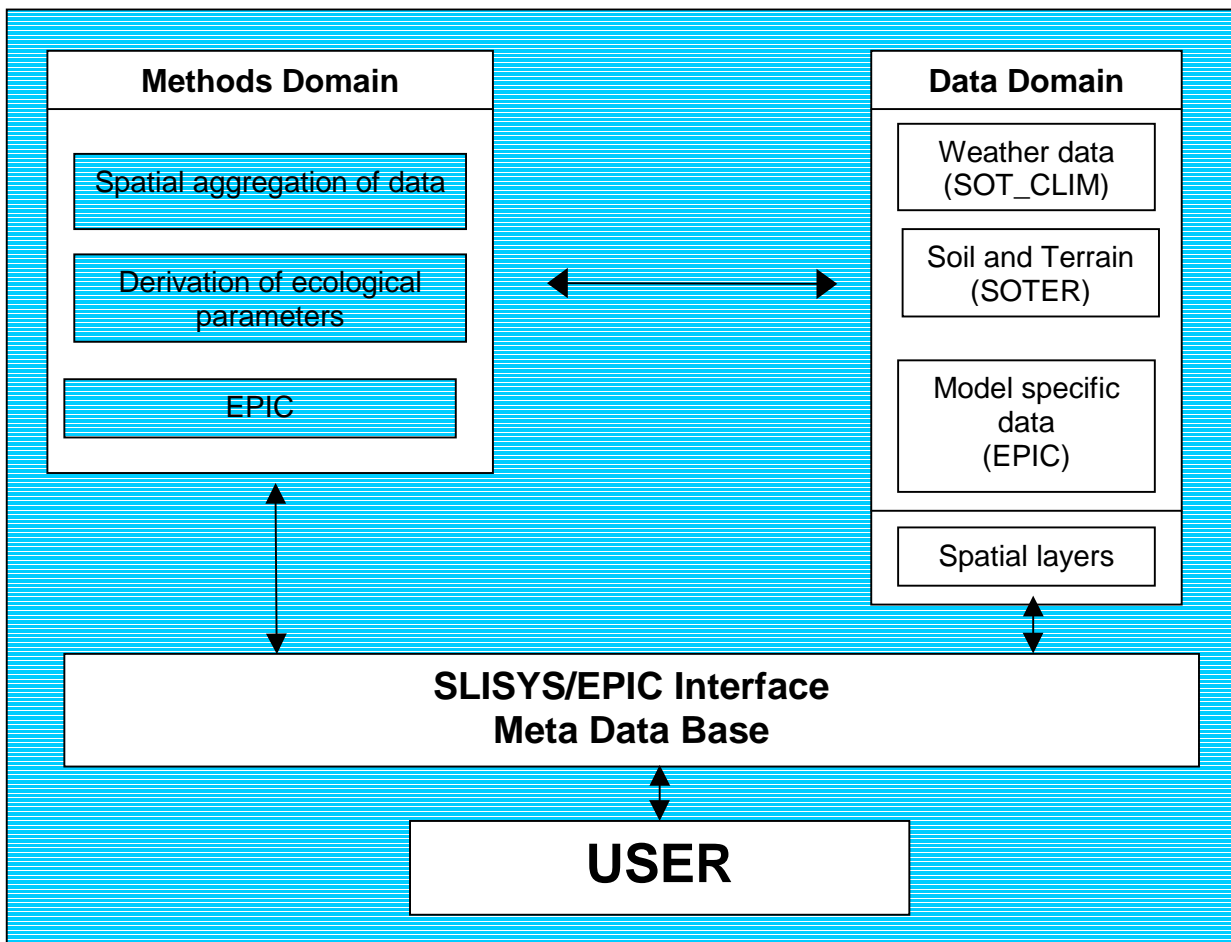


Figure1: SLISYS Database structure

c. Land use/crop management

In order to simulate different land use types and to evaluate their effects on water quality, SLISYS stores a large range of land use types and within the arable land various crop management practices (ploughing, reduced tillage, fertilizer types, rates and distribution etc.) depending on the crop type.

The crop management tables are stored in the table space (subdirectory) EPIC in three tables. The first table BASEDATA (Table 1) contains general information about the control of the simulation (number of years to simulate, starting date, output definitions etc.), general conditions (CO₂ concentration in atmosphere, salt content in irrigation water etc.) and terrain conditions (slope inclination, slope length, soil albedo, depth to groundwater etc.) which are partially extracted automatically from the soil and terrain data tables (see above). For explanations of the codes see Annex II.

Table 1: The table BASEDATA in the SLISYS crop management section

Table name	Table fields	PK	FK relation	Data type	Max length / Precision
BASEDATA	TITLE1	PK		CHAR	80
	TITLE2			CHAR	80
	Simulation control data				
	NBYR			INTEGER	
	IYR			INTEGER	
	IMO			INTEGER	
	IDA			INTEGER	
	NIPD			INTEGER	
	IPD			INTEGER	
	NGN			INTEGER	
	IGN			INTEGER	
	IGSD			INTEGER	
	LPYR			INTEGER	
	IET			INTEGER	
	ISCN			INTEGER	
	IGRAF			INTEGER	
	ICODE			INTEGER	
	ITYP			INTEGER	
	ISTA			INTEGER	
	IHUS			INTEGER	
	NCOW			INTEGER	
	NVCN			INTEGER	
	INFL			INTEGER	
	MASP			INTEGER	
	BUS1			DECIMAL	7.4
	BUS2			DECIMAL	7.4
	BUS3			DECIMAL	7.4
	Terrain data				
	WSA			DECIMAL	7.4
	CN2			DECIMAL	7.4
	CHL			DECIMAL	7.4
	CHS			DECIMAL	7.4
	CHN			DECIMAL	7.4
	SN			DECIMAL	7.4

	APM			DECIMAL	7.4
	YLT			DECIMAL	7.4
	SNO			DECIMAL	7.4
	RCN			DECIMAL	7.4
	RTN			DECIMAL	7.4
	SL			DECIMAL	7.4
	S			DECIMAL	7.4
	PEC			DECIMAL	7.4
	DRV			DECIMAL	7.4
	FL			DECIMAL	7.4
	FW			DECIMAL	7.4
	ANG			DECIMAL	7.4
	STD			DECIMAL	7.4
	UXP			DECIMAL	7.4
	DIAM			DECIMAL	7.4
	ACW			DECIMAL	7.4
	YWI			DECIMAL	7.4
	BTA			DECIMAL	7.4
	EXPK			DECIMAL	7.4
	GWST			DECIMAL	7.4
	GWMX			DECIMAL	7.4
	SALB			DECIMAL	5.4
	TSLA			DECIMAL	6.4
	ZQT			DECIMAL	6.4
	ZTK			DECIMAL	7.4
	ZF			INTEGER	
	FFC			DECIMAL	5.4
	WTMN			DECIMAL	5.4
	WTMX			DECIMAL	5.4
	WTBL			DECIMAL	5.4
	XIDS			DECIMAL	5.4
	RFTT			DECIMAL	7.4
	General conditions				
	CO2			DECIMAL	7.4
	CNO3I			DECIMAL	7.4
	CSALT			DECIMAL	7.4
	CHD			DECIMAL	7.4
	DALG			DECIMAL	7.4
	VLGN			DECIMAL	7.4
	VLGM			DECIMAL	7.4
	COWW			DECIMAL	7.4

The second table MANAGEBASE contains general data about the crop management like irrigation type, fertigation options, liming option, drainage system etc.

Table 2: The table MANAGEBASE in the SLISYS crop management section

Table name	Table fields	PK	Explanation	Data type	Max length / Precision	Unit
MANAGE BASE	Managebaseid			CHAR	20	
	NRO		Crop duration rotation	INTEGER		Years
	NIRR		Rigidity of irrigation	INTEGER		Code
	IRR		Irrigation code	INTEGER		Code
	IRI		Minimum application interval for automatic irrigation	INTEGER		Days
	IFA		Minimum application interval for fertilizer application for auto option	INTEGER		Days
	LM		Liming Code	INTEGER		Code
	IFD		Furrow dike code	INTEGER		Code
	IDR		Drainage code	INTEGER		Code
	IDFT		Fertilizer ID in the fertilizer file for automatic fertilization	INTEGER		Code
	MNU			INTEGER		
	BIR		Water stress factor to trigger automatic irrigation	DECIMAL	7.3	Stress level/ kPa
	EFI		Portion of runoff of the irrigation volume	DECIMAL	4.4	Dec%
	VIMX		Max. annual irrigation volume allowed	DECIMAL	7.3	Mm
	ARMN		Minimum single application volume for auto irrigation	DECIMAL	7.4	Mm
	ARMX		Maximum single application volume for auto irrigation	DECIMAL	7.3	Mm
	BFT		N stress factor to trigger automatic fertilization	DECIMAL	4.4	Stress level (0-1)
	FNP		Amount of fertilizer per automatically scheduled application	DECIMAL	7.3	Kg/ha
	FMX		Max. annual N fertilizer applied	DECIMAL	7.3	Kg /ha
	DRT		Time required for drainage system to end plant stress	DECIMAL	5.4	Days
	FDSF		Fraction of furrow dike volume available for water storage	DECIMAL	4.4	Dec%

The third table is OPSCHED which stores individual field operations that are pertinent to different management options, which must be defined for each crop.

Table 3: The table OPSCHED in the SLISYS crop management section

Table name	Table fields	PK/FK relation	Explanation	Data type	Max length / Precision	Unit
OPSCHED	BASEID	PK / MANAGE- BASE		CHAR	20	
	OP_NR	PK		INTEGER		
	MON		Number of month	INTEGER		1 to 12
	DAY		Number of day	INTEGER		1 to 31
	COD		Operation/Tillage code number *)	INTEGER		Code
	CRP/GR Z / PST		Crop identification number **) OR Grazing duration in days OR Pesticide ID ***)	INTEGER		Code
	MAT		Years necessary to mature or years until harvest. (For trees only)	INTEGER		Year
	PHU /NAPP /PCF		Potential Heat Units / Mineral nitrogen applied / Pesticide efficiency factor	DECIMAL	7.3	Accum. Temp. Degrees
	CND/PAR / ??		Mineral P applied/ Runoff curve number after this operation/Pesticide application rate	DECIMAL	7.4	Kg per ha or curve number or g/ha of active ingredient
	WSF / FDP		Plant water stress factor / Depth of fertilizer placement	DECIMAL	7.3	0 to 1 / mm
	(FNMX) = FNO/QVOL		Organic N applied/ Fraction Runoff volume per irrigated volume	DECIMAL	7.3	Kg/ha or Dec%
	FPP/FPO		Fraction of original plant population / Organic P applied	DECIMAL	7.3	Dec% or kg/ha
	(QVOL)		Not used			
	HUSC		Time of this operation as a fraction of the growing season or of the year if no crop is growing; using 0°C as the base temperature	DECIMAL	4.3	Dec%

*) From tillage file (clastill.dat)

**) from crop parameter file (clascrop.dat)

***) from pesticide file (pest0941.dat)

d. Yield and nutrient emissions (Simulation output)

The tables that contain crop yield and nutrient emissions in relation to land use types and crop management are the results of the linkage between the SLISYS database and the simulation model EPIC (Erosion Productivity Impact Calculator, USDA 1990). Essentially three tables were created for that purpose

d1 The EPAUS table (table 4)

It contains the intermediate results of the simulations that were obtained at characteristic points (soil profile) in the landscape. The variables are the target variables that are of importance for the RIVERTWIN-Moneris model and the RIVERTWIN-ACRE model i.e. crop yield, N and P in surface runoff, subsurface flow, deep percolation and sediments in relation to land use type (incl. Crop management), weather station, soil and terrain. In addition, soil hydrological variables are stored for crosschecking with the output of the hydrological model HBV. Presently the columns "Rain" and "Q" (runoff) have two different meanings depending on the parameter setting in the simulation control file EPICFILE.DAT, which considers a maximum of 5 variables at the same time.

Table 4: The table EPAUS in the section yield and nutrient emissions

Table name	Table fields	PK/ FK relation	Explanation	Data type	Max length / precision	Unit
EPAUS	Station_id		Climate station ID	VARCHAR	10	
	Soter_unit		Terrain Unit ID	VARCHAR	4	
	Terrain_component		Terrain Component ID	INTEGER		
	Soil_component		Soil Component ID	INTEGER		
	Profil_id		Soil profil ID	VARCHAR	20	
	Jahr		Year	INTEGER		
	Yield		(Marketeable) Yield of crop	REAL		ton/ha
	Run_id		ID of the simulation run (usually the ID of the crop including the ID of the management)	VARCHAR	10	
	Biom		Total biomass production at harvest (incl. Root biomass)	REAL		Ton/ha
	HI		Harvest index	REAL		Dec%
	WUEF		Water Use Efficiency	REAL		kg/mm
	Rain / YN		Annual precipitation / Total nitrogen in eroded soil material	REAL		mm/kg per ha
	Q / YP		Surface Runoff / Total P in eroded soil material	REAL		mm/kg per ha
	SSF / DN/YON *		Subsurface flow / Annual amount of nitrogen lost through denitrification	REAL		mm/kg per ha
	PRK / DR/YP *		Percolation / Delivery ratio	REAL		mm /Dec%
	ET		Annual evapotranspiration	REAL		mm
	Musl		Soil loss through water erosion	REAL		mm
	YNO3		Mineral Nitrogen in surface runoff	REAL		kg / ha
	SSFN		Mineral nitrogen in subsurface flow	REAL		kg / ha
	PRKN		Minreal nitrogen in deep percolation	REAL		kg / ha
	YAP		Mineral P in surface runoff	REAL		g / ha

* The last variable is used for scenario simulations with the reduced parameter output

After the simulation run for each crop the data in the intermediate table EPAUS are aggregated to spatial units that belong to the same terrain unit (=Soter unit) and the same climate station and are then transferred into the table BWDIFPOL by a database query.

d2. The BWDIFPOL table (table 5)

This table contains the parameters that refer to the crop yield, the hydrological balance components and the soluble fractions of N and P in surface runoff, subsurface flow and percolation per year and per spatial units that belong to the same climate station (station_id) and soil association (Soter_unit). It is assumed that phosphorous leaching through soil material (percolation and subsurface flow) can be neglected.

Table 5: The table BWDIFPOL in the section yield and nutrient emissions

Table name	Table fields	PK	FK relation	Data type	Max length / Precision	Unit
BWDIFPOL	Station_id			VARCHAR	10	
	Soter_unit			VARCHAR	10	
	Crop_id			VARCHAR	10	
	Year			INTEGER		
	Yield			DEC	5.1	t/ha
	HI			DEC	4.1	Dec.-%
	WUEF			DEC	4.1	Kg/mm
	Rain			DEC	5.0	mm
	Q			DEC	5.0	mm
	SSF			DEC	5.0	mm
	PRK			DEC	5.0	mm
	ET			DEC	5.0	mm
	MUSL			DEC	5.1	kg/ha
	YNO3			DEC	6.1	kg/ha
	SSFN			DEC	6.1	kg/ha
	PRKN			DEC	6.1	kg/ha
	YAP			DEC	6.1	g/ha
	YP			DEC	6.1	kg/ha
	YN			DEC	6.1	Kg/ha
	REGION			CHAR	3	
MANAGE_ID			CHAR	10		
SCENARIO_ID			CHAR	20		
BIOMASS			REAL	5.1	t/ha	

The abbreviations of the column headers are explained as: Climate station (Station_id), Terrain unit (Soter_unit), Year, Region, Crop_id, Yield, Harvest index (HI), Total biomass including root mass (BIOM), Rainfall (RAIN), Surface runoff (Q), Subsurface flow (SSF), Percolation (PRK), Evapotranspiration (ET), Water erosion (MUSL), Mineral nitrogen in surface runoff (YNO3), Mineral nitrogen in subsurface flow (SSFN), Mineral nitrogen in percolation (PRKN), Mineral phosphorus in surface runoff (YAP).

d3. The YNYP table (table 6)

This table contains the not soluble (suspended) loads of nitrogen (YN) and phosphorous (YP) as well as denitrification rate (DN) in kg/ha and year in the same temporal and spatial resolution as the variables in the BWDIFPOL table.

Table 6: The YNYP table in the section yield and nutrient emissions

Table name	Table fields	PK	FK relation	Data type	Max length / Precision	Unit
YNYP	Station_id			VARCHAR	10	
	Soter_unit			VARCHAR	4	
	Year			INTEGER		
	Yield			REAL		
	Crop_id			VARCHAR	10	
	YN			REAL		kg/ha
	YP			REAL		kg/ha
	DN			REAL		kg/ha
	DR			REAL		%

For scenario calculations, a modified BWDIFPOL table is used to minimize calculation time. The table is called BWDIFPOLSCEN.

Table 7: The table BWDIFPOLSCEN in the section yield and nutrient emissions

Table name	Table fields	PK	FK relation	Data type	Max length / Precision	Unit
BWDIFPOLSCEN	Station_id			VARCHAR	10	
	Soter_unit			VARCHAR	4	
	Crop_id			VARCHAR	10	
	Year			INTEGER		
	Yield			DEC	5.1	t/ha
	HI			DEC	4.1	Dec.-%
	WUEF			DEC	4.1	Kg/mm
	RAIN			DEC	5.0	Mm
	Q			DEC	5.0	Mm
	YN			DEC	6.1	Mm
	YP			DEC	6.1	Mm
	ET			DEC	5.0	Mm
	MUSL			DEC	5.1	kg/ha
	YNO3			DEC	6.1	kg/ha
	SSFN			DEC	6.1	kg/ha
	PRKN			DEC	6.1	kg/ha
	YAP			DEC	6.1	g/ha
	REGION			CHAR	3	
	MANAGE_ID			CHAR	10	
	SCENARIO_ID			CHAR	20	
BIOMASS			REAL	5.1	t/ha	

3. Spatial layers

The attribute tables in SLISYS are accompanied by various spatial layers with point, linear or polygon objects.

3.1. Point objects

The most important point objects are the climate stations located in the basin. They are stored as point layer with Thysen polygons for delimitation of the area of coverage of each station (Fig.2).



Fig. 2: 98 climate stations with daily values of radiation, precipitation, air humidity, min. and max. temperature, wind from 1989 to 2003. (Source: LfU)

In addition settlements and the soil profile locations are stored as a point layer (Figure 3).



Fig. 3: Location of 168 soil profiles with complete description and soil chemical and physical analysis. (Source: LGRB, UHOH-IBS)

3.2. Line objects

The major line object for the applications in RIVERTWIN is the drainage network.

3.3. Polygon objects and raster layers

Polygon and raster layers that are stored in SLISYS are as follows:

- 1- Land use /Land cover layer of the year 2000 with 16 land cover types (source: LfU) (Fig 4)
- 2- Digital Elevation model (50m) (source: Landesvermessungsamt BW)
- 3- Soil associations in Baden-Württemberg at the scale of 1:200.000 (source: LGRB) (Fig. 5)
- 4- Water bodies
- 5- Moneris areas (Fig 6)

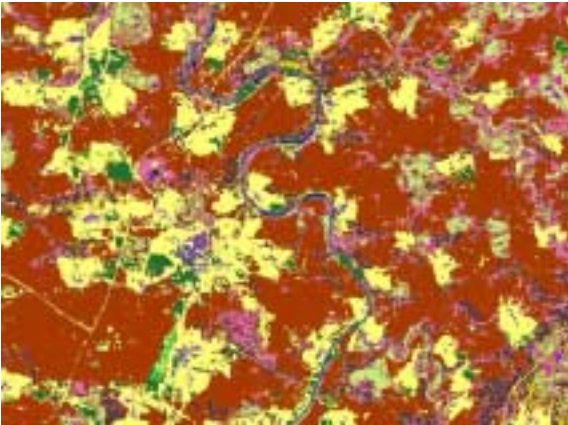


Fig. 4: Portion of the land use classification layer (raster) containing 16 land cover classes (Source: LfU, LANDSAT ETM 2000)

There are some shortcomings with respect to the resolution of the land use and the soil association layer.

a. the land use layer distinguishes within the agricultural areas grassland, arable land, fallow and plantations (vineyards and orchards). No distinctions of different field crops is made within the arable land.

Hence, a Restricted Random Distribution of crops (according to the agricultural census 1999 by Statistisches Landesamt) to the arable land (according to satellite image interpretation by LfU) within each district (Landkreis) has been developed.

- b. In the soil association layer, as a first approach, each mapping unit is represented by one or more representative soil profiles of the **dominant** soil type. However, in each mapping unit there exist between one and 10 associated soil types. This heterogeneity of the soil will be taken into account in a second step by disgregation of the mapping units according to geomorphological features within each mapping unit.

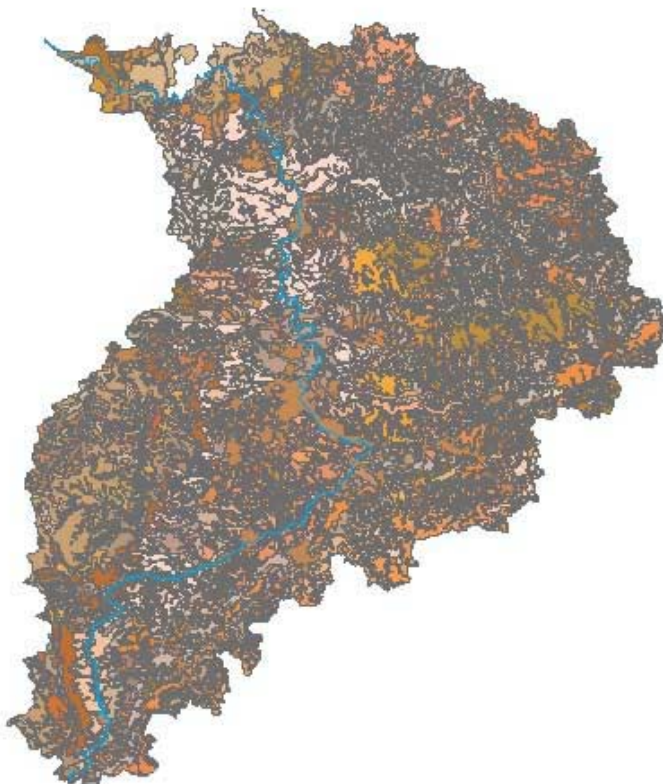
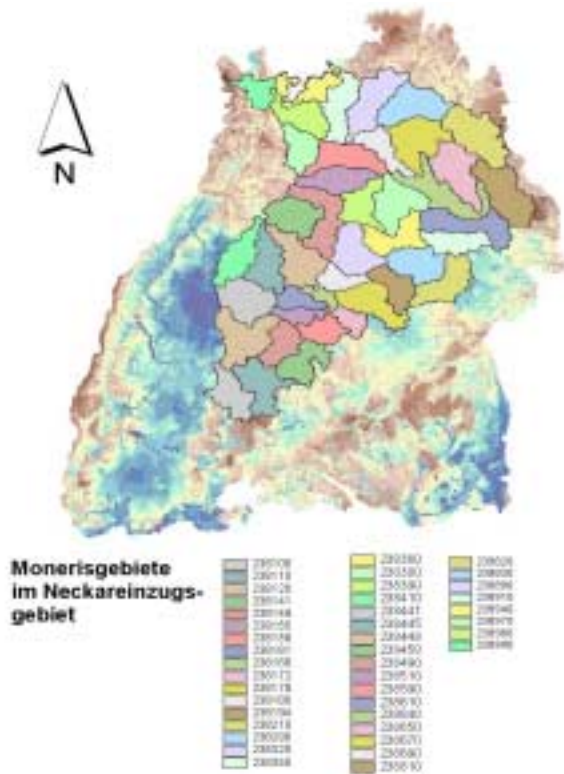


Fig. 5: Soil association map of the Neckar basin at the scale 1:200.000 with 395 mapping units – Legend not shown (Source: LGRB)



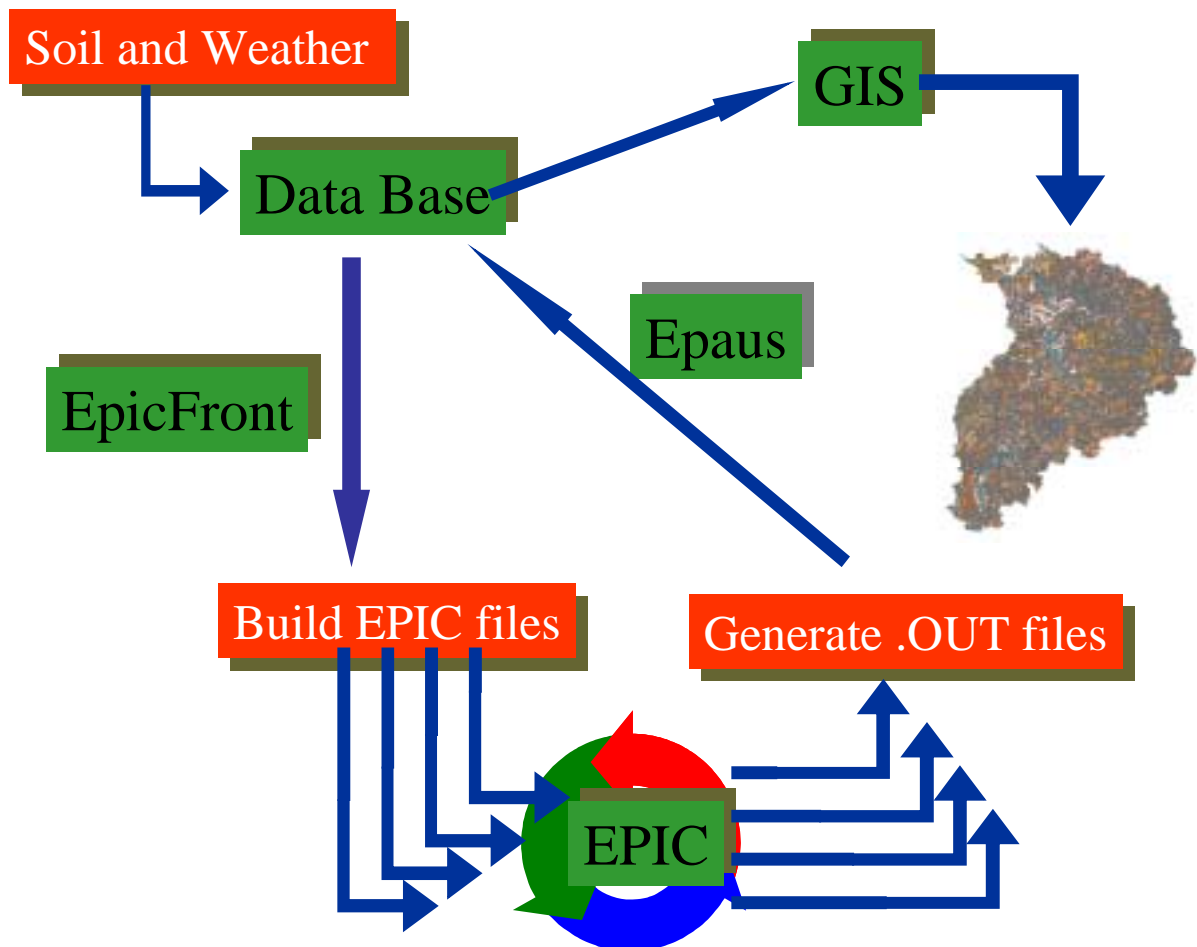


Figure 7: Linkage and workflow in SLISYS for estimation of nutrient loads into water bodies

A detailed description of the simulation procedures (including preprocessing of new climate data sets) is given in Annex V.

5. Results

The performance of the estimations calculated by SLISYS with respect to crop yield and diffuse emissions into the water bodies has been tested in selected subbasins against observations carried out in the year 2000 by the Landesanstalt für Umweltschutz Baden-Württemberg (LfU) and by the Statistisches Landesamt Baden-Württemberg (StaLa).

5.1. Validation of crop productivity at the regional scale

SLISYS estimates yield production at the regional scale based on the aggregation of crop yields realized in each LUSAC depending on the respective climate, soil and crop management conditions. Since the LUSAC units are relatively small (<10 ha) the results can be aggregated to larger units like moneris areas or districts (Landkreise) (Fig 8). In the reference year 2000 the average crop yields over the basin estimated with SLISYS were compared to statistical yields (Fig 9). The estimated crop yield correlated very well with the observed yields. The coefficient of determination is 0.97 for all crops. However, the cereal yields were underestimated on average by 20%. The same trend was observed with tuber crops (potatos) and sugar beets.

Fig. 8: Estimation of the total wheat production per moneris area in the year 2000

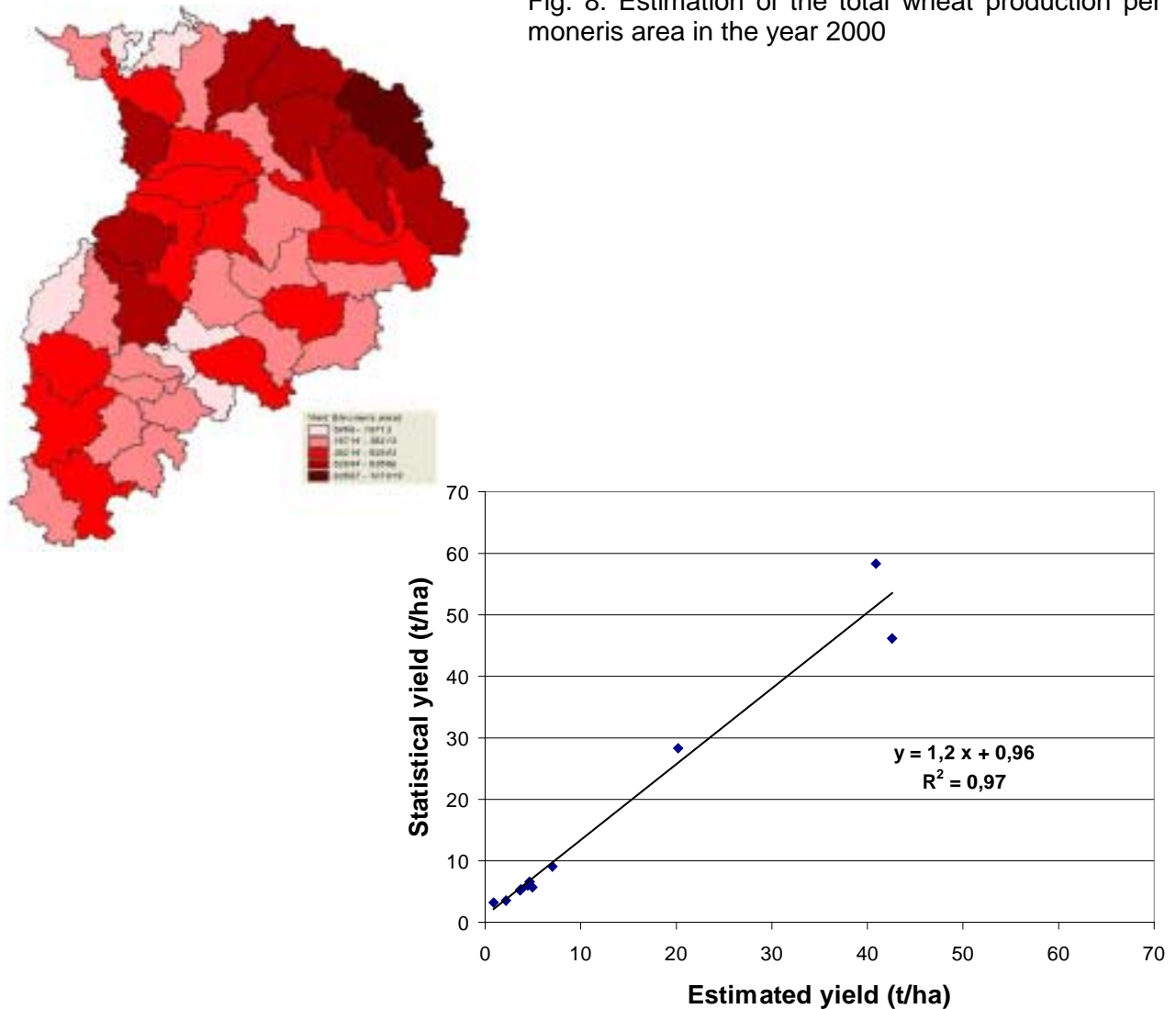


Fig. 9: Comparison of productivity of cereals with agricultural statistics in the year 2000 over the whole basin (SW=Spring wheat, WW = Winter wheat, WBAR=Winter barley, SBAR = Spring barley)

It seems that the main reason for the trend to underestimate crop yields is a bias in the available soil profiles in the Neckar basin. The majority of the soil profiles that are available are from forest sites. The chemical and physical properties of forest soils differ in most cases considerably from the arable soils (although they may belong to the same soil group). Compared to the arable soils, forest soils have higher coarse fragment contents (i.e. lower water holding and nutrient retention capacity), lower pH and sometimes organic layers. The model results of the first version of SLISYS are therefore adequate for showing trends in yield increase or decrease in the Neckar basin due to changes in climatic or crop management conditions. However, for transferring absolute yield values to the ACRE model, the values will be adapted according to crop specific correlation equations as shown in Figure 9.

5.2. Estimation of nitrate loads to groundwater aquifers

SLISYS estimates the total amount of nitrate that is percolating beyond the rooting zone. These values are aggregated to e.g. moneris areas, giving the total load of nitrate to the groundwater per year (Figure 10). In order to check the validity of the results, concentrations of nitrate in the groundwater aquifers are available. In order to produce comparable units, the nitrate concentration

in the leachate is calculated as the total annual nitrate loads divided by the total amount of percolated water. When comparing the leachate and the groundwater concentrations for all moneris areas, the correlation between leachate concentrations is weak (Figure 11a). Figure 9a shows in general higher concentrations in the leachate (factor of about 2 to 3). This is due to the fact that denitrification occurs during the travel time of the leachate into the groundwater aquifers and within the aquifers. There are very few informations about denitrification rates in the Neckar basin. Denitrification can amount up to 50 mg/l depending on the travel time and the age of the waters (Meyer et al. 2005). In fact, most of the moneris areas with highest deviations between groundwater concentration and leachate concentration are in mudstone and claystone areas of the middle and lower Jurassic with long traveling times. When these areas are omitted from the regression plot, then there is a clear linear correlation between leachate concentrations and groundwater concentrations (Figure 11b). The regression line indicates that the mean denitrification rate is a little bit less than 60% all over the basin. The amount of denitrification ranges between 5 and 40 mgNO₃/l.

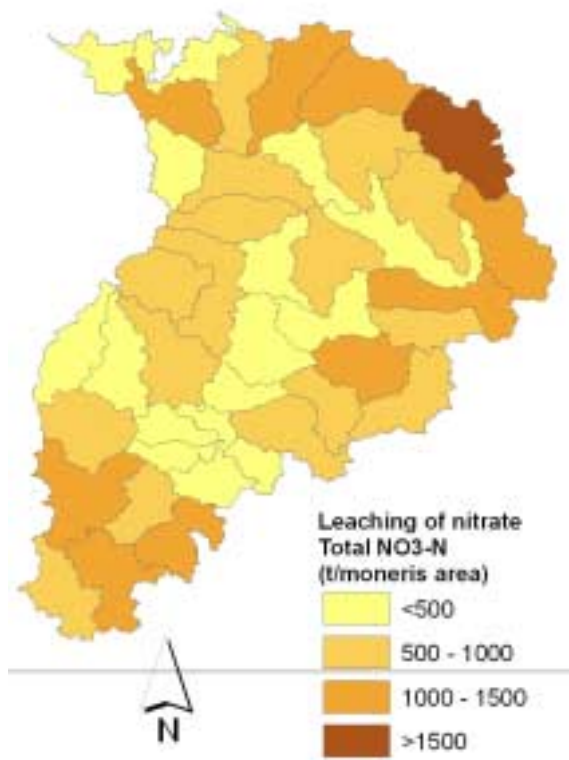


Fig. 10: Total amount of leached nitrate in tons per moneris area in the year 2000

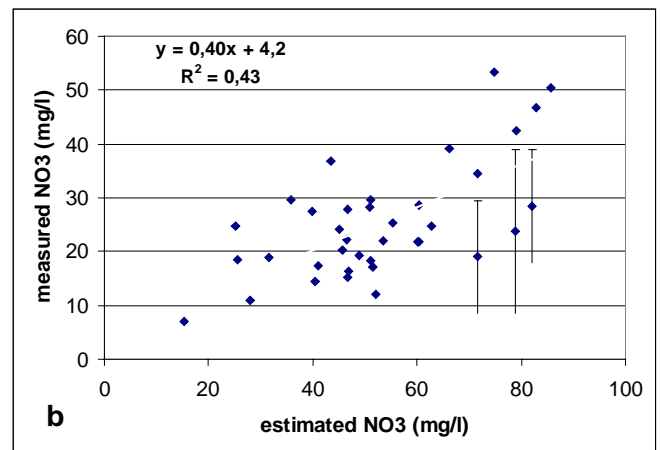
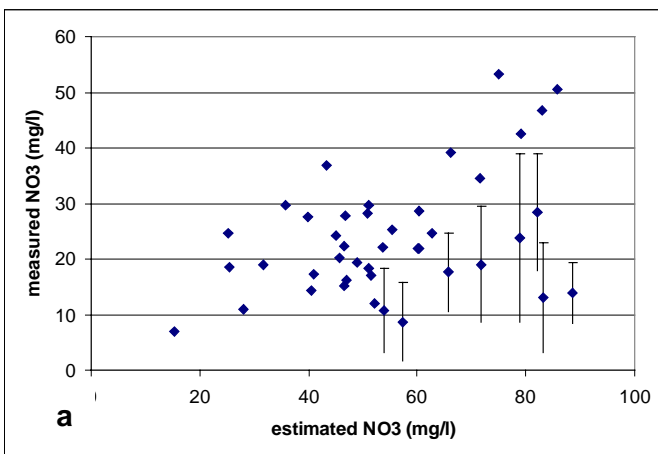


Fig. 11: Correlation between mean nitrate leachate concentration and mean groundwater concentrations in moneris areas (a) including aquifers with long travel time (clay and mudstones from lower and middle Jurassic) (b) without aquifers with long travel time

In conclusion, the SLISYS estimates for nitrate leaching into the groundwater at the regional scale are adequate to assess the increase or decrease of nitrate loads into most of the aquifers. Denitrification rates derived from the relation between calculated leachate concentrations and groundwater concentrations can be used as input into the MONERIS model together with the total annual nitrate loads. This approach will also take into account the enhanced denitrification rate in certain moneris areas with long travel time of the leachates. In the future, the calculated denitrification rates should be validated against measurements of denitrification by advanced methods like the N/Ar method (Eyre et al. 2002).

5.3. Estimation of N and P loads into surface waters

In the integrated model, SLISYS is directly related to the MONERIS model. It creates input for MONERIS like nitrate loads into the groundwater from agricultural production as well as inorganic and organic N and P loads to the drainage network through surface runoff and subsurface flow. Based on the SLISYS input, MONERIS estimates the total N and P inputs into the rivers by calculating the groundwater concentrations, baseflow and adding the point source pollution from WWTPs and urban systems. Then the subsequent model (QUAL2K) calculates the mean transformation losses in the river during the residence time. Therefore, the validation of the pollution loads into the surface water through comparison with measures N and P concentrations in the rivers is only possible in connection with the MONERIS and QUAL2K models. Preliminary results of combined SLISYS and MONERIS results are shown for inorganic N and and inorganic P in Figures 12 and 13. In general the correlation between the estimated and measured annual loads of inorganic N and P is satisfactory in the year 2000 (Figure 13). Nevertheless, there is a discrepancy between measured and estimated loads with respect to the magnitude (Figure 11). As expected, the preliminary results underestimate the N and P immissions because emissions from the small WWTPs and industries are not yet included in the MONERIS model due to lack of data and protective regulations. In addition, the transformation of the pollutants in the river has to be considered as well, which is carried out by QUAL2K.

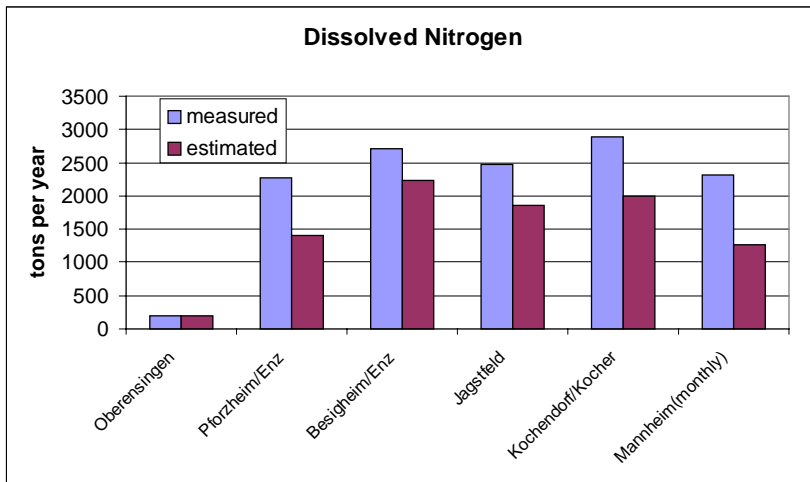


Fig. 12: Comparison of estimated and measured loads of inorganic nitrogen

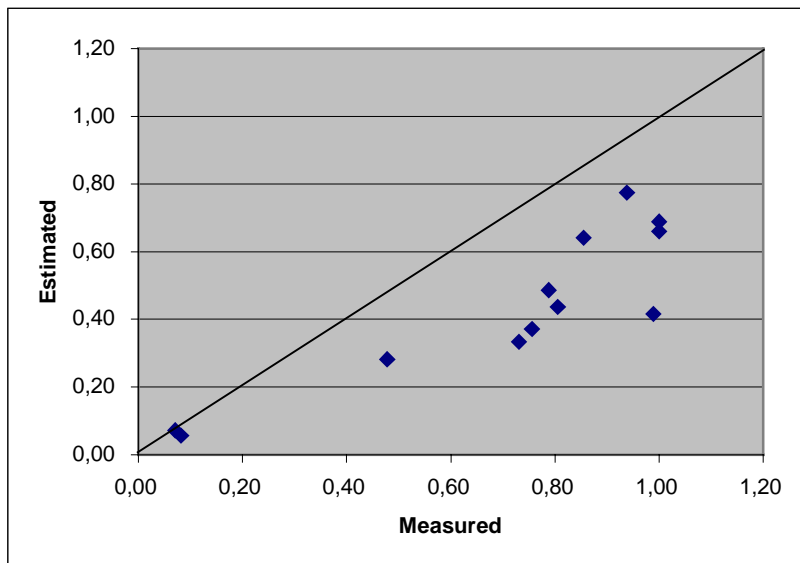


Fig. 13: Correlation between estimated and measured loads of inorganic N and P at six randomly selected monitoring stations in the Neckar basin

In conclusion, the results show that SLISYS and MONERIS describe the tendencies of N and P loads in the tributaries and Neckar river sufficiently well. When including additional data on point source emissions from industries and small WWTP, the SLISYS/MONERIS/QUAL2K model

cascade will be a powerful tool to assess changes in N and P loads in ground- and surface waters due to climatic and land management changes in the Neckar basin.

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- Eyre, B. D., Rysgaard, S., Dalsgaard, T. and Christensen, P. B. 2002. Comparison of isotope pairing and N₂/Ar methods for measuring sediment denitrification rates - assumptions, modifications and implications. *Estuaries* 25, 1077-1087.

6. Annex I: Definition of database tables

Table A1: Relational database tables in the SLISYS climate data section

Table name	Table fields	PK/ relation	FK	Explanation	Data type	Max length / Precision	UNIT
STATION	Station_id	PK		ID of the climate station	CHAR	10	
	Stat_name			Name of the climate station	CHAR	50	
	Latitude				DECIMAL	7.4	
	Longitude				DECIMAL	7.4	
	Rechtswert			Longitude in the German UTM projection	INTEGER	variable	
	Hochwert			Latitude in the German UTM projection	INTEGER	Variable	
	Altitude			Elevation asl of the climate station	INTEGER	Variable	
DATA_SET	Set_id	PK		ID of the data set with monthly data	CHAR	10	
	Station_id	FK/ STATION		ID of the climate station	CHAR	10	
	Kind_data			Specification of the parameter *)	CHAR	4	
	Source_id	FK SOURCE_DATA		ID of the data source	CHAR	10	
	First_year			First year of the period from which the monthly means are calculated	INTEGER		
	Last_Year			Last year of the period from which the monthly means are calculated	INTEGER		
	N_years			Number of years used for the calculation of monthly mean values	INTEGER		
MON_DATA	Set_id	PK / DATA_SET		ID of the Data set	CHAR	10	
	Mon	PK		Number of month	INTEGER		
	Data_values			Data value	DECIMAL	7.2	
DAY_VAL	Station_id	PK / FK STATION		ID of the climate station	CHAR		
	Date	PK		Date	DATE		
	Kind_data	PK		Specification of the parameter *)	CHAR		
	Values				DECIMAL		
SOURCE_DATA	Source_id	PK		ID of the data source	CHAR	10	
	Description				VARCHAR	100	

*) Definition of climate parameter codes: RAIN, TMAX, TMIN, STMN, STMX, HUMI, AVDR, RAD, TEMP,WIND

Table A2: Relational database tables in the SLISYS terrain and soil data section

Table name	Table fields	PK/ FK relation	Explanation	Data type	Max length / Precision	UNit
TERRAIN	Soter_unit_id	PK / SOURCE_MAP	ID of the terrain unit (association of terrain and soil units)	CHAR	4	
	Date_data_collect		Publishing date of the terrain unit map	DECIMAL	4.0	
	Map_id		ID of the terrain unit map	VARCHAR	12	
	Min_elev		Lowest elevation in the terrain unit	DECIMAL	3	m
	Max_elev		Highest elevation in the terrain unit	DECIMAL	3	m
	Slop_gradient		Dominant slope angle	DECIMAL	2	%
	Relief_intensity		Mean relief intensity *)	DECIMAL	3	Code
	Major_landform		Code of major land form*)	CHAR	2	Code
	Regional_slop		Regional slope class	CHAR	2	Code
	Hypsometry		Indication of the elevation of the local base level or above the local base	CHAR	2	Code
	Dissection		Degree of dissection of the terrain	CHAR	1	Code
	General_lithology		Dominant parent material	CHAR	3	Code
	Perman_water_surf		Proportion of permanent water surfaces	CHAR	2	%
	Description		Description of the terrain unit	VARCHAR	100	
TERRAINCOMPONENTS	Soter_unit_id	PK / TERRAIN	ID of terrain unit	CHAR	4	
	Terrain_comp_nbr	PK	The ID number of the terrain component within a certain terrain unit	INTEGER		
	Description		Description of the terrain component	VARCHAR	100	
	Prportion_su		Proportion of the terrain component within the terrain unit	DECIMAL	4.1	%
	Terr_compntdata_id		ID of the terrain component data set	CHAR	6	

Table A3: Relational database tables in the SLISYS terrain and soil data section (cont.)

TERRAIN_COMP_DATA	Terr_compntdata_id	PK	ID of the terrain component data set	CHAR	6	
	Dominant_slope	TERRAINCOMPONENTS		DECIMAL	3.0	
	Lenth_of_slop			DECIMAL	4.0	
	Form_of_slop			CHAR	1	
	Local_surf_form			CHAR	1	
	Average_height			DECIMAL	3.0	
	Coverage			DECIMAL	3.0	
	Surf_lithiology			CHAR	3	
	Txt_nconslid_mater			CHAR	1	
	Depth_to_bedrock			DECIMAL	4.1	
	Surf_drainage			CHAR	1	
	Depth_groundwater			DECIMAL	3.1	
	Frequency_flooding			CHAR	1	
	Duration			CHAR	1	
	Start_flooding			DECIMAL	2.0	
	Description			VARCHAR	100	
SOILCOMPNTS	Soter_unit	PK / TERRAINCOMPONENTS		CHAR	4	
	Terrain_comp_nbr	PK / TERRAINCOMPONENTS		INTEGER		
	Soil_comp_nbr	PK		INTEGER		
	Proport_soter_unit			INTEGER		
	Position_ter_profi			CHAR	1	
	Surf_rockiness			CHAR	1	
	Surf_stoniness			CHAR	1	
	Type_erosion_depos			CHAR	1	
	Area_affected			CHAR	1	
	Degree_erosion			CHAR	1	
	Sensitivity_capping			CHAR	1	
	Rootable_depth			CHAR	1	
	Rlat_othersoilcomp			VARCHAR	254	
	Profil_set	FK PROFIL_SET		CHAR	12	
PROFIL_SET	Profil_set_id	PK		CHAR	12	
	Description			VARCHAR	100	

Table A4: Relational database tables in the SLISYS terrain and soil data section (cont.)

PROFIL	Profil_id	PK		CHAR	12	
	Profil_dbase_id	FK / PROF_D ATA_SO URCE		CHAR	5	
	Latitude			DECIMAL	7.4	
	Longitude			DECIMAL	8.4	
	Elevation			DECIMAL	5.1	
	Sampling_date			DATE		
	Lab_id	FK / LABORA TORY		CHAR	6	
	Drainage			CHAR	1	
	Infiltration_rate			CHAR	1	
	Surf_organicmatter			CHAR	1	
	Classification_FAO			CHAR	5	
	Classificatio_Vers			CHAR	4.0	
	National_classific			DECIMAL	12	
	Soil_taxonomy			CHAR	12	
	Phase			CHAR	2	
	Profil_set	/ PROFIL_ SET		CHAR	12	
	Vegetation			CHAR	10	
	Rechtswert			INTEGER		
	Hochwert			INTEGER		
PROF_DATA_S OURCE	Prof_database_id	PK		CHAR	5	
	Name			VARCHAR	40	
	Reference_id			VARCHAR	10	
LABORATORY	Lab_id	PK		VARCHAR	5	
	Lab_name			VARCHAR	40	
LAB_METHOD	Lab_id	PK / LABORA TORY		VARCHAR	5	
	Lab_date			CHAR	6	
	Attribute			VARCHAR	4	
	Anal_id	PK / ANAL_M ETHOD		VARCHAR	6	
ANAL_METHO D	Anal_id	PK		VARCHAR	6	
	Description			VARCHAR	256	
HORIZON	Profil_id	PK / PROFIL		CHAR	12	
	Horizon_nbr	PK		INTEGER		
	Diagnostic_horizon			CHAR	2	
	Diagnostic_prperty			CHAR	2	
	Horeizon_dsignation			CHAR	5	

	Lower_depth			INTEGER		
	Distincnss_transi			CHAR	1	
	Moist_color			CHAR	9	
	'Dry_color			CHAR	9	
	Grade_of_structure			CHAR	1	
	Siz_struct_element			CHAR	1	
	Type_of_structure			CHAR	1	
	Abundance_c_fragmt			CHAR	1	
	Size_coarse_fragmt			CHAR	1	
	Very_coarse_sand			DECIMAL	3.1	
	Coarse_sand			DECIMAL	3.1	
	Medium_sand			DECIMAL	3.1	
	Fine_sand			DECIMAL	3.1	
	Very_fine_sand			DECIMAL	3.1	
	Total_sand			DECIMAL	3.1	
	Silt			DECIMAL	3.1	
	Clay			DECIMAL	3.1	
	Partcl_size_class			CHAR	4	
	Bulk_density			DECIMAL	4.2	
	Hydrlic_conduct			DECIMAL	4.1	
	Exchangeable_ca			DECIMAL	4.1	
	Exchangeabl_mg			DECIMAL	3.1	
	Exchangeabl_na			DECIMAL	3.1	
	Exchangeabl_k			DECIMAL	3.1	
	Exchangeabl_al			DECIMAL	3.1	
	Xchangeabl_acidity			DECIMAL	3.1	
	Cec_soil			DECIMAL	4.1	
	Total_carb_equival			DECIMAL	3.1	
	Gypsum			DECIMAL	3.1	
	Total_carbom			DECIMAL	4.1	
	Total_nitrogen			DECIMAL	4.1	
	P2O5			INTEGER		
	Phosphate_retention			INTEGER		
	Fe_dithionite			INTEGER		
	Fe_pyrophosphate			INTEGER		
	Al_dithionite			INTEGER		
	Al_pyrophosphate			INTEGER		
	Clay_mineralogy			CHAR	2	
	P_bray			DECIMAL	5.2	
	Root_dens			CHAR	1	

*) For further explanation refer to ISRIC (1993)

7. Annex II: Explanation of codes in the Operation schedule and General data table

AIR	Aeration stress on crop growth (d)
AL5	1/2 Hour alpha (-qpt file)
ALPH	0.5-h precipitation/total storm precipitation
AL SAT	Soil aluminum saturation (%)
ALT	Index of crop tolerance to aluminum saturation (1-5; 1 = sensitive, 5 = tolerant)
ALTC	Alpha (-qpt file)
AOF	Soil loss from water erosion using Onstad-Foster modified USLE (t ha ⁻¹), (T/ac)
AS	Aeration stress factor (0-1)
AVOL	Nitrogen volatilization NH ₃ -N (kg ha ⁻¹), (lb./ac)
BD	Moist soil bulk density (t m ⁻³)
BDD	Dry soil bulk density (t m ⁻³)
BIOM	Crop biomass (shoot + root) (t ha ⁻¹), (T/ac)
BN1	Normal fraction of N in crop biomass at emergence
BN2	Normal fraction of N in crop biomass at midseason
BN3	Normal fraction of N in crop biomass at maturity
BP	Normal fraction of P in crop biomass at emergence
BP2	Normal fraction of P in crop biomass at midseason
BP3	Normal fraction of P in crop biomass at maturity
BW1	Wind erosion factor for standing live biomass
BW2	Wind erosion factor for standing dead crop residue
BW3	Wind erosion factor for flat residue
C	Average water-erosion/crop-management factor
CACO3	Free soil calcium carbonate (%)
CAF plant	Critical aeration factor-fraction of soil porosity where poor aeration starts limiting growth
CAW	Crop available water (mm), (in.)
CEC	Cation exchange capacity (cmol kg ⁻¹)
CF	Wind erosion equation climatic factor

CHT	Crop height (m)
CN	SCS runoff curve number
CN2	SCS runoff curve number for moisture condition 2
CNY	Normal fraction of N in yield (g g ⁻¹)
COSD	Seed cost (\$ /kg ⁻¹), (\$/ lb)
COST	Total production cost (\$)
CPY	Normal fraction of P in yield (g g ⁻¹)
CVM	Minimum value of water erosion C factor
DAYP	Number of days with precipitation
DAYQ	Number of days with runoff
DKH	Furrow dike height (mm)
DKI	Furrow dike interval (m)
DLAI	Fraction of growing season when leaf area index starts declining
DMLA	Maximum potential leaf area index (m ² m ⁻²)
DN	N loss by denitrification (kg ha ⁻¹), (lb./ac)
DP	Depth of tillage (mm)
DUR	Duration (hr) (-qpt file)
EI	Rainfall energy factor
EK	Soil erodibility factor for water erosion
ELEV	Elevation of the site (m)
EP	Transpiration (mm), (in.)
ER	Enrichment ratio (nutrient content of sediment/nutrient content of top soil layer)
ET	Evapotranspiration (mm), (in.)
FC	Soil water content at field capacity (33 kPa for many soils) (m m ⁻¹)
FN	Average annual N fertilizer rate (kg ha ⁻¹)
FP	Average annual P fertilizer rate (kg ha ⁻¹)
FRS(1,2) tem- specified	Two points on the frost damage curve. Numbers before decimal are the minimum peratures (°C) and numbers after decimal are the fraction of biomass lost when minimum temperature occurs.
HI	Harvest index (crop yield/above ground biomass)

HMN	N mineralized from stable organic matter (kg ha-1), (lb./ac)
HMX	Maximum crop height (m)
HRLT	Day length (h)
HU	Heat units-average daily temperature minus base temperature of crop (iC), (iF)
HUM	Stable organic matter (humus) in profile (t ha-1), (T/ac)
HUSC	Heat unit schedule as a fraction; crop heat units to maturity if a crop is growing of fraction of average annual heat units accumulated with 0 iC as the base
temperature	
HV EF	Harvest efficiency. Fraction of yield removed from field by harvest operation
IDC	Crop category number (integer)
	<ul style="list-style-type: none"> 1 Warm-season annual legume 2 Cold-season annual legume 3 Perennial legume 4 Warm-season annual 5 Cold-season annual 6 Perennial 7 Tree erop
IMN	N immobilized by decaying residue (kg ha-1), (lb./ac)
IMP	P immobilized by decaying residue (kg ha-1), (lb./ac)
IRGA	Irrigation water applied (mm), (in.)
LAI	Leaf area index (m ² m ⁻²), (sq. ft./sq. ft.)
LAP(1,2) of leaf area	Two points on optimal leaf area development curve. Numbers before decimal are % growing season. Numbers after decimal are fractions of maximum potential index.
LIME	Limestone applied (CaCO ₃ equivalent) (t ha-1), (T/ac)
MAT-HV	Tree crops only. Years from planting to maturity or harvest
MN P AC	Mineral P concentration in the active pool (g t-1)
MN P ST	Mineral P concentration in the stable pool (g t-1)
MNN	N mineralized (kg ha-1), (lb./ac)
MNP	P mineralized (kg ha-1), (lb./ac)
MSS	Soil loss from water erosion using small watershed MUSLE options (t ha-1), (T/ac)
MUSL	Soil loss from water erosion using modified USLE (MUSLE) (t ha-1), (T/ac)
MUSI	Soil loss from water erosion using modified MUSLE equation with user supplied coefficients (t ha-1), (T/ac)

MUST	Soil loss from water erosion using modified MUSLE theoretically based equation (t ha ⁻¹), (T/ac)
MXEF	Mixing efficiency of tillage operation-fraction of crop residue and other materials in each soil layer of the plot depth that is mixed uniformly within the plow depth
NITR	Nitrification NH ₃ -N conversion to NO ₃ -N (kg ha ⁻¹), (lb./ac)
NFIX	N fixed by leguminous crops (kg ha ⁻¹), (lb./ac)
N03	Nitrate concentration (g t ⁻¹), (oz./T)
NS	N stress factor (0-1)
OP CD	Tillage equipment operation code: -2 Destroys furrow dikes -1 Builds furrow dikes 1 Terminates crop 2 Harvests crop 3 Applies irrigation water 4 Applies fertilizer 5 Plants in rows 6 Plants with drill 7 Applies a pesticide
OR N AC	Organic N concentration in the active pool (g t ⁻¹)
OR N ST	Organic N concentration in the stable pool (g t ⁻¹)
ORG C	Organic C content (%)
ORG P	Organic P concentration (g t ⁻¹)
P5MX	Monthly maximum 0.5 h rainfall for period of record (mm), (in.)
PAPL ha -1)	Pesticide applied with consideration to the application efficiency of the machine (g
PDGF	Pesticide biodegraded on the foliage (g ha ⁻¹)
PDGS	Pesticide biodegraded in the soil (g ha ⁻¹)
PEP	Potential plant water evaporation (mm), (in.)
PET	Potential evaporation (mm), (in.)
PFOL	Pesticide on foliage at the end of a month (g ha ⁻¹)
PH	Soil pH in water
PHU	Potential heat units from planting to physiological maturity (°C)
PLAB	Labile (plant-available) P in profile (kg ha ⁻¹), (lb./ac)
PLCH	Pesticide leached below the soil profile (g ha ⁻¹) 1/
PMIN	Mineral P present in the soil profile (kg ha ⁻¹), (lb./ac)

PRK	Percolation below the root zone (mm), (in.)
PRKN	Mineral N loss in percolate (kg ha ⁻¹), (lb./ac) 1/
PRY	Price of yield (\$ t ⁻¹)
PS	Phosphorus stress (0 - 1)
PSED	Pesticide in the sediment (g ha ⁻¹)
PSOL	Pesticide in the soil at the end of a month (g ha ⁻¹)
PSP	Stress factor (0-1)
PSRO	Pesticide in runoff (g ha) 1/
PSSF	Pesticide in subsurface flow (g ha ⁻¹) 1/
PST damage	Pest damage factor (insects, weeds, disease)-fraction of yield remaining after damage
PSTF residue	Generic pest damage factor that is a function of temperature, moisture and crop residue
PW/D	Monthly probability of wet day after dry day
PW/W	Monthly probability of wet day after wet day
Q	Surface runoff (mm), (in.)
QIN	Inflow to the root zone from the water table (mm), (in.)
QP	Peak runoff rate (mm h ⁻¹), (in./hr.)
RAD	Solar radiation (MJ m ⁻²), Langely's
PRCP	Precipitation (mm), (in.)
RBMD	Biomass-energy ratio decline rate parameter
RD	Root depth (m), (ft.)
RDMX	Maximum root depth (m), (ft.)
REG	Crop growth regulator (minimum stress factor 0-1)
RHT	Ridge height after tillage operation (mm)
RHUM	Relative humidity
RIN	Ridge interval after tillage operation (m)
RLAD	Leaf-area-index decline rate parameter
RN	N in precipitation (kg ha ⁻¹), (lb./ac)
ROCK	Soil coarse-fragment content (volume %)

RR	Random roughness of soil surface (mm), (in.)
RSD	Crop residue on soil surface (t ha ⁻¹), (T/ac)
RSDK	Residue decay (t ha ⁻¹), (T/ac)
RTRN	Total income from crop sales (\$)
RW	Total root weight (t ha ⁻¹), (T/ac)
RWT	Root weight in a soil layer (t ha ⁻¹)
SDW	Normal planting rate (kg ha ⁻¹), (lb./ac)
SDRF	Monthly standard deviation of daily precipitation (mm), (in.)
SKCF	Monthly skew coefficient for daily precipitation
SM BS	Sum of bases in soil (cmol kg ⁻¹)
SNOA	Snow accumulation (mm), (in.)
SNOW	Water content of snowfall (mm), (in.)
SSF	Lateral subsurface flow travel time (d)
SSFN	Mineral N loss in subsurface flow (kg ha ⁻¹), (lb./ac) 1/
STD	Standing dead crop residue (t ha ⁻¹), (T/ac)
STL	Standing live plant biomass (t ha ⁻¹), (T/ac)
STMN	Monthly average standard deviation of daily minimum air temperature (°C), (°F)
STMX	Monthly average standard deviation of daily maximum air temperature (°C), (°F)
STRS variables.	The type and number of days of stress by month for the three highest stress variables. Water = 1, N = 2, P = 3, Temperature = 4, Aeration = 5. Example: 411107201 means that there were 11 days of temperature stress (411), 7 of water stress (is 107), and 1 day of nitrogen stress (is 201).
days	
SW	Total soil water in the profile (m m ⁻¹), (in/in.)
TB	Optimal temperature for plant growth (°C)
TEMP	Temperature stress on crop growth (d)
TG	Minimum temperature for plant growth (°C)
THK	Thickness of soil eroded by wind and water (mm), (in.)
TMN	Minimum daily air temperature (°C), (°F)
TMP	Temperature in second soil layer (°C), (°F)
TMX	Maximum daily air temperature (°C), (°F)

TNH3	Total NH ₃ -N present in the soil profile (kg ha ⁻¹), (lb./ac)
TNO3	Total NO ₃ -N present in the soil profile (kg ha ⁻¹), (lb./ac)
TS	Temperature stress factor (0 -1)
UNO3	N uptake by the crop (kg ha ⁻¹), (lb./ac)
UPP	P uptake by the crop (kg ha ⁻¹), (lb./ac)
USLE	Soil loss from water erosion using USLE (t ha ⁻¹), (T/ac)
VPD	Vapor pressure deficit (kPa)
WA	Energy to biomass conversion factor(t ha ⁻¹ MJ ⁻¹ m ⁻²)
WCY	Fraction water in yield
WENG	Wind energy (kWh m ⁻²), (kWh/sq. ft.)
WK	Soil erodibility factor for wind erosion
WP	Soil water content at wilting point (1500 kPa for many soils) (m m ⁻¹)
WS	Water stress factor (0 - 1)
WSYF	Coefficient of crop yield sensitivity to water stress at the most critical stage of growth
WTBL	Depth from soil surface to water table (m), (ft.)
WSPD	Wind velocity (m s ⁻¹), (mph)
YAP	Soluble P loss in runoff (g ha ⁻¹), (lb./1000.ac)**1
YLD etc.	Crop yield (t ha ⁻¹), (T/ac) NOTE: this is crop dependent, ie: bushels, pounds, tons, etc.
YLN	N in crop yield (kg ha ⁻¹), (lb./ac)
YLP	P in crop yield (kg ha ⁻¹), (lb./ac)
YN03	NO ₃ loss in surface runoff (kg ha ⁻¹), (lb./ac) **1
YON	Organic N loss with sediment (kg ha ⁻¹), (lb./ac)
YP	P loss with sediment (kg ha ⁻¹), (lb./ac)
YW	Soil loss from wind erosion (t ha ⁻¹), (T/ac)
X4	Time of concentration for overland flow (hr) (-qpt file)

1/ Numbers to the right of the decimal are concentration, where the last digit identifies the units
(1 = PPM, 2 = PPB, 3 = PPT)

8. Annex III: EPIC Variables With Their Subscripts and Metric to English Conversions

Accumulated Variables

1.	TMX	*1.8+32	Fahrenheit
2.	TMN	*1.8+32	Fahrenheit
3.	RAD	*23.9	Langley's
4.	RAIN	/25.4	inches
5.	SNOW	/25.4	inches
6.	Q	/25.4	inches
7.	SSF	/25.4	inches
8.	PRK	/25.4	inches
9.	ET	/25.4	inches
10.	EP	/25.4	inches
13.	EI	*1	
14.	MUST	*.4494	ton/acre
15.	C	*1	
16.	YW	*.4494	ton/acre
17.	YON	*.8927	pounds/acre
18.	YNO3	*.8927	pounds/acre
19.	SSFN	*.8927	pounds/acre
20.	PRKN	*.8927	pounds/acre
21.	MNN	*.8927	pounds/acre
22.	TNH3	*.8927	pounds/acre
23.	DN	*.8927	pounds/acre
24.	NFIX	*.8927	pounds/acre
25.	UNO3	*.8927	pounds/acre
26.	HMN	*.8927	pounds/acre
28.	YP	*.8927	pounds/acre
29.	YAP	*.8927	pounds/acre
30.	UPP	*.8927	pounds/acre
31.	MNP	*.8927	pounds/acre
32.	AVOL	*.8927	pounds/acre
40.	TMP	*1.8+32	Fahrenheit
42.	PET	/25.4	inches
43.	RHUM	*1	
44.	MSS	*.4494	tons/acre
45.	VPD	*1	
46.	MUSI	*.4494	tons/acre
47.	AOF	*.4494	tons/acre
48.	USLE	*.4494	tons/acre
51.	WVL	*2.237	miles/hour
52.	MUSL	*.4494	tons/acre
57.	QP	/25.4	inches

State Variables

11.	SW	*1	
12.	WTBL	*3.281	feet
27.	TNO3	*.8927	pounds/acre
33.	HU	*1	
34.	LAI	*1	
35.	RD	*3.281	feet
36.	RW	*.4494	tons/acre
37.	BIOM	*.4494	tons/acre
38.	RSD	*.4494	tons/acre
39.	STD	*.4494	tons/acre
49.	PLAB	*.4494	tons/acre
50.	STL	*.4494	tons/acre
56.	CN	*1	
59.	HRLT	*1	hours

Miscellaneous Variables

41.	IRGA	/25.4	inches
53.	NITR	*.8927	pounds/acre
54.	FN	*.8927	pounds/acre
55.	FP	*.8927	pounds/acre
58.	LIME	*.4494	tons/acre
60.	WS	*1	
61.	NS	*1	
62.	PS	*1	
63.	TS	*1	
64.	AS	*1	
65.	REG	*1	
66.	TAV	*1.8+32	Fahrenheit
67.	ALPH	*1	
68.	WENG	*1	
69.	DAYQ	*1	
70.	QIN	/25.4	inches
71.	STMX	*1.8+32	Fahrenheit
72.	STMN	*1.8+32	Fahrenheit
73.	RN	*.8927	pounds/acre
74.	DAYP	*1	
75.	STRS	*1	
77.	YLN	*.8927	pounds/acre
78.	ER	*1	
79.	PSTF	*1	
80.	COST	*2.47	\$/acre
81.	RTRN	*2.47	\$/acre

* denotes multiplication

/ denotes division

9. Annex IV: Definition of user specific management practices in the EPICSOTER interface

This paragraph gives just a short introduction into the definition of user specified schedules of field operations in the Management window of the EPICSOTER interface software.

The management window consists of 3 parts

1. drop down field
2. definition of number of years of the rotation and definition of irrigation management
3. definition of chronological field operations

1. Drop down field

It is used for selection of predefined management practices. If you want to specify your own management practice then write your identification name or ID into this field

2. Definition of number of years of the rotation and definition of irrigation management

When you need an explanation of the input parameters, this is given for each field in the status bar on the lower edge of the window when you go with the cursor to the respective input field.

EPIC allows the user to simulate complex crop rotations with a variety of irrigation, fertilizer, pesticide, and runoff control (furrow dike) options. The example given in section C.1 illustrates a two-year cotton-wheat cover crop-grain sorghum rotation with a complex combination of tillage, fertilizer, irrigation, furrow diking, and pesticides. Cotton is planted in year 1 with automatic irrigation, manual fertilizer, pesticide applications and a wheat cover crop for winter wind erosion control. The second crop year is irrigated grain sorghum with furrow dikes to conserve water. This system would have:

NRO-Crop Rotation Duration

The duration of this example rotation is 2 years. It is unusual for rotations to exceed four years in decision making applications. However, in model tests involving multi-year research results, it is possible to define the rotation as the entire period of record (up to 30 years) because any change in management (crop, fertilizer application, planting and harvest dates, or tillage) requires a separate year in the rotation.

NIRR-Rigidity of Irrigation Code

[0] for flexible applications

[1] for rigid applications - maximum application rate at each irrigation

The rigidity of irrigation code is used to specify the irrigation strategy.

There are two modes of irrigating -- manual and automatic.

Manual has two types.

- 1.) If the rigidity code is set at rigid application (NIRR = 1), irrigation occurs on user specified dates at specified volumes.
- 2.) If flexible application is selected (NIRR = 0), but the volume of water applied would exceed the soil water storage capacity, then irrigation on the specified day is reduced to the amount necessary to fill the soil profile.

Automatic also has two types.

- 1.) If NIRR is set to zero (flexible), the irrigation is applied only when needed and only as much as is needed. This is subject to upper and lower application limits.
Irrigation water is not applied unless the soil can store at least the minimum per application amount.

2.) If NIRR is set to 1 (rigid), application amounts are the maximum single application, but they are applied only when the irrigation rules permit.

IRR-Irrigation Code

- [0] for dryland
- [1] for sprinkler irrigation
- [2] for furrow irrigation
- [3] for fertigation

The irrigation code is used to specify the type of irrigation system.

IRI-Minimum Application Interval

Minimum number of days between automatic irrigation applications.

8.1.4 7 **IRI**

The variable, IRI controls the minimum number of days between irrigations. Sprinkler and furrow irrigation systems usually have limited capacity. For example, center pivot systems may complete a circle every three to seven days, depending on the size of the circle and capacity of the well. For example: 450 gpm is about 1 acre-inch or 12.5 mm per ha per hour. Thus, 135 acres / 2 inches per hour (900 gpm well) = 67.5 hours per acre-inch = 3 days.

IFA-Minimum Application Interval

There are three basic types of automatic fertilizer application options. The first (IFA = 0) assumes that the farmer fertilizes to bring the kg. of N available in the soil to a level equal to the fraction at planting (FNP) times the maximum N application per crop year (FMX). Fertilizer applications are triggered any time the biomass produced on a given day divided by the potential biomass that could be produced that day is less than the fraction specified by the N stress trigger factor. If N stress triggers an application then the fertilizer is applied to raise the soil N to (FNP x FMX). This is subject to two restrictions:

1. The number of days since the last application must be greater than the fertilizer application interval (IFA)
2. The accumulative amount of fertilizer applied that crop year does not exceed the maximum fertilizer that can be applied for crop year (FMX).
3. The soil P and N concentrations are less than miscellaneous parameters 16 and 20 respectively.

For example, if IRI = 30; IFFA = 0, BFT = .85, FNP = .5 and FMX = 200 then enough fertilizer would be applied to raise the soil N to 100 kg/ha when the biomass produced under N stress / potential biomass production that day is less than .85 and it has been 30 days since the last fertilizer application and the total of all previous applications plus this application for this crop year are less than 200 kg.

The second automatic fertilizer option is the same as the first except that automatic fertilizer is not triggered at planting for the option IFFA = 1.

The third automatic fertilizer option works like the previous two except that each time stress triggers a fertilizer application, the application is equal to $FNP \times FMX$ (100 kg/ha in the above example).

BFT- N stress factor to trigger automatic fertilization

Fertilizer applications are triggered any time the biomass produced on a given day divided by the potential biomass that could be produced that day is less than the fraction specified by the N stress trigger factor.

FMX Max annual fertilizer applied

The accumulative amount of fertilizer applied to a crop per year that can not be exceeded.

FNP Amount of fertilizer per automatically scheduled application or Fraction of maximum N fertilizer applied at planting

If N stress triggers an application then the fertilizer is applied to the amount specified as FNP (when $FNP > 1$ in kg/ha) or to raise the soil N to $FNP \times FMX$ (if $FNP < 1$). This is subject to restrictions mentioned above.

LM Liming Code

(0) = Automatic application of lime

(1) = No automatic fertilization

IFD-Furrow Dike Code

Furrow dikes (or tied ridges) are small dams constructed, usually by tillage equipment, in the furrows. They are designed to impede runoff and promote infiltration of rainfall and/or sprinkler irrigation. EPIC simulates the construction, function, and destruction of furrow dikes. The furrow dike code IFD is used to determine whether dikes are simulated.

[1] Furrow dikes simulated

[0] Furrow dikes not simulated

IDR-Drainage Code

Artificial drainage systems (tiles, perforated pipes, open ditch drains, etc.) are often installed to remove excess water from fields. The drainage code, IDR, is set to [0] if a drainage system is not considered. If a drainage system is present, IDR is the soil layer number containing the system (1 through 10).

IDFT Fertilizer ID in the fertilizer file for automatic fertilization

In later versions (Version 5300 and later) the fertilizer IDs for different fertilizer types are defined in the file "fert5300.dat" In version 0941 there is no such option

BIR-Water Stress Factor to Trigger Irrigation Automatically

To trigger automatic irrigation, the crop water stress factor is set to a stress level between 0 and 1, with 1 representing no stress and 0 indicating complete cessation of transpiration. When the plant water stress factor reaches BIR, the plants may be irrigated. If manual irrigation is selected, BIR is entered as [0].

If a value of BIR > 1 is entered, the model understands the value to be the soil moisture tension in the second soil layer (Kilopascals, 33 to 1500, positive values) needed to trigger irrigation.

If a value less than 0 is entered, the model understands the value to be millimeters of soil water below field capacity. Thus, -100 will schedule irrigations whenever the soil has 100mm less water stored in the root zone than that stored at field capacity.

EFI-Irrigation Runoff Ratio

Runoff vol./vol. irrigation water applied. Irrigation water is often lost to runoff, especially with furrow irrigation systems. The irrigation runoff ratio specifies the fraction of each irrigation application that is lost to runoff. A value of zero indicates no runoff.

VIMX-Maximum Annual Irrigation Per Crop (mm)

Irrigation volumes can be limited by VIMX, the maximum allowed for each crop. VIMX=[0] defaults to 2000mm. This example assumes no more than 24 inches (600 mm) is applied per crop.

ARMN-Minimum single application volume automatic irrigation (mm)

The minimum volumes allowed for single application regulates individual irrigation applications.

ARMX-Maximum single application volume automatic irrigation (mm)

The maximum volumes allowed for single application regulates individual irrigation applications. This is the amount applied if rigid automatic irrigation is selected. Enter 0 if unknown.

DRT-Time Required for Drainage System to Reduce Plant Stress

Artificial drainage systems may be very efficient and quickly reduce water tables or it may take several days for the water level to decline sufficiently to eliminate aeration stress. The variable DRT is used to specify the time needed for the drainage system to eliminate stress. In this case time is measured days. If drainage is not considered, enter 0.

FDSF-Fraction of furrow dike volume available for storage

When furrow dikes or tied ridges are constructed, some fraction of the total volume is available for water storage. The variable FDSF allows the user to specify this value. For paddy rice e.g. this is set to a paddy volume of 99% of the theoretical volume it could hold.

3. Definition of chronological field operations

For the definition of the operation schedule it is useful to prepare a narrative of the field activities. The following narrative describes all the crop management activities used in our example of cotton - terminated wheat - grain sorghum two year rotation. Then the following two tables (one for each year) show how the narrative descriptions are converted into numerical EPIC inputs.

Year 1:

Grain sorghum residue from the previous crop is chiseled on March 25. Cotton is planted May 20, and water stress is set at 0.75 to turn on automatic irrigation. Cotton is cultivated June 25 and July 15. Anhydrous ammonia is injected July 30, and a pesticide is applied. On September 1, the automatic irrigation is shut off by setting the water stress to 9999. The cotton is harvested October 15 and terminated. The field is chiseled the next day and a winter wheat cover-crop is planted October 20.

Year 2:

February 15, the winter wheat is shredded. March 15, it is sprayed with glyphosate to terminate the wheat on March 16. March 17, the grain sorghum is planted and fertilizer is applied. Automatic irrigation is turned on, and the plant water stress trigger is set to 0.85. On April 1, furrow dikes are built. Fertilizer is applied again on April 25, when the crop is cultivated and furrow dikes are rebuilt. On July 15, the automatic irrigation is turned off. August 15, the furrow dikes are removed and the grain sorghum is harvested and terminated. The grain sorghum residue is shredded on August 20 and chiseled on September 1.

8.3 Management Information-Irrigation/Fertilizer/Tillage Schedule
(One for each year of rotation)

MON	DAY	COD	CRP/GRZ	MAT	PHU	CND	WSF	FPP	FNMX
	HUSC		FN		FAP	FDP			
			PST		IA	PAR		QVOL	
<u>3</u>	<u>25</u>	<u>32</u>							
<u>5</u>	<u>20</u>	<u>2</u>	<u>10</u>		<u>1700</u>		<u>.075</u>		
<u>6</u>	<u>25</u>	<u>21</u>							
<u>7</u>	<u>15</u>	<u>21</u>							
<u>7</u>	<u>30</u>	<u>12</u>	<u>57</u>		<u>200E</u>	<u>3E</u>			
<u>7</u>	<u>30</u>	<u>11</u>	<u>8</u>		<u>0.90</u>		<u>.38E</u>		
<u>9</u>	<u>1</u>	<u>9</u>					<u>9999</u>		
<u>10</u>	<u>15</u>	<u>50</u>							
<u>10</u>	<u>15</u>	<u>41</u>							
<u>10</u>	<u>18</u>	<u>32</u>							

10 20 3 4 1500 _____

- MON = Month of the operation
- DAY = Day of the operation
- COD = Operation/Tillage code number
- CRP/GRZ = Crop identification number OR Grazing duration in days
- MAT = Years necessary to mature or years until harvest. (For trees only)
- PHU = Potential Heat Units
- CND = Runoff curve number after this operation
- WSF = Plant water stress factor
- FPP = Fraction of original plant population
- FNMX = Maximum annual nitrogen fertilizer applied to a crop
- HUSC = Time of this operation as a fraction of the growing season or of the year if no crop is growing; using 0°C as the base temperature
- FN = Fertilizer ID number applied
- FAP = Fertilizer application rate (kg/ha - 0% moisture)
- FDP = Depth of fertilizer placement (mm)
- IA = Irrigation volume (mm)
- QVOL = Runoff VOL/VOL of irrigation water applied
- PST = Pesticide ID number
- PCF = Pest control factor (fraction)
- PAR = Pesticide application rate (kg/ha or lbs/ac of active ingredient)

8.3 Management Information-Irrigation/Fertilizer/Tillage Schedule

(One for each year of rotation)

MON	DAY	COD	CRP/GRZ	MAT	PHU	CND	WSF	FPP	FNMX
HUSC		FN	FAP	FDP	IA	QVOL			
		PST	PCF	PAR					
<u> 2 </u>	<u> 15 </u>	<u> 57 </u>	_____	_____	_____	_____	_____	_____	_____
<u> 3 </u>	<u> 15 </u>	<u> 11 </u>	<u> 57 </u>	_____	<u> 0.90 </u>	<u> .75E </u>	_____	_____	_____
<u> 3 </u>	<u> 16 </u>	<u> 41 </u>	_____	_____	_____	_____	_____	_____	_____
<u> 3 </u>	<u> 17 </u>	<u> 2 </u>	<u> 3 </u>	_____	<u> 1600 </u>	<u> .85 </u>	_____	_____	_____
<u> 3 </u>	<u> 17 </u>	<u> 10 </u>	<u> 53 </u>	_____	<u> 100E </u>	<u> 3.0E </u>	_____	_____	_____
<u> 4 </u>	<u> 1 </u>	<u> 75 </u>	_____	_____	_____	_____	_____	_____	_____
<u> 4 </u>	<u> 25 </u>	<u> 10 </u>	<u> 62 </u>	_____	<u> 50E </u>	<u> 3.0E </u>	_____	_____	_____
<u> 4 </u>	<u> 25 </u>	<u> 19 </u>	_____	_____	_____	_____	_____	_____	_____
<u> 4 </u>	<u> 25 </u>	<u> 75 </u>	_____	_____	_____	_____	_____	_____	_____
<u> 7 </u>	<u> 15 </u>	<u> 9 </u>	_____	_____	_____	<u> 9999 </u>	_____	_____	_____
<u> 8 </u>	<u> 15 </u>	<u> 77 </u>	_____	_____	_____	_____	_____	_____	_____
<u> 8 </u>	<u> 15 </u>	<u> 50 </u>	_____	_____	_____	_____	_____	_____	_____
<u> 8 </u>	<u> 15 </u>	<u> 41 </u>	_____	_____	_____	_____	_____	_____	_____
<u> 8 </u>	<u> 20 </u>	<u> 57 </u>	_____	_____	_____	_____	_____	_____	_____
<u> 9 </u>	<u> 1 </u>	<u> 32 </u>	_____	_____	_____	_____	_____	_____	_____

- MON = Month of the operation
- DAY = Day of the operation
- COD = Operation/Tillage code number
- CRP/GRZ = Crop identification number OR Grazing duration in days
- MAT = Years necessary to mature or years until harvest. (For trees only)

PHU = Potential Heat Units
CND = Runoff curve number after this operation
WSF = Plant water stress factor
FPP = Fraction of original plant population
FNMX = Maximum annual nitrogen fertilizer applied to a crop
HUSC = Time of this operation as a fraction of the growing season or of the year if no crop is growing; using 0°C as the base temperature
FN = Fertilizer ID number applied
FAP = Fertilizer application rate (kg/ha - 0% moisture)
FDP = Depth of fertilizer placement (mm)
IA = Irrigation volume (mm)
QVOL = Runoff VOL/VOL of irrigation water applied
PST = Pesticide ID number
PCF = Pest control factor (fraction)
PAR = Pesticide application rate (kg/ha or lbs/ac of active ingredient)

10. Annex V: SLISYS manual

A Reference year 2000

This manual refers to the estimation of diffuse pollution (emissions of dissolved N and P through leaching, surface runoff, subsurface flow as well as N and P in eroded soil material) from all land use types except settlements and swamps at the river basin scale. The estimation is based on simulations with the agroecosystem model EPIC (Erosion Productivity Impact calculator). The basin has been subdivided into quasi-homogenous units of land use, soil and climate so called LUSACs. EPIC calculates the target variables for each LUSAC unit. Therefore, in a first step the EPIC input files for the different LUSACs have to be created from the database as described above and after the simulation the output variables have to be extracted from the output files and must be returned to the data base.

The main steps are (Figure 7):

- f. creation of EPIC input for the river basin area (a total of 1779 files is produced)
 - g. Running the EPIC simulations
 - h. Extracting the EPIC output files into the SLISYS database
 - i. Aggregation of the simulation results to the LUSAC areas
 - j. Aggregation from LUSAC areas to water body, moneris area or subbasin level
- a. Creation of EPIC input files for the river basin area (all profiles within each terrain unit)

The EPIC input files for each soil profil in each terrain unit in the river basin are created using the EPICSOTER software. This is a windows based menu driven software that allows the input and retrieval of crop management patterns into the data domain of SLISYS (called NECKAR3, status September 2005). It consists of a login window, a main menu window and four input windows. Each window consists of several buttons in the upper left corner and input fields (with or without drop down option). The meaning of the buttons is :

U-button= Update the data set
 y-button: Retrieve the data set
 + button= Add a new data set
 - button= delete a new data set

The meaning of the buttons is highlighted when the cursor is placed over the buttons.

After clicking on the program icon EpicSoter the procedure is as follows:

- Login window: give your user id, password, and the name of the database you want to access (in this case NECKAR3, in upper case letters). Then press "connect"
- Change to the Main menu window. Click in the menu bar on "Management". Either input a userspecified crop management pattern or select from the first drop down field.
- In the case of selecting a predefined crop management press the retrieve button and then go to the Main menu window and press "General data" in the menu bar. Otherwise you have to fill the parameters that define your userspecified crop management pattern. This requires the EPIC0941 manual (Annex 2).
- General data window: In this window you select the time period (one or several years) that you want to simulate In addition you can specify different simulation control variable like Output control (NIPD and IPD), equation to calculate ETP (IET), and initial soil water content as a fraction of the field capacity (FFC). Select a predefined data set. If your preference data set is not available, then go to the EPIC0941 user manual (see Annex 2).
- Terrain select window: In this window you can choose the terrain (SOTER) units that you want to simulate. In order to launch a run for the whole Neckar basin just put in the 'B%' as the code for the soter unit and press the U-Button (update button)

- The last step is to define the folder where the input files should be written to. Therefore, go to the "file creation" window. Put in the path of the folder or select from the explorer by pressing the ?-button. Finally press the "Do it"-button. After the completion of the task, please take note of the number of input files that were created.

b. Running the EPIC simulations

After writing the files to the specified folder, go to the MS-DOS command window and change to the folder with the input files. Copy the files in the subdirectory c:\EPICBWSOTER into your folder by typing `copy c:\epicbwsoter*.*`. Then type the command "eprun" and launch the simulation.

c. Extracting the EPIC output files into the SLISYS database

The extraction of the results of the simulations into the SLISYS database requires some preprocessing of the output files. Before the preprocessing you should check, whether all input files were running successfully. This is done by using the SEARCH option from the WINDOWS START menu. Search your folder for all *.epy and all *.c?? files and check whether they match with the total number of input files. If the number of files is lower then you have to check the *.out files, whether there are *.out files that are much smaller than the others. Usually problems may occur in the water flux simulation, when daily rainfall data are used. After identification of the file name that did not successfully finish the simulation, go to the input file and change the weather input code from daily (1) to monthly (0). This is in the input file (*.dat) the ??? number in line 4. Then start the simulation on the MS-DOS command line for this particular file by entering "ewq <filename> /OA". Then check again the number of *.epy and *.c?? files in your folder.

- (1) Processing of the EPY Files: The *.EPY files contain output variables specified in the PRNT0941.dat file (e.g. Rain, surface runoff, subsurface flow etc.) at a yearly resolution. The transformation of the files is done by typing "epy1y2" in the command line for all crops EXCEPT Apple (crop ID 050) and Forest (cropID 130). The program asks the number of input files that have to be processed. Give the number of input files as stated in the File creation window (see section above). Since apple plantations (cropID 050) and forest (cropID 130) are simulated for 10 (1991-2000) and 30 years (1971-2000) the transformation is carried out by the program „epy1y10“ and „epy1y30“ respectively.
- (2) Processing the C??-files: The *.C??-files contain information about the yield, harvest index, biomass production and water use efficiency. Type "cf2000" and give again the number of input files and in addition the extension of your C??-file. The extension number is equivalent to the crop ID (e.g. c01 for summer wheat or c07 for oats) (ONLY NECESSARY, WHEN SIMULATING SUMMER CROPS IN THE YEAR 2000!!!!).
- (3) Some crops are not harvested (e.g. forest ID=130). In this cases C??- files are produced by the programs creatc32 (for forest). It produces .c32 files with a one year result line. This program requires the presence of the file „FILELIST.TXT“ containing a list of filenames (with the structure ewq filename.dat) that should be produced and a the sample file „IN.CO2“. For pasture and grassland (cropID 070, 080,090, 110 and 416) where crop is harvested in 1999 and 2000 the program „cf2000wps“ must be used. Apple plantations, which are run on a 10 years basis, the output files (*.c30) must be converted into output files with the yield of the year 2000 only. This is carried out with the program „c30y10“.

Table 8: Crop ID, File ID and converting programm for EPY output files during calculations for reference year 2000

Crop ID	Output file extension	Conversion program
050	Epy	Epy1y10
070	Epy	Epy1y2

080	Epy	Epy1y2
090	Epy	Epy1y2
110	Epy	Epy1y2
130	Epy	Epy1y30
401	Epy	Epy1y2
402	Epy	Epy1y2
403	Epy	Epy1y2
405	Epy	Epy1y2
406	Epy	Epy1y2
4ß7	Epy	Epy1y2
408	Epy	Epy1y2
409	Epy	Epy1y2
410	Epy	Epy1y2
411	Epy	Epy1y2
412	Epy	Epy1y2
413	Epy	Epy1y2
414	Epy	Epy1y2
415	Epy	Epy1y2
416	Epy	Epy1y2

The extraction of the results from the two file types (*.epy and *.c??) is carried out when typing the EPAUS command. This command contains several arguments, which are explained in the following:

Epaus <database name> <run_id> <extension of c?? file> <number of input files +1> <user name> <password>

where the options are:

<database name> = This is in the case of the Neckar basin BWSOTER

<run_id>= User specific

<extension of c?? file>= extension of the c?? file (see above)

<number of input files +1> = This is again the number of input files but in this case you have to add one.

<user name>= your user_id provided by the database or system administrator

<password> = your password provided by the database or system administrator

Table 9: Crop ID, File ID and converting programm for crop output files during calculations for reference year 2000

Crop ID	Crop output file Extension	Conversion program
050	C30	cf2030
070	C33	cf2030
080	C33	cf2030
090	C33	cf2030
110	C33	cf2030
130	C30	Creatc00
401	C01	cf2030
402	C02	cf2030wps
403	C03	cf2030wps
405	C05	cf2030wps
406	C06	cf2030
4ß7	C07	cf2030

408	C08	cf2030
409	C09	cf2030
410	C10	cf2030
411	C11	cf2030
412	C12	cf2030wps
413	C13	cf2030
414	C13	cf2030
415	C14	cf2030
416	C33	cf2030

d. Aggregation of the simulation results to the LUSAC areas

The Epaus interface transfers the selected EPIC simulation results to a table called EPAUS in the SLISYS database. The table EPAUS must have been created beforehand in your personal database subdirectory. In the original EPAUS version the table contains the following predefined parameters on a yearly basis:

Station_id, Soter_unit, Region, Yield, Harvest index (HI), Water use efficiency (WUEF), Rainfall, Surface runoff (Q), Subsurface flow (SSF), Percolation (PRK), Evapotranspiration (ET), Water erosion (MUSL), mineral nitrogen in surface runoff (YNO3), mineral nitrogen in subsurface flow (SSFN), mineral nitrogen in percolation (PRKN), mineral phosphorus in surface runoff (YAP). In the EPAUS table the results of the simulations are at the soil profile level. The next step is therefore to aggregate the results to the Terrain unit (=Soter unit) level. In future versions, a lower aggregation level will be implemented, which is the Terrain component level. The aggregation is carried out by the view EPIC.dif_pol_su which is implemented in SLISYS. This view (or query) averages the soil profile values over spatial units that belong to the same terrain unit (soil association) and the same climate station. The aggregation results are transferred to the table BWDIFPOL (see section 1d.)

e. Additional output parameters

Since the EPIC0941 version allows only the output of a maximum of 10 output parameters, additional output like the total N in eroded soil material (YN), the total P in eroded soil material and the denitrification rate (DN), require a second model run. For these parameters the file EICFILE.DAT has to be modified before launching the EPRUN command in the respective directory. The file is opened with the MS-Editor NOTEPAD (or any other ASCII editor) and the line 7 the file name of the printfile must be changed from prnt0941.dat to prntynyp.dat. Then changes are saved and the steps described in section 2e have to be repeated.

As soon as the results are transferred to the EPAUS table the aggregation is then carried out by the view EPIC.dif_pol_su_ynyp which is also implemented in SLISYS. As the view EPIC.dif_pol_su, this view (or query) averages the soil profile values over spatial units that belong to the same terrain unit (soil association) and the same climate station. The aggregation results are transferred to the table YNYP (see section 1d.)

k. Merging the output tables

For easier use the pollution related values that are aggregated in the tables BWDIFPOL and YNYP should be merged into the table YEAR2000TEST. This is carried out by inserting the results of the view all_difpol_2000 into the table YEAR2000TEST.

g. Aggregation from LUSAC areas to level of the moneris areas

In order to be usable by other RIVERTWIN models which depend on the SLISYS output (e.g. MONERIS, ACRE), the simulation results at the LUSAC level must be transferred into the

respective spatial units. This is the MONERIS area (in the case of the MONERIS model). Since the MONERIS area is bigger than the LUSAC areas, an aggregation step is necessary. The aggregation step to the MONERIS areas is performed by the view EPIC.DIF_POL_MONERIS. The view is using the area distribution of the LUSAC units within the MONERIS areas. This distribution is stored in the table MONERIS_LUSAC. The output of the view is

Table 10: The table MONERIS_LUSAC

Table name	Table fields	PK /FK relation	Explanation	Data type	Max length / Precision	Unit
MONERIS_LUSAC	LUSAC		ID of Land Use-Soil Association-Climate unit	CHAR	12	
	MONERIS		ID of MONERIS area	CHAR	6	
	AREA_KM2		Total area of each LUSAC	DECIMAL	7.4	Km2
	PERCENT		Proportion of each LUSAC within the respective MONERIS area	DECIMAL	7.4	%

h. Aggregation of yield data from LUSAC areas to the district level

To be usable by the ACRE model. The SLISYS simulation results at the LUSAC level must be transferred to the LANDKREIS (district) level. The aggregation step to the LANDKREIS areas is performed by the view EPIC.DIF_POL_MONERIS. The aggregation step to the districts is performed by the view YIELD_LK2000.

The view is using the area distribution of the LUSAC units within each districts. This distribution is stored in the table LANDKREIS_LUSAC. The output of the view is total production and average hectare yield per crop and district in the year 2000. The yield is expressed NOT in dry matter, but in marketable yield (as used in the agricultural statistics). Since the SLISYS calculates dry matter yield, the simulation results have to be transformed into marketable yield by adding the specific water content of each crop at harvest. The dry matter content of each crop is listed in the table WATERINYIELD.

Table 11: The table LANDKREIS_LUSAC

Table name	Table fields	PK FK relation	Explanation	Data type	Max length / Precision	Unit
LANDKREIS_LUSAC	LUSAC		ID of Land Use-Soil Association-Climate unit	CHAR	15	
	LANDKREIS		ID of the landkreis	CHAR	6	
	AREA_KM2		Total area of each LUSAC	DECIMAL	7.4	Km2
	PERCENT		Proportion of each LUSAC within the respective MONERIS area	DECIMAL	7.4	%
	CROP_ID		ID of the crop	CHAR	10	

B Scenario runs

The compilation of input files for the scenario runs requires some transformation of the climate data provided by the downscaling approaches both by YANG and by ENKE. In the following the transformation procedure is briefly described:

a. Transformation of climate data from the downscaling procedure by YANG

a1. ECHAM output

YANG provides climate data (daily minimum temperature, maximum temperature, precipitation) for 31 years (2000-2030) in a sequential file for each squarekilometer grid point in the Neckar basin. The ECHAM output contains only 360 days per year. From these grid point data the grid points that are closest to the 98 selected climate stations are extracted with the DOS programs gridtmaxseq (for maximum temperature), gridtminseq (for minimum temperature) and gridrainseq2 (for precipitation). These programs need the input data files (A2ntmax, A2ntmin, A2prep), a list of the stations with their coordinates (station_coordinates.txt) as well as a list with the grid point coordinates (gridcoordinates.txt)- Then they create ascii format files (preseq.pre, tminseq.pre, tmaxseq.pre) with the daily weather data of the 98 stations in sequential order.

These station related data are transformed to data files that contain the daily weather data of each year for all 98 stations (e.g. prep2000.txt, tmin2000.txt, tmax2000.txt etc.) together with the respective date and the stationID in sequential order by the programs convtmax1 (for maximum temperature), convtmin1 (for minimum temperature) and convpre2 (for precipitation). The ascii files preseq.pre, tminseq.pre, tmaxseq.pre and the file with the station IDs and coordinates (station_coordinates.txt) must be in the same folder with the executable files.

From these files that contain the daily weather for all stations but separately for each year, either data input files for SLISYS or for direct EPIC input can be produced.

Creation of data input for SLISYS: In this case ascii files with the structure (station_Id, Date, kind_data, values) are produced from the year based daily weather files (e.g. p2000.prn, tmin2000.prn, tmax2000.prn etc.) with the programs convrain (for precipitation), convtmax2 (for maximum temperature) and convtmin2 (for minimum temperature). The programs need the daily weather files as well as a list of the names of these files (yearlist.txt) in the same directory. The created input files (allrain_ok.txt, alltmax_ok.txt etc.) can be imported into the

SOT_CLI.DAY_VAL table of the SLISYS database with the IMPORT wizard in the control center. Der Import erfolgt im DELIMITED ASCII Format als INSERT statement (delimiter optionen wie default, this means column delimitation is ",", Strings are marked with double apostrophes " and decimals are defined with dot ".").

Creation of data for EPIC runs: For this step the year based daily weather files with TXT-extension (e.g. prep2000.txt, tmin2000.txt, tmax2000.txt) must be sorted with EXCEL according to the climate station and date). Make sure that the station_id is aligned to the right, format of date is read as yyyy-mm-dd, and that the number has one decimal throughout the data set. Then save the files as PRN (formatted text files). The program convweat2 converts these files (e.g. p2000.prn, tn2000.prn, tx2000.prn etc.) into EPIC input files for each station, containing precipitation, maximum and minimum temperature in one file with the name of the station+A as file name (the A in the station_id distinguishes the observed data of a climate station from the downscaled scenario values). To carry out the program all daily weather files as well as lists of these input files for each parameter (rainlist.txt, tminlist.txt, tmaxlist.txt) as well as the list of the station files that are to be created (e.g. 4448A.dat in the files statlist.txt) must be in the same directory with the executable file convweat2.exe.

a2. ENKE scenarios

The LfU (Environmental protection agency) provides climate data (daily Minimum temperature, maximum temperature, precipitation) for 30 years (2021-2050) in a sequential file for each squarekilometer grid point in the Neckar basin. In contrast to the ECHAM output, ENKE scenarios contain 365 days per year also in leap years. From these grid point data the grid points that are closest to the 98 selected climate stations are extracted with the DOS programs gridtmaxseq (for maximum temperature), gridtminseq (for minimum temperature) and gridrainseq2 (for precipitation). These programs need the input data files (A2ntmax, A2ntmin, A2prep), a list of the stations with their coordinates (station_coordinates.txt) as well as a list with the grid point coordinates (gridcoordinates.txt). Then they create ascii format files (preseq.pre, tminseq.pre, tmaxseq.pre) with the daily weather data of the 98 stations in sequential order.

These station related data are transformed to data files that contain the daily weather data of each year for all 98 stations (e.g. p2000.txt, tmin2000.txt, tmax2000.txt etc.) together with the respective date and the stationID in sequential order by the programs convtmaxenke (for maximum temperature), convtminenke (for minimum temperature) and convpreenke (for precipitation). The ascii files preseq.pre, tminseq.pre, tmaxseq.pre and the file with the station IDs and coordinates (station_coordinates.txt) must be in the same folder with the executable files.

From these files that contain the daily weather for all stations but separately for each year, input file for direct EPIC input can be produced.

Creation of data for EPIC runs: For this step the year based daily weather files with TXT-extension (e.g. prep2000.txt, tmin2000.txt, tmax2000.txt) must be sorted with EXCEL according to the climate station and date). Make sure that the station_id is aligned to the right, format of date is read as yyyy-mm-dd, and that the number has one decimal throughout the data set. Then save the files as PRN (formatted text files). The program convweat2 converts these files (e.g. prep2000.prn, tmin2000.prn, tmax2000.prn etc.) into EPIC input files for each station, containing precipitation, maximum and minimum temperature in one file with the name of the station+A as file name (the A in the station_id distinguishes the observed data of a climate station from the downscaled scenario values). To carry out the program all daily weather files as well as lists of these input files for each parameter (rainlist.txt, tminlist.txt, tmaxlist.txt) as well as the list of the station files that are to be created (e.g. 4448A.dat in the files statlist.txt) must be in the same directory with the executable file convweat2.exe.

The procedure for running scenario simulations is similar to the simulation of the reference year 2000. The basin is subdivided into LUSACs. EPIC calculates the target variables for each LUSAC unit for 31 years.

The main steps are

- a. creation of EPIC input for the river basin area (a total of 1992 files is produced due to larger number of climate stations compared to the runs for the year 2000)
- b. Adjusting the tables sot_clim.synoptic stations and sot_clim.climterrain to the number of 98 stations
- c. Running the EPIC simulations
- d. Extracting the EPIC output files into the SLISYS database
- e. Aggregation of the simulation results to the LUSAC areas
- f. Aggregation from LUSAC areas to water body, moneris area or subbasin level

a Creation of EPIC input files for the river basin area (all profiles within each terrain unit)

This step is identical to the procedure described in 2.1a. In the window "General data" the scenario ID has to be selected (do not forget to press the RETRIEVE button after the selection).

b. Running the EPIC simulations for 30 year scenarios

After writing the files to the specified folder, go to the MS-DOS command window and change to the folder with the input files. In the case of the scenario runs, you must copy the EPIC system files and the daily weather files of the respective scenario in the subdirectories c:\template_scenarioXX into your folder by typing copy c:\template_scenarioXX*.*. Then type the command "eprun" and launch the simulation. In order to minimize the disk space requirements for the output files you may change the commands in the file EPRUN.BAT from EWQ EPINXXXX /OA into EWQ EPINXXXX /OA3. In this case the simulations will produce only annual output files.

c. Extracting the EPIC output files into the SLISYS database

As in the simulations of the reference year, the extraction of the results of the simulations into the SLISYS database requires some preprocessing of the output files. Please follow the guidelines given in 2.1.c.

(1) EPY Files: The scenario calculations do not require a preprocessing of the EPY files

(2) C??-files: The *.C??-files must be transform in the scenario calculations depending on the crop type you have chosen: For winter crops (Winter wheat, Winter barley, Rye and Winter rape) type "cf2030ww" in the DOS prompt and give the number of input files. Enter and then specify in addition the extension of your C??-file. The extension number is equivalent to the crop ID (e.g. c02 for winter wheat). For summer crops including apple plantations (ID050) type "cf2030" and make the specifications that are requested by the program.

(3) Some crops are not harvested (e.g. forest ID=130). In these cases C00- files are produced by the program creatc00. The program produces *.c00 with a 31 dummy result lines. The program requires the presence of the file „FILELIST.TXT“ containing a list of filenames (with the structure ewq filename.dat) that should be produced and a the sample file „IN.C00“. Fallow and bare fallow produce also yield results. In the former it is assumed that the fallow consists of grassland (crop_id 33), the latter assumes that there is some vegetation (grass, crop ID 33) during a short period within the vegetation period in summer.

The extraction of the results from the two file types (*.epy and *.c??) is the carried out as described in 2.1.c with the EPAUS command.

Table12: Crop ID, File ID and converting programm for crop output files during scenario calculations

Crop ID	Crop output file Extension	Conversion program
050	C30	cf2030
070	C33	cf2030
080	C33	cf2030
090	C33	cf2030
110	C33	cf2030
130	C30	Creatc00
401	C01	cf2030
402	C02	cf2030ww
403	C03	cf2030ww
405	C05	cf2030ww
406	C06	cf2030
407	C07	cf2030
408	C08	cf2030
409	C09	cf2030
410	C10	cf2030
411	C11	cf2030
412	C12	cf2030ww
413	C13	cf2030
414	C13	cf2030
415	C14	cf2030
416	C33	cf2030

d. Aggregation of the simulation results to the LUSAC areas

The Epaus interface transfers the selected EPIC simulation results to a table called EPAUS in the SLISYS database. The table EPAUS must have been created beforehand in your personal database subdirectory. In the original EPAUS version the table contains the following predefined parameters at the SOIL PROFILE level on a yearly basis:

Station_id, Soter_unit, profil_id, year, run_id, Region, Yield, Harvest index (HI), Water use efficiency (WUEF), Rainfall, Surface runoff (Q), Subsurface flow (SSF), Percolation (PRK), Evapotranspiration (ET), Water erosion (MUSL), mineral nitrogen in surface runoff (YNO3), mineral nitrogen in subsurface flow (SSFN), mineral nitrogen in percolation (PRKN), mineral phosphorus in surface runoff (YAP). In the EPAUS table the results of the simulations are at the soil profile level. The next step is therefore to aggregate the results to the Terrain unit (=Soter unit) level. In future versions, a lower aggregation level will be implemented, which is the the Terrain component level.

Before the aggregation the YEAR variable is updated with the command 'update19_2000'. Then the aggregation is carried out by different views depending on the scenario type. For the climate scenario YangA2 it is performed by the view EPIC.dif_pol_Akonv which is implemented in SLISYS. This view (or query) averages the soil profile values over spatial units that belong to the same terrain unit (soil association) and the same climate station. The aggregation results are transferred to the table BWDIFPOLSCEN (see section 1d.) or any other table as specifies by the user in the comand 'INSERT INTO <tablename>'.

g. Aggregation from LUSAC areas to water bodies, moneris area or districts

In order to be usable by other RIVERTWIN models which depend on the SLISYS output (e.g. MONERIS, ACRE), the simulation results at the LUSAC level must be transferred into the

respective spatial units. This is the MONERIS area (in the case of the MONERIS model) or the district (in the case of the ACRE model). Since these spatial units are bigger than the LUSAC areas, an aggregation step is necessary. The aggregation step to the MONERIS areas is performed by the view EPIC.DIF_POL_MONERIS. The aggregation step to the DISTRICTS is performed by the view EPIC.DIF_POL_DISTRICT. The views are using the area distribution of the LUSAC units within the MONERIS areas (or within the districts). This distribution is stored in the table MONERIS_LUSAC.

g1. Aggregation from LUSAC areas to the MONERIS areas

In order to be usable by other RIVERTWIN models which depend on the SLISYS output (e.g. MONERIS,, the simulation results at the LUSAC level must be transferred into the respective spatial units. This is the MONERIS area (in the case of the MONERIS model). Since the MONERIS areas are bigger than the LUSAC areas, an aggregation step is necessary. The aggregation step to the MONERIS areas is performed by the view EPIC.DIF_POL_MONERIS. The view is using the area distribution of the LUSAC units within the MONERIS areas. This distribution is stored in the table MONERIS_LUSAC (Table 10).

g2. Aggregation of yield data from LUSAC areas to the district level

To be usable by the ACRE model. The SLISYS simulation results at the LUSAC level must be transferred to the LANDKREIS (district) level. The aggregation step to the LANDKREIS areas is performed by the view EPIC.DIF_POL_MONERIS. The aggregation step to the districts is performed by the view YIELD_LK2000.

The view is using the area distribution of the LUSAC units within each districts. This distribution is stored in the table LANDKREIS_LUSAC (Table 11). The output of the view is total production and average hectare yield per crop and district in the year 2000. The yield is expressed NOT in dry matter, but in marketable yield (as used in the agricultural statistics). Since the SLISYS calculates dry matter yield, the simulation results have to be transformed into marketable yield by adding the specific water content of each crop at harvest. The dry matter content of each crop is listed in the table WATERINYIELD.