UNESCO-IHE
Institute for Water Education

Soil and Water Assessment Tool (SWAT)

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UNESCO-IHE, the Netherlands

Course objectives

- Get familiar with SWAT
  - What are the key processes, key parameters?
  - What are the main application domains?
- How can we set up a model (get a bit a feeling)?
- What are the main data needed?

Outline

- Introduction
- Hydrology
- Environmental processes
- SWAT for water policy
- Data
- Applications

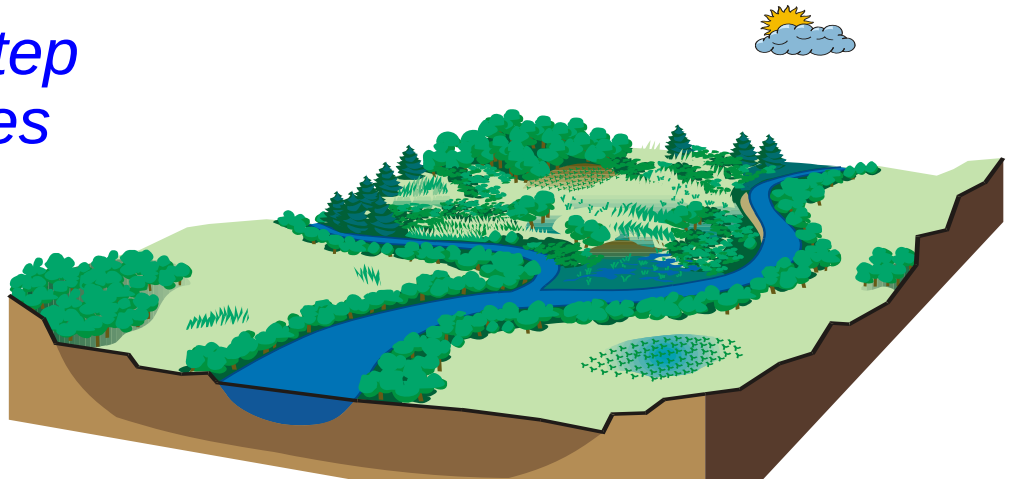
SWAT

- Developed by Jeff Arnold at USDA/ARS Temple, Texas, USA
- GIS interface (ArcView): DEM, Landuse, Soils maps
- Open sources
- User and developers community
- swatmodel.tamus.edu

What are the objectives of SWAT

- Simulation of processes at land and water phase
- Spatially distributed (different scales)
- Semi physically based / empirical approaches
- Simulation of changes (climate, land use, management etc.)
- **Water quantities**, incl. different runoff components
- **Water quality**: Nutrients, Sediments, Pesticides, Bacteria, (algae and oxygen), etc.

…. all that on a daily time step and at different spatial scales and (more or less) readily available data sets!!



WWW

http://swatmodel.tamus.edu/

Download software
Download source code
Documentation
User group mailing list !
Internet Forum

Publications
Applications

Philosophy (1)

Aims

- Management analysis
- Water, sediments, crops, nutrients, pesticides

➡ Comprehensive – Process Interactions

Input

- Readily available input

➡ Physically based input

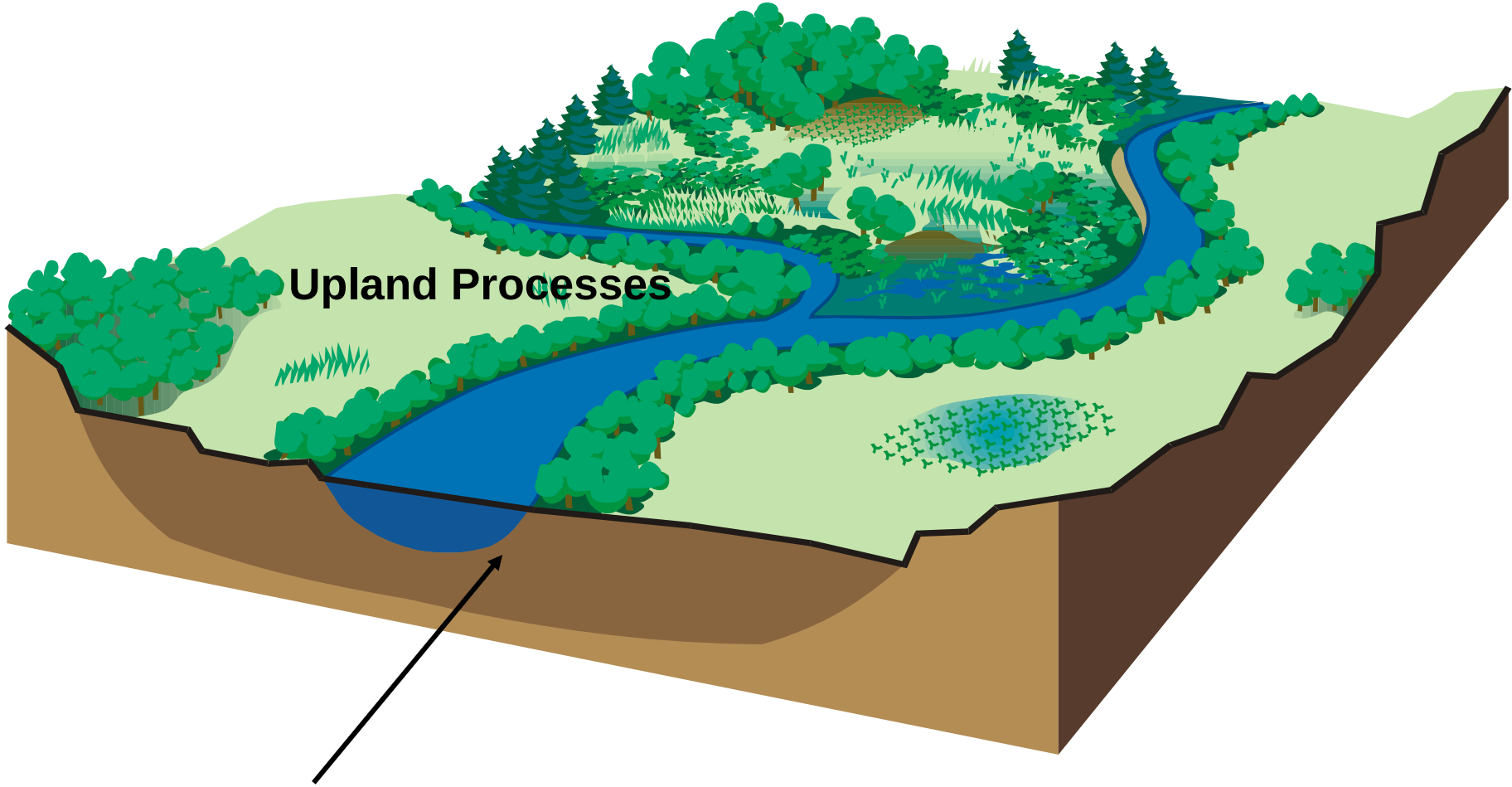
Philosophy (2)

- **Long term simulations**
- **Continuous Time – Daily/hourly time step**

Problem of computational efficiency

- Semi-distributed model
- Conceptual model

SWAT Watershed System



Channel/Flood Plain Processes

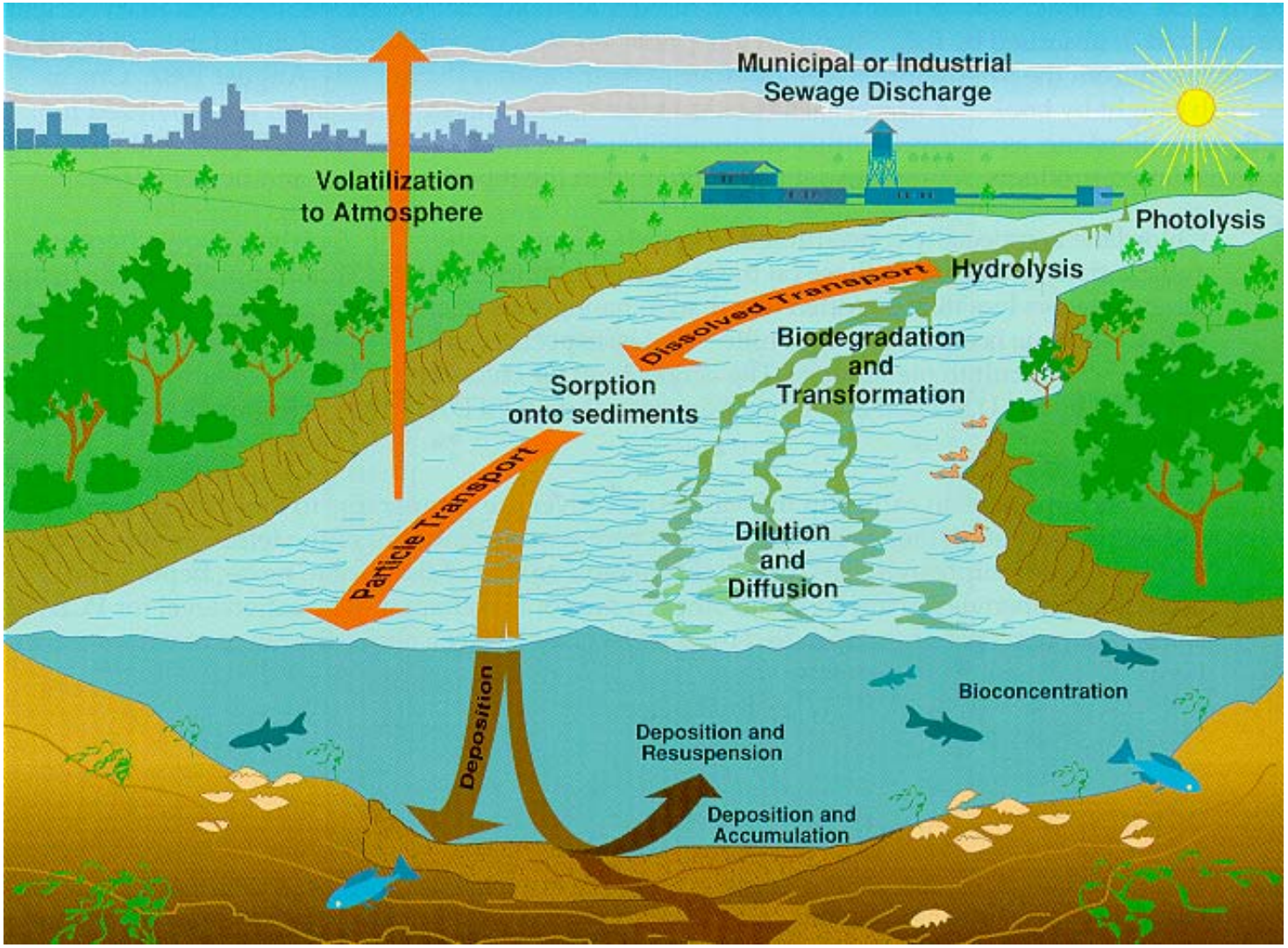
Interface

- GRASS (open sources GIS)
- Mapwindow (open sources GIS)
- AVSwat-X (ArcView)
- ArcSWAT (ArcGIS)

Structure

- Basin
- Subbasins (based on DEM)
  Weather, Routing

Channel Processes



Structure

- Basin
- Subbasins
  Weather, Routing
- Hydrological Response Units
  = Combination of soil type and land use properties

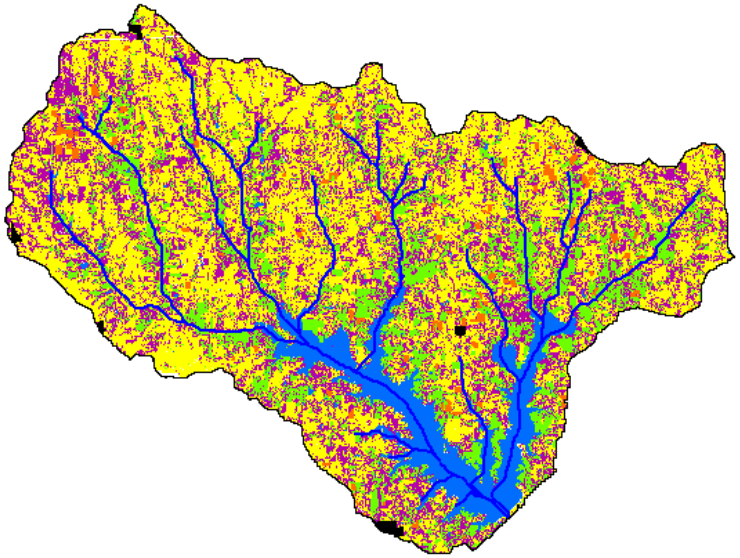
HRU
Hydrologic Response Unit

A unique combination of land use and soil type

Soil map

Land use map

+

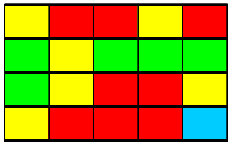


HRU (2)

ARCVIEW

GIS subbasin

Pixels : 20
Pixel area = A



GEO - REFERENCED

HRU	# of pixels
1	**6**
2	**5**
3	**8**
4	**1**

SWAT DATABASES
HRU parameters

SWAT

input → Output 1
input → Output 2
input → Output 3
input → Output 4

1 unit area

Output 1 x A x **6**
Output 2 x A x **5**
Output 3 x A x 8
Output 4 x A x **1**

+ → Total output

NOT GEO - REFERENCED

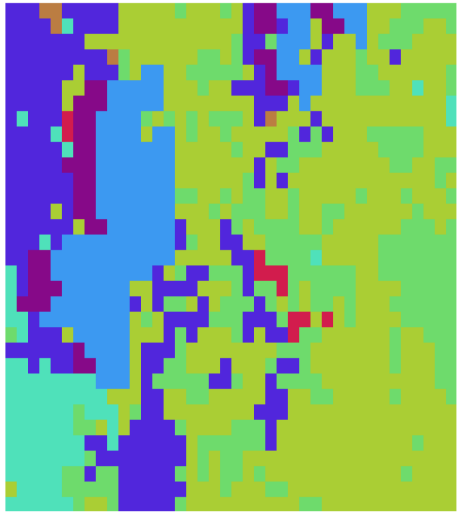
HRU's in model

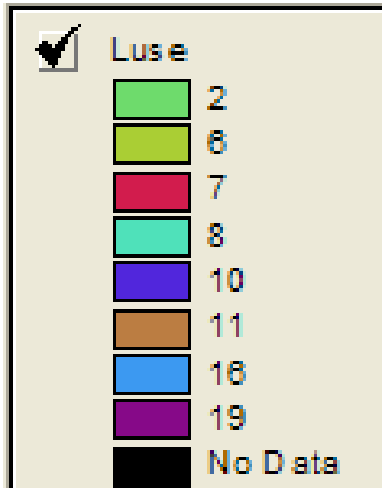
- Created on the basis of Land Use maps and Soil Maps + databases (with parameters)!!!

- Soil map ↔ lookup table ↔ usersoil.dbf (swat2005.mdb)
- Land use map ↔ lookup table ↔ crop.dbf (swat2005.mdb)
- Slope classes (drived from DEM)

Preparing landuse data

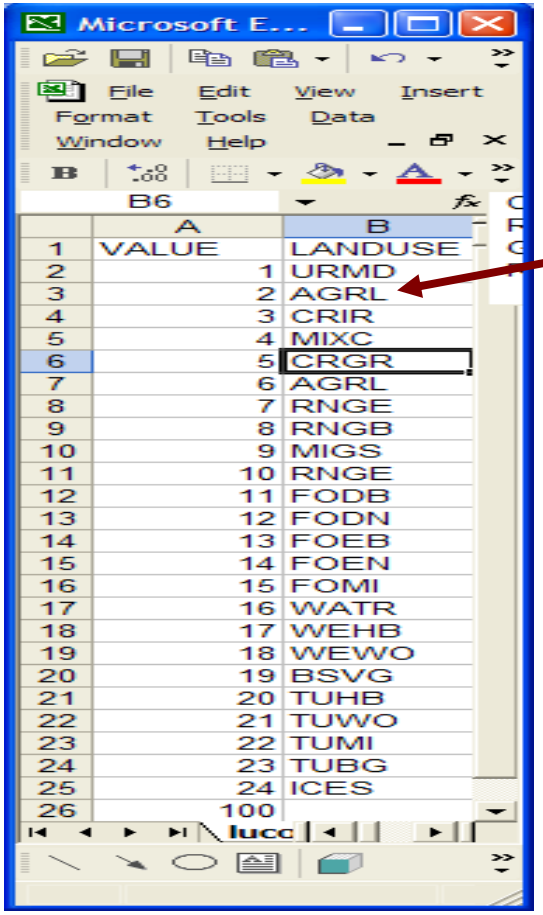
Landuse





Landuse legend (raw)

Look up table



	A	B
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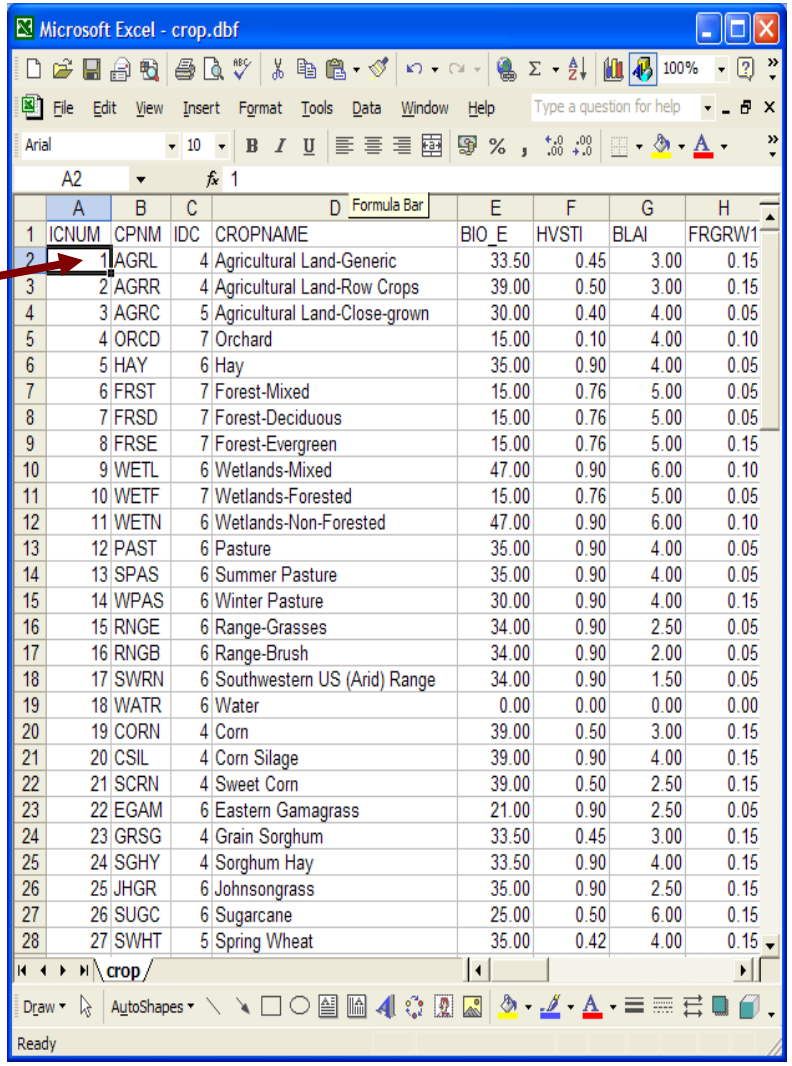
12	11	FODB
13	12	FODN
14	13	FOEB
15	14	FOEN
16	15	FOMI
17	16	WATR
18	17	WEHB
19	18	WEWO
20	19	BSVG
21	20	TUHB
22	21	TUWO
23	22	TUMI
24	23	TUBG
25	24	ICES
26	100	

Database (crop.dbf



	A	B	C	D	E	F	G	H
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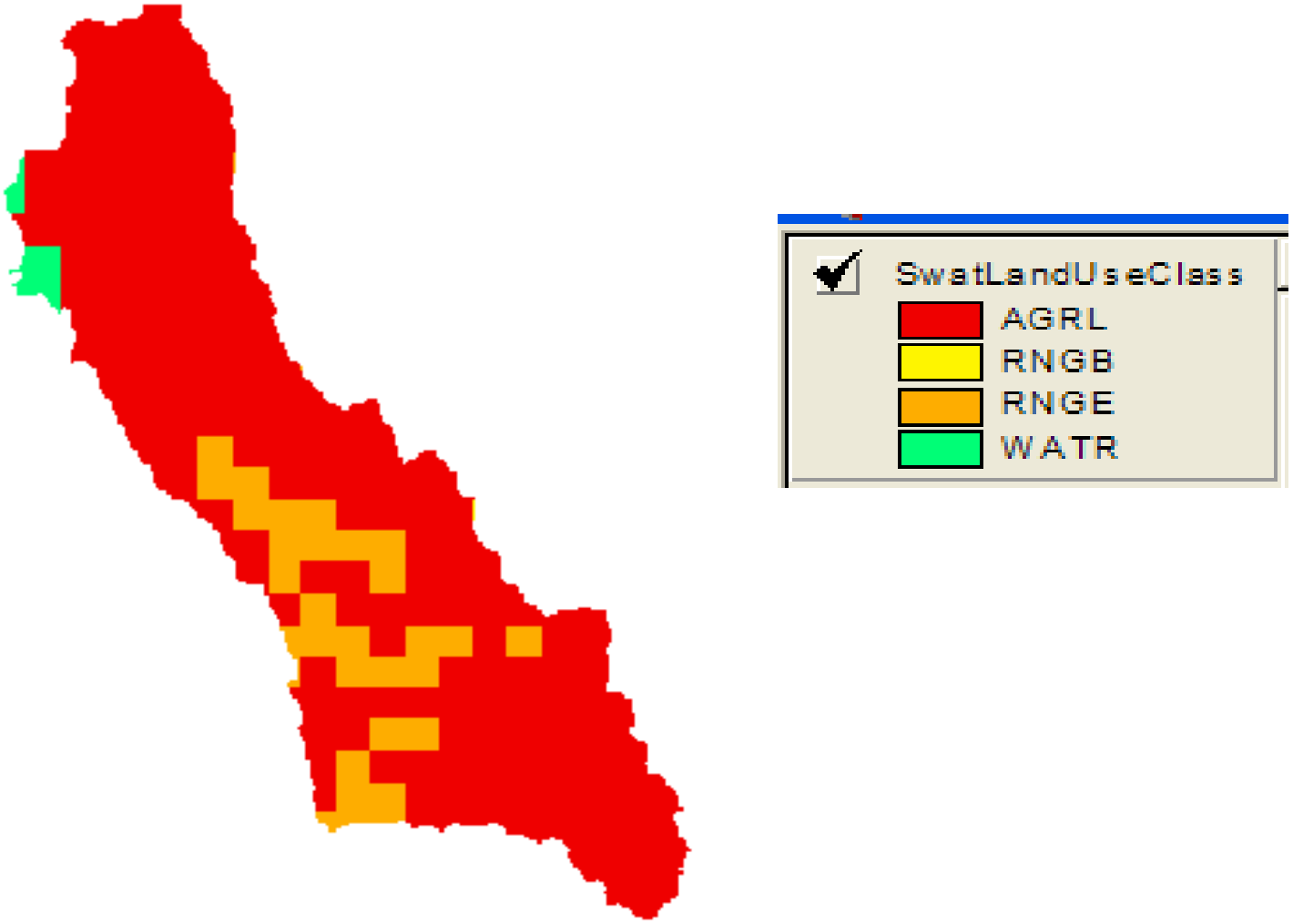
Reclassified/overlaid Landuse



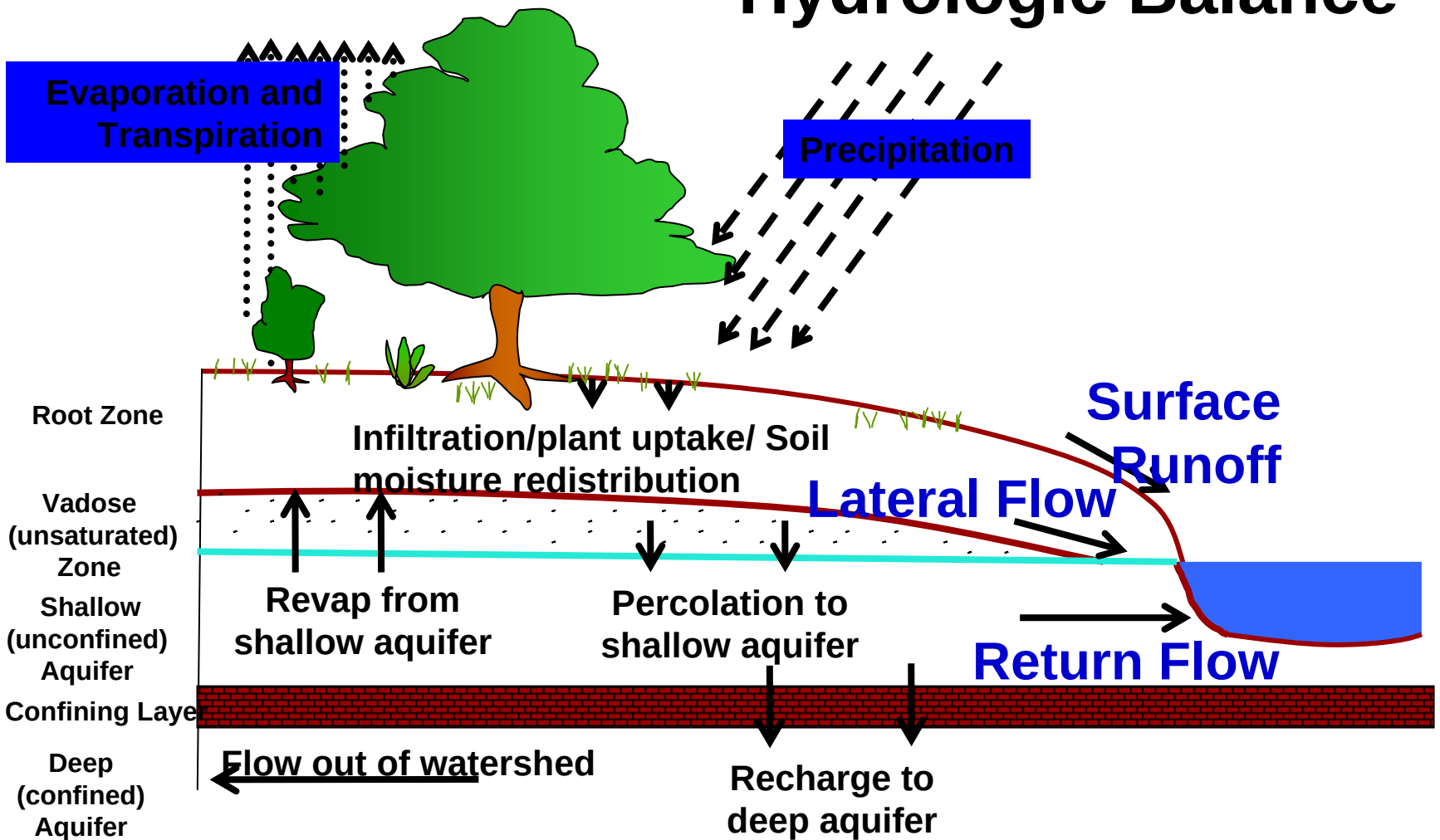
HRU Processes

- Hydrology
- Erosion
- Plant Growth
- Nutrient Cycling
- Pesticide Dynamics
- Agricultural Management

How is SWAT solving the problems?

SWAT

Hydrologic Balance



Curve Number Values

(many more can be found in the manual)

Land use	% imper-vious	Soil group			
		A	B	C	D
Residential	20	51	68	79	84
	25	54	70	80	85
	30	57	72	81	86
	38	61	75	83	87
	65	77	85	90	92
Parking, roads, rofs	100	98	98	98	98
Cobbles	-	76	85	89	91
Commercia	85	89	92	94	95
Industria	72	81	88	91	93
Open (park, grass...)					
> 75% grass cover	-	39	61	74	80
50 tot 75% grass cover	-	49	69	79	84
Meadow	-	30	58	71	78
Woods					
Open	-	45	66	77	73
Dense	-	25	55	70	77
Agricultural land	-	62	71	78	81

$$S = 25.4\left(\frac{1000}{CN} - 10\right)$$

Key parameter!

1) Wetness condition 2

2) 5 % slope

Empirical equations exist to adjust for different slopes

Curve Number Value Variations

Soil Groups

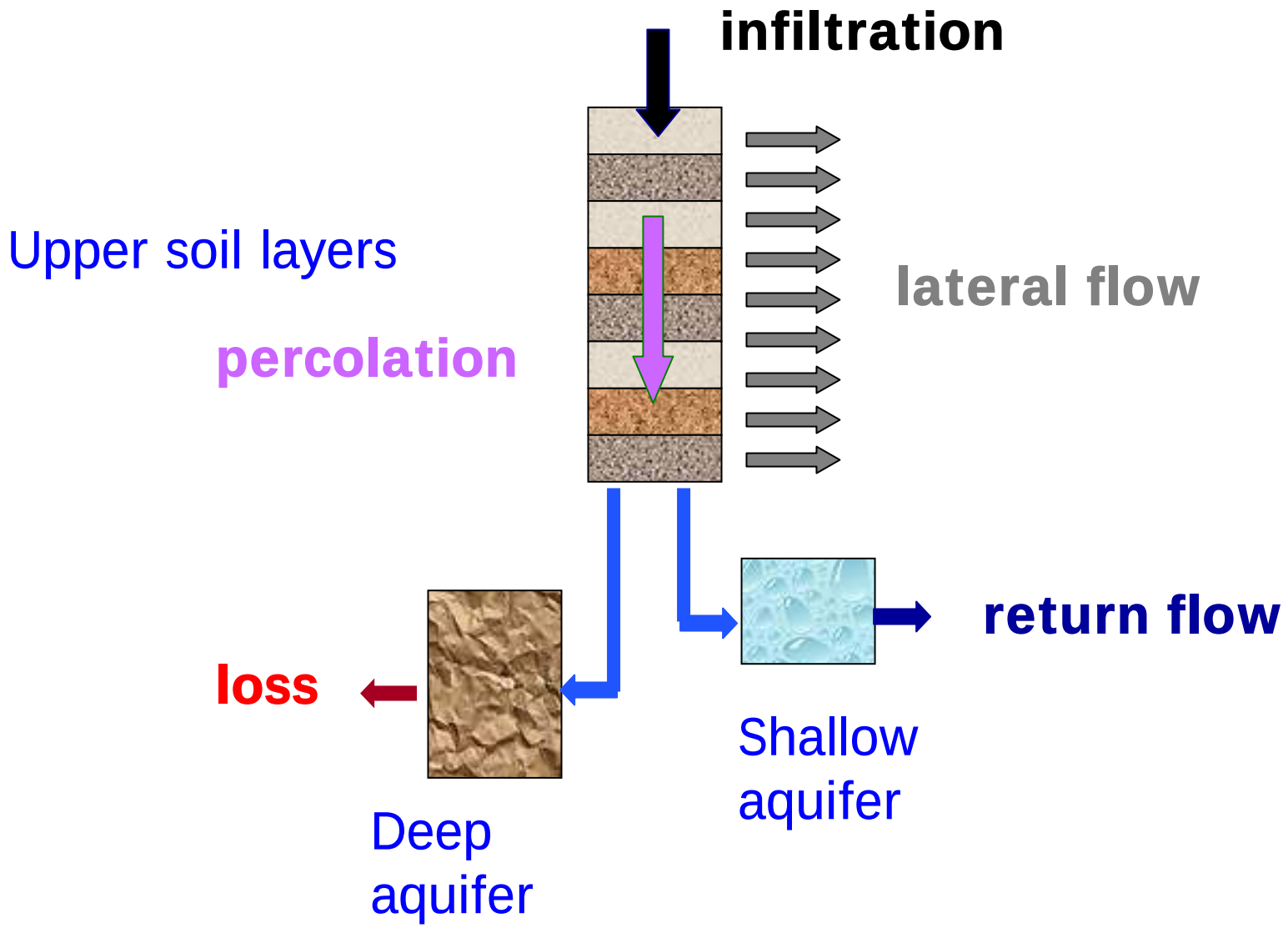
A Deep sand, deep loess (*low* runoff potential)
B Sandy loam, shallow loess (*low to moderate* runoff potential)
C Clay-loam, shallow sandy loam (*moderate to high* runoff potential)
D Heavy plastic clay, swelling soil, silty soil (*high* runoff potential)

Wetness conditions

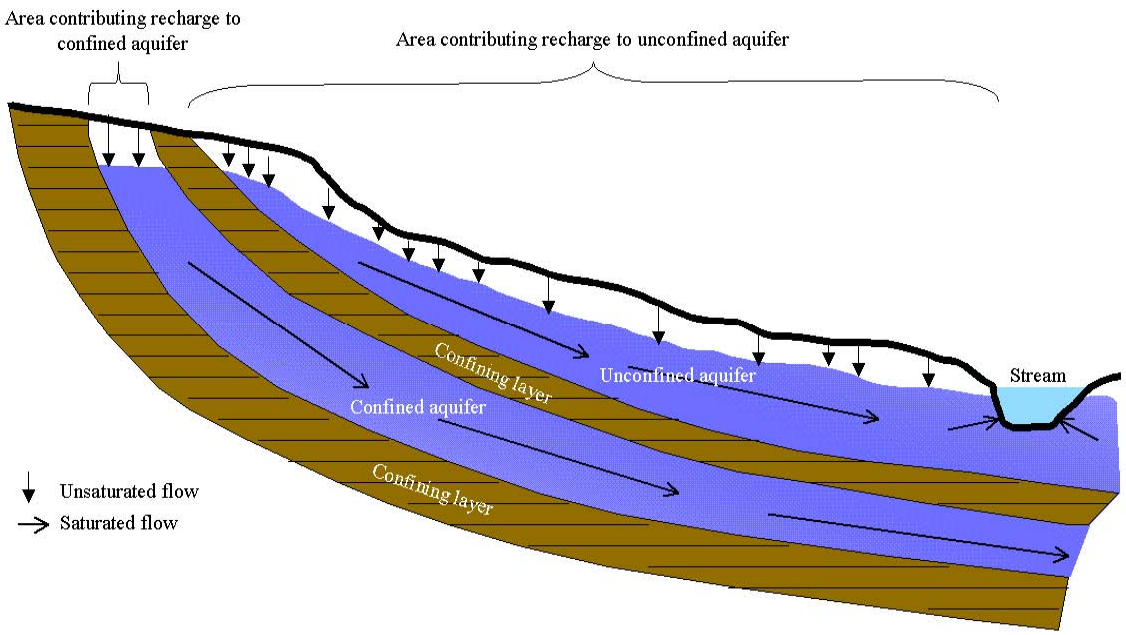
CN1 Dry but above wilting point
CN2 Average
CN3 Above field capacity, near saturation

Empirical equations exists to calculate CN1 and CN3 from CN2

Subsurface flow



Groundwater flow



(Slide from W. Bauwens, 2006)

Erosion

- Modified Universal Soil Loss Equation (MUSLE)

$$Y = 11.8\,(V\,q_p)^{0.56}\,(K)(C)(PE)(LS)$$

V = surface

qp = is the peak flow rate

K = erodibility factor

C = crop management factor

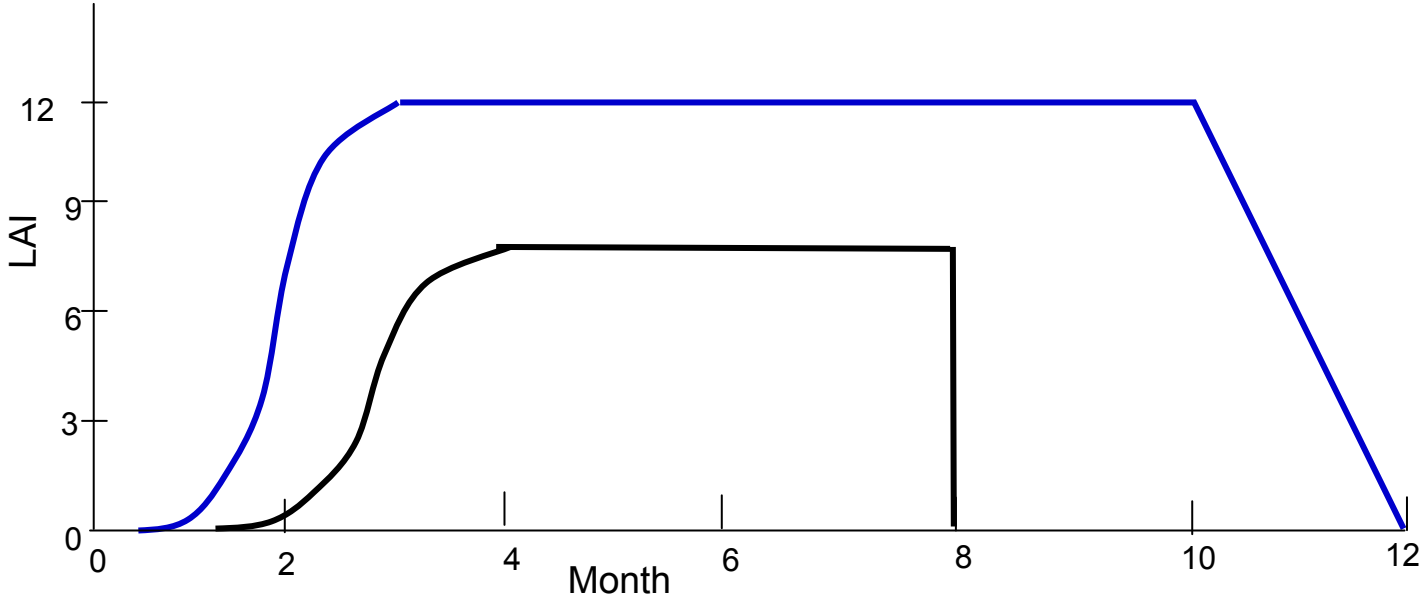
PE = the erosion control practice factor

LS = slope length and steepness factor.

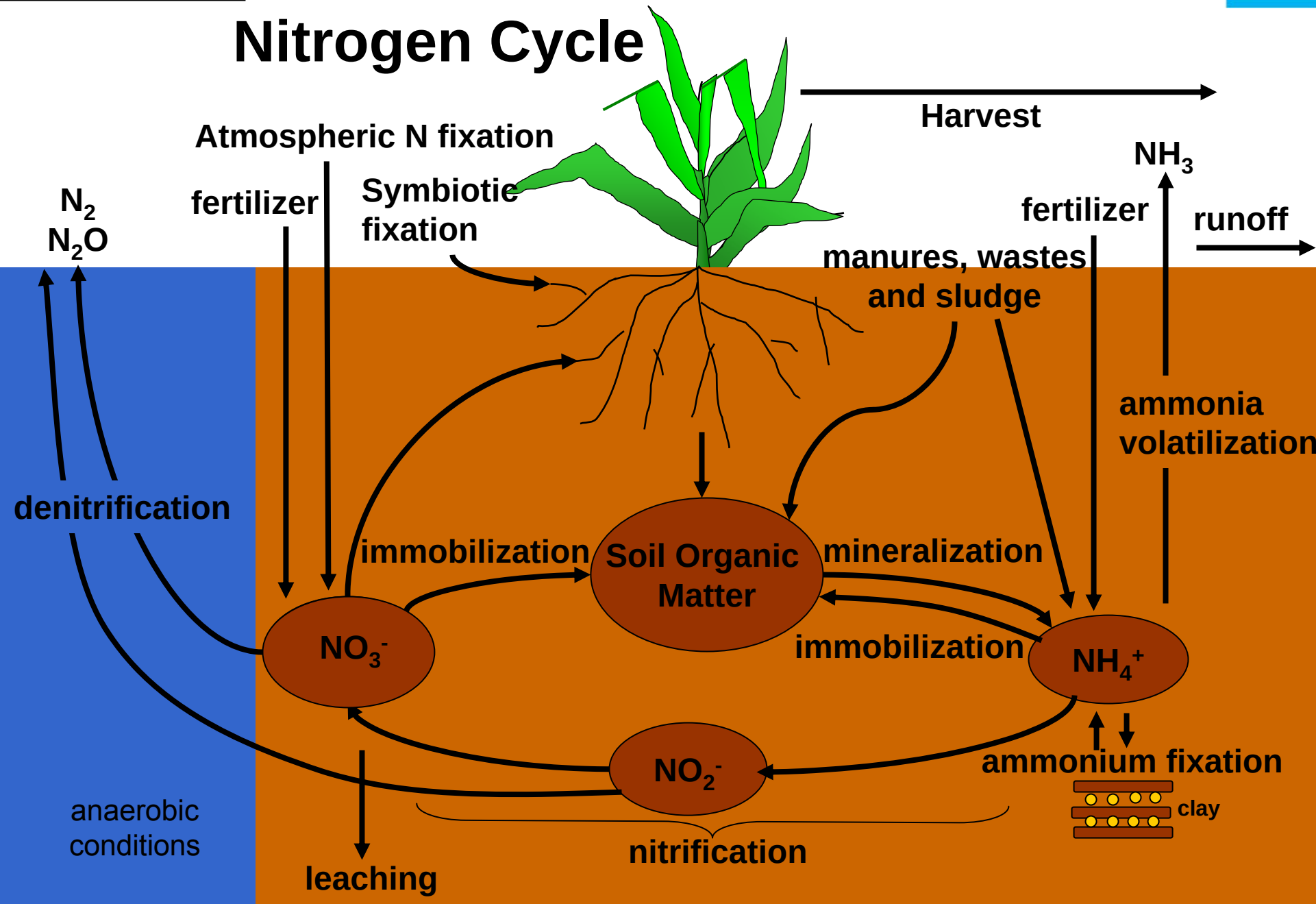
Crop processes

- Planting
- Plant growth: water, nutrient uptake
- Harvesting, Grazing, Kill

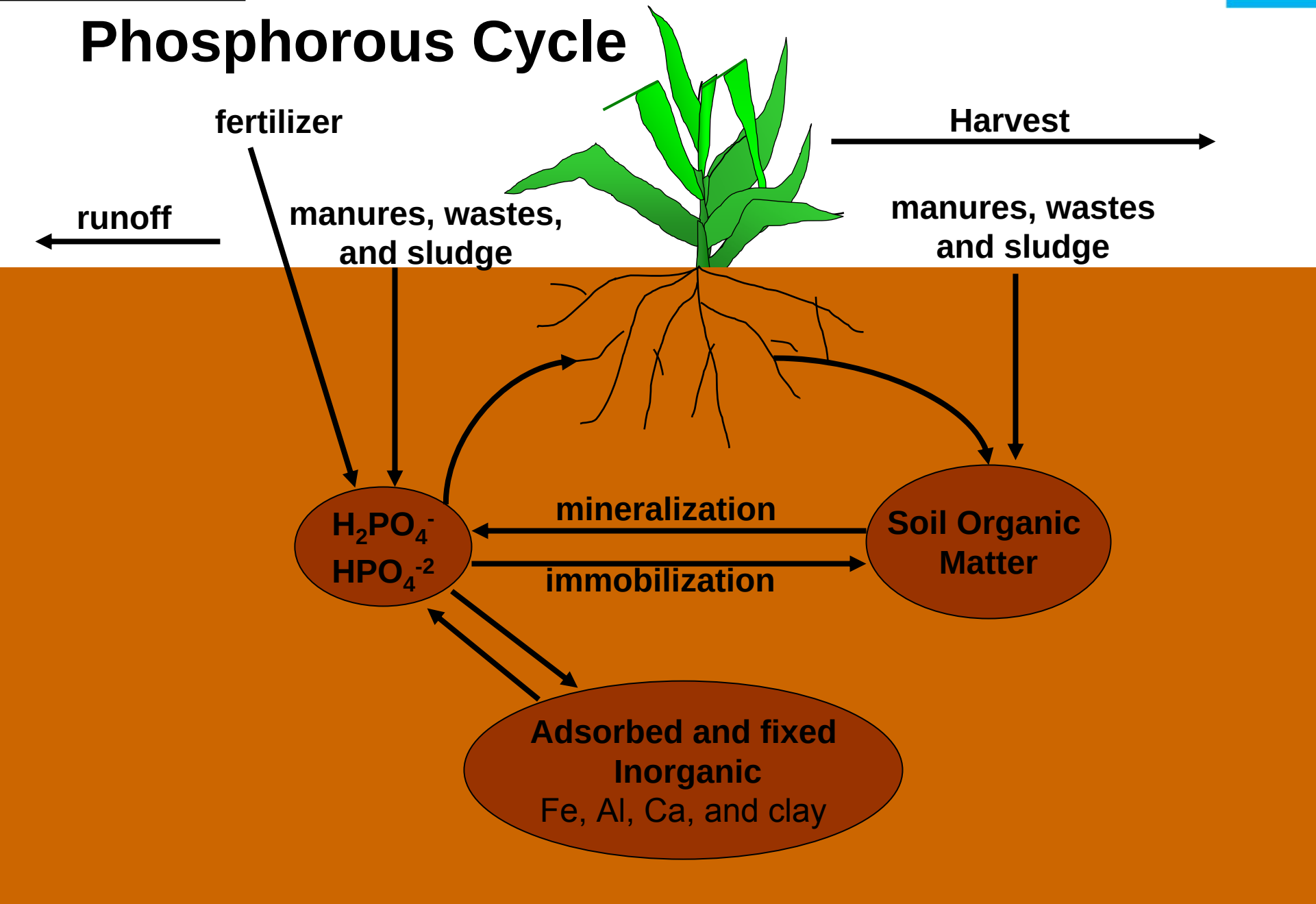
Plant Growth



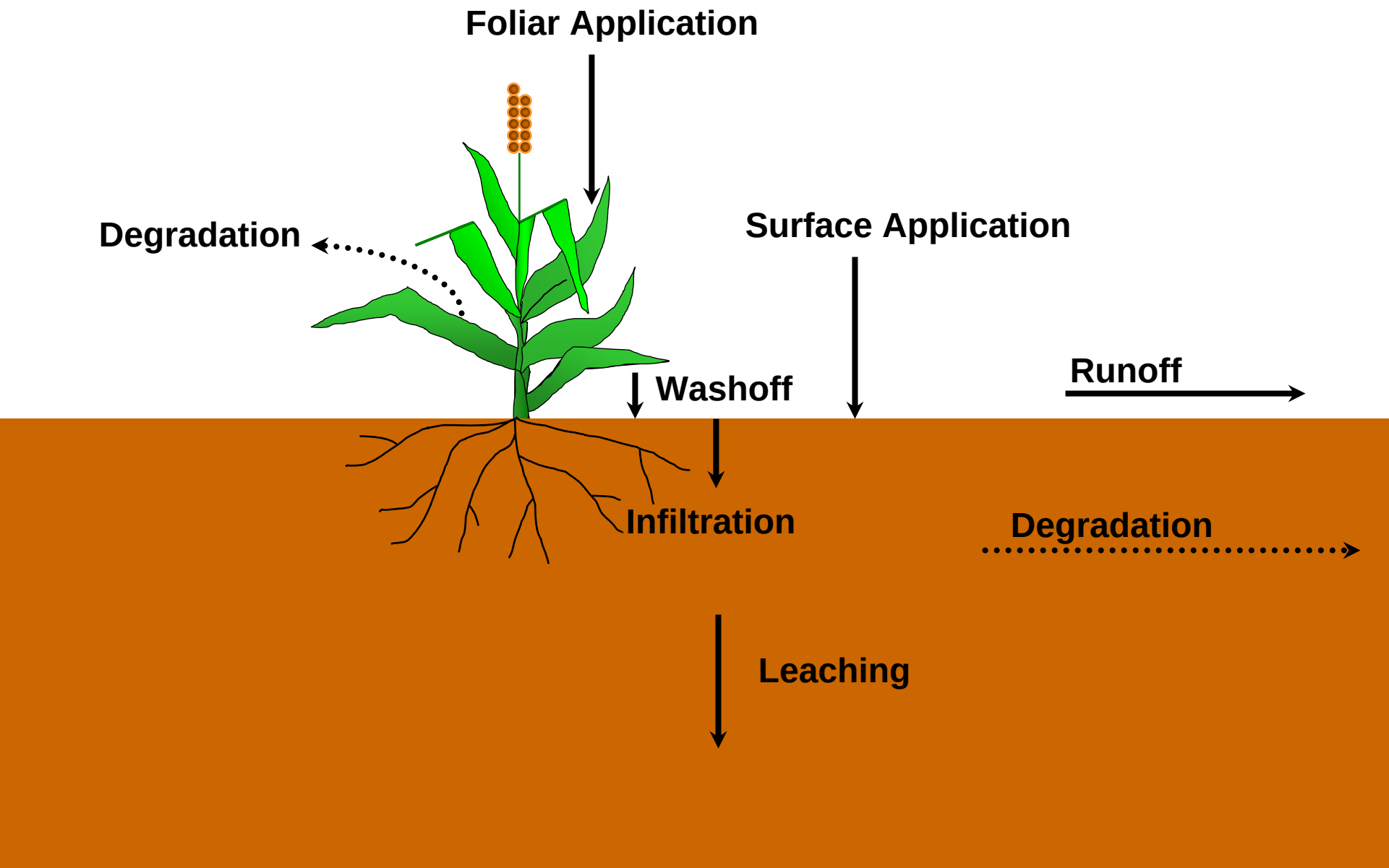
Nitrogen Cycle



Phosphorous Cycle



Pesticide dynamics



Management

- Ponds, reservoirs
- Urban areas
- Agricultural management

Agricultural management (1)

- Crop Rotations
- Removal of Biomass as Harvest
- Conversion of Biomass to Residue
- Tillage / Biomixing of Soil
- Fertilizer Applications
- Grazing
- Pesticide Applications
- Filter strips

Agricultural management (2)

- Irrigation
- Subsurface (Tile) Drainage
- Water Impoundment (e.g. Rice)

Urban management

- **Urban Areas**
  - **Pervious/Impervious Areas**
  - **Street Sweeping**
  - **Lawn Chemicals**

Data for SWAT

Ann van Griensven (UNESCO-IHE)

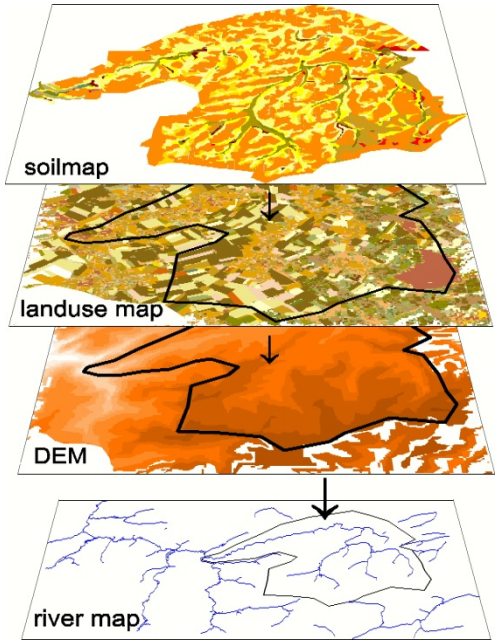
Data

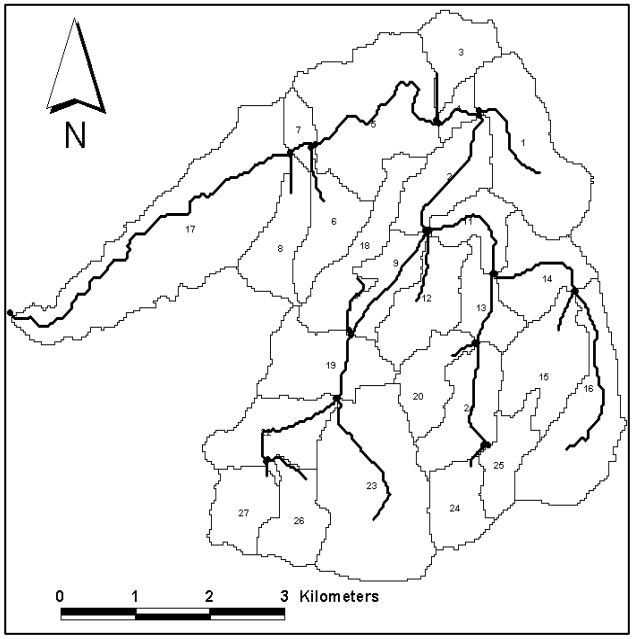
- Weather data
  - Rainfall
    - Raingage and RADAR
  - Temperature
- Landuse data
  - Remote Sensing
- Land management
- Soils and its attributes
- Streamflow (quantity)
- Water quality

Databases in swat2005.mbd

- **Soil**
- **Land cover / plant growth**
- **Tillage**
- **Fertilizer**
- **Pesticide**
- **Urban**
- **Weather generator**

GIS integration





Data preparation (1)

- GIS maps:
  - DTM
  - Land use
  - Soil
- Databases (in swat2005.mdb)
  - Userwgn.dbf
  - Usersoil.dbf
  - Crop.dbf -> create crop.dat

Data preparation (2)

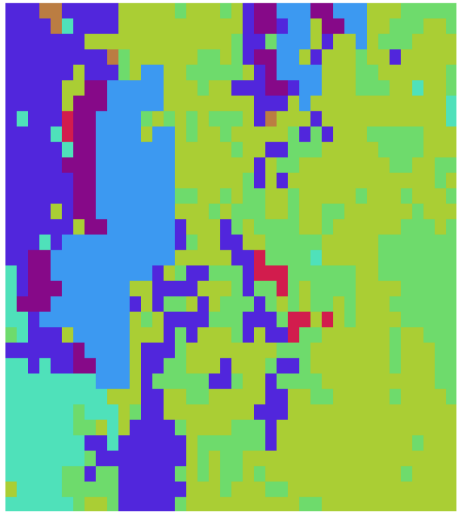
- Lookup tables
  - For soil
  - For land use

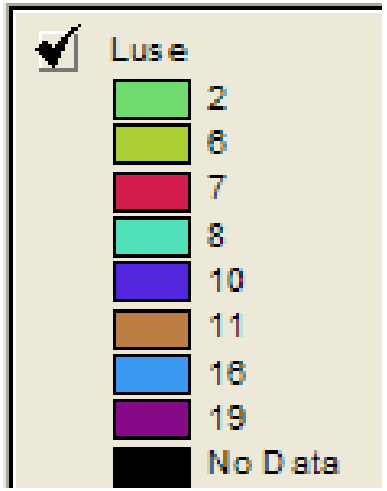
- Soil map ↔ lookup table ↔ usersoil.dbf
- Land use map ↔ lookup table ↔ crop.dbf

Preparing landuse data

UNESCO-IHE
Institute for Water Education

Landuse





Landuse legend (raw)

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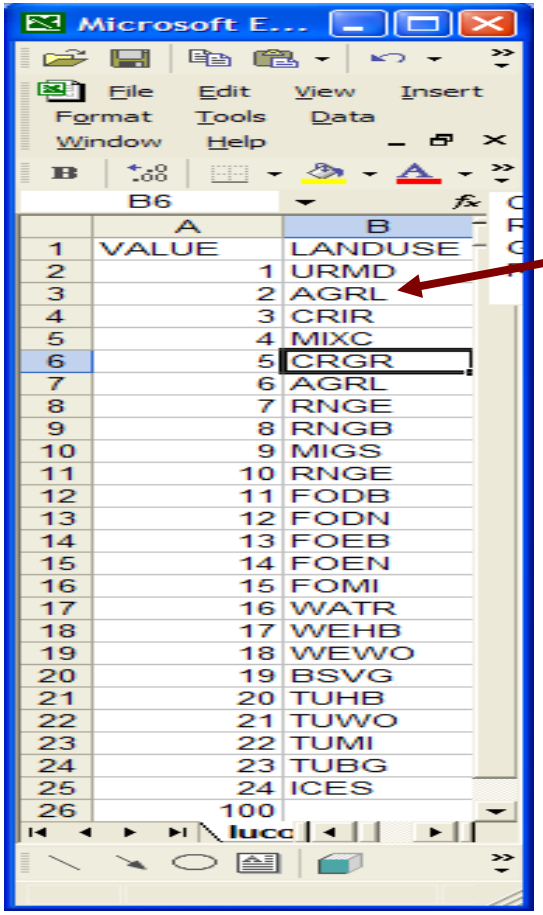

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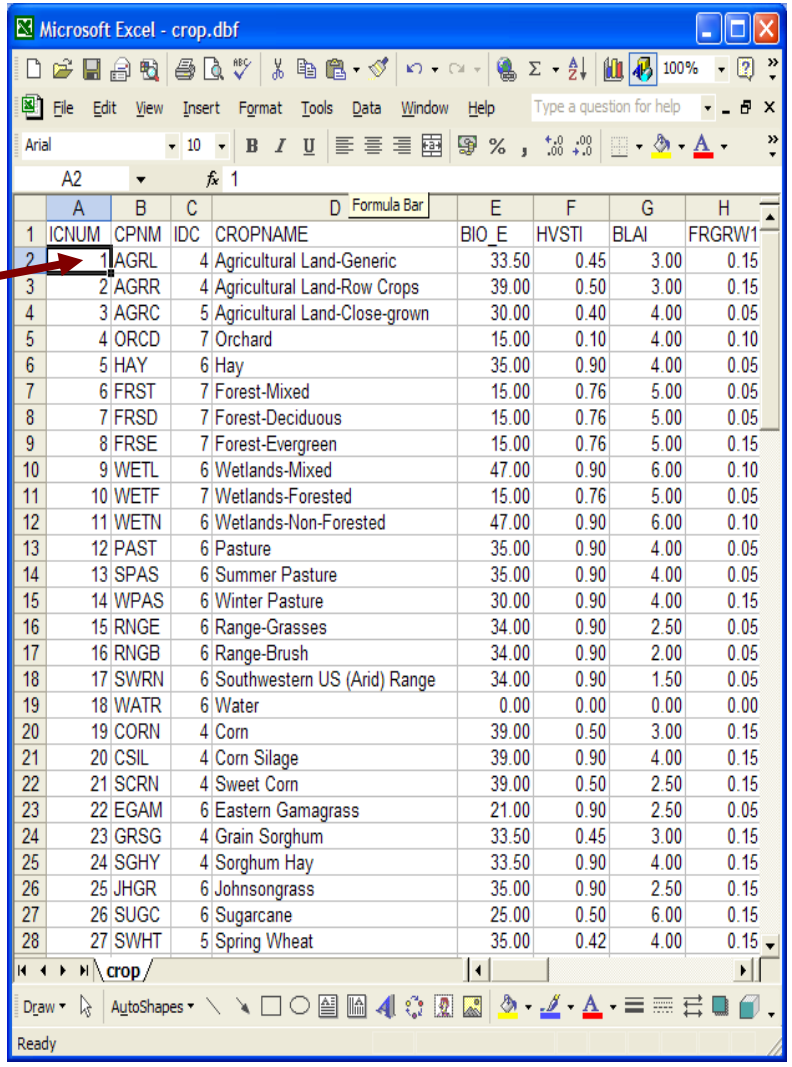

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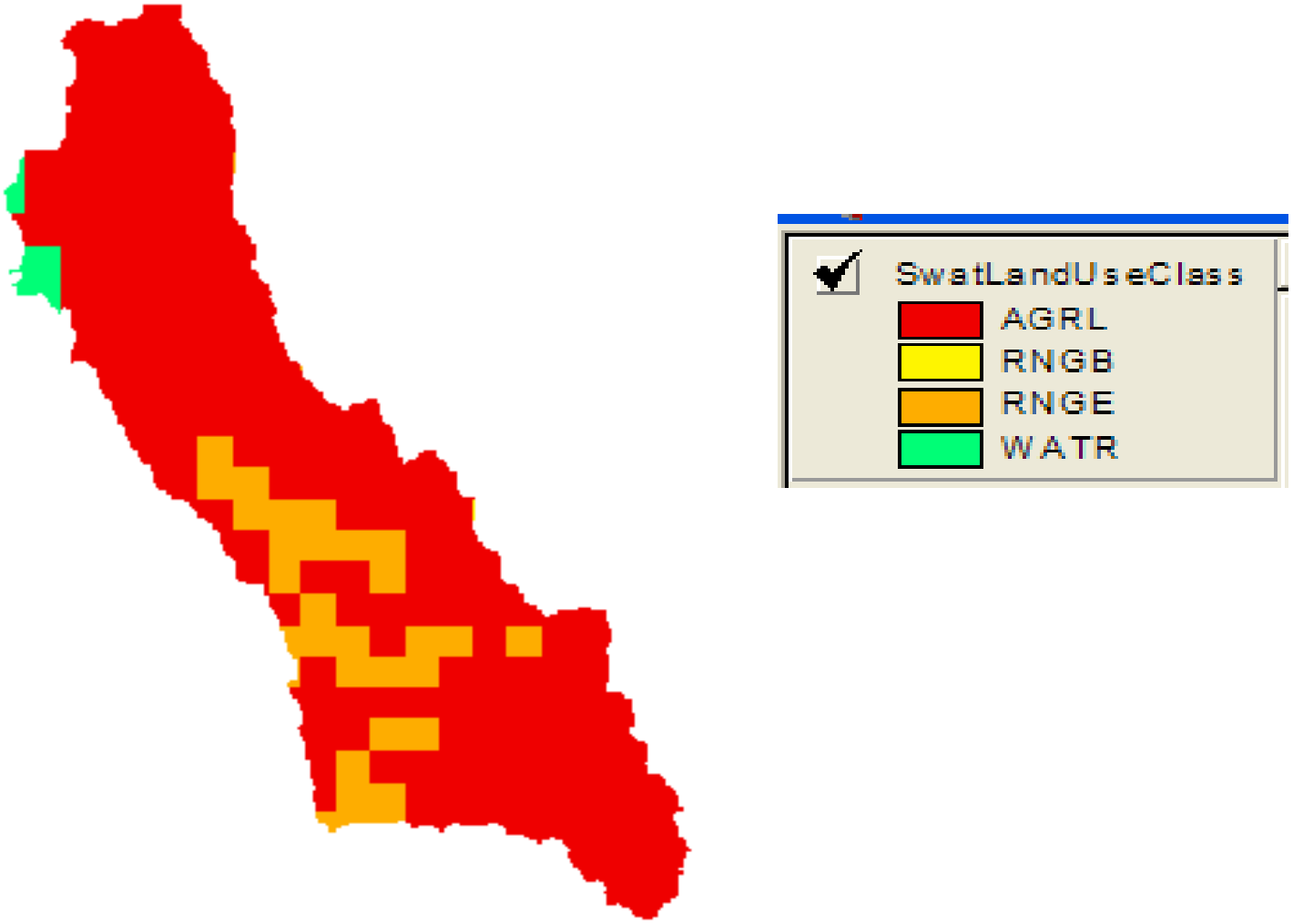
Reclassified/overlaid Landuse



Data preparation (3)

- Rainfall data
  - Table with station names and locations (batch files)
  - Data file for each station
- Temperature data
  - Table with station names and locations
  - Data file for each station

Rainfall data file format

Data file

Microsoft Excel - pcpbatch.dbf

	A	B	C	D	E
1	ID	NAME	XPR	YPR	ELEVATION
2	1	R001	1124830	-768421	1490
3	2	R002	1084286	-703638	1862
4	3	R003	1064907	-716751	1878
5	4	R004	1074817	-721238	1800
6	5	R005	1097630	-721238	2312

Microsoft Excel - R002.dbf

	A	B	C
1	DATE	PCP	
2	01/01/1970	-99.0	
3	02/01/1970	0.0	
4	03/01/1970	0.0	
5	04/01/1970	0.0	
6	05/01/1970	47.0	
7	06/01/1970	0.0	
8	07/01/1970	0.0	
9	08/01/1970	0.0	
10	09/01/1970	9.0	
11	10/01/1970	-99.0	
12	11/01/1970	0.0	
13	12/01/1970	0.0	

File name: R002

Save as type: DBF 4 (dBASE IV)

Save

Cancel

Batch file

Temperature data file format

Data file

Microsoft Excel - T93370...

File Edit View Insert Format Tools Data Window Help

C8 -99

	A	B	C
1	DATE	MAX	MIN
2	01/01/1958	32	17
3	02/01/1958	32	16
4	03/01/1958	30	16
5	04/01/1958	31	18
6	05/01/1958	32	15
7	06/01/1958	34	17
8	07/01/1958	-99	-99
9	08/01/1958	33	15
10	09/01/1958	33	14
11	10/01/1958	30	14

Microsoft Excel - tempbatch.dbf

File Edit View Insert Format Tools Data Window Help

F5

	A	B	C	D	E
1	ID	NAME	XPR	YPR	ELEVATION
2	1	T9337004	314790.073	9629596.738	813
3	2	T9337016	296530.371	9539218.967	1263
4	3	T9337090	327873.087	9581743.588	1240
5	4	T9438023	446441.168	9467594.163	1524
6	5	T9438074	422337.461	9508139.796	510
7	6	T9438075	435359.942	9458411.210	350
8	7	T9438076	418713.936	9471327.707	1400
9	8	T9538079	394753.854	9399444.727	690
10	9	T9539015	507426.634	9438212.222	40
11					

tempbatch

Draw AutoShapes

Ready

File name: T9337004

Save as type: DBF 4 (dBASE IV)

Save

Cancel

Batch file

Data preparation (4)

- Climate stations
  - Table with station names and locations (batch file)
  - Userwgn.dbf with data for each station

Climate stations

Batch file

Microsoft Excel - wgnstations.dbf

	A	B	C	D	E
1	ID	NAME	XPR	YPR	
2	1	T001	1124829.910	-768420.680	
3	2	T003	1064906.910	-716750.610	
4					

Microsoft Excel - userwgn.dbf

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	ST	STATION	WLATITUDE	WLONGITUDI	WELEV	ID	FILE	RAIN_YF	TMPMX1	TMPMX	TMPMX	TMPMX	TMPMX
2	1	T001	0.00	0.00	1490	0		35.00	27	27	27	26	26
3	2	T003	0.00	0.00	1862	0		10.00	24	24	24	24	24

Microsoft Excel - userwgn.dbf

	A	B	BD	BE	BF	BG	BH	BI	BJ	BK	BL
1	ST	STATION	TMPST	PCPMM1	PCPMM2	PCPMM3	PCPMN	PCPMN	PCPMN	PCPMN	PCPMN
2	1	T001	1.24	72.73	86.95	116.98	158.35	96.98	21.68	12.80	35.56
3	2	T003	2.00	68.05	86.70	123.89	144.54	109.62	48.25	29.00	64.41

Microsoft Excel - userwgn.dbf

	A	B	EW	EX	EY	EZ	FA	FB	FC	FD	FE
1	ST	STATION	DEWPT1	DEWPT2	DEWPT3	DEWPT4	DEWPT	DEWPT	DEWPT	DEWPT	DEV
2	1	T001	0.76	2.42	4.85	10.55	16.45	19.86	20.56	20.07	17
3	2	T003	0.76	2.42	4.85	10.55	16.45	19.86	20.56	20.07	17

Userwgn.dbf

Userwgn.dbf (long term climatic condition)

Rainfall Statistical parameters derivation

- Use pcpSTAT.exe
- Use *ASCII text file format* to create Input file (e.*g*. R002.txt)
- The line of input data file must be a blank
- One column of rainfall data values
- The record should start Jan 1 and End Dec. 31
- The missing rainfall values should be assigned -99.0

The outputs (e.*g.* R002.out)

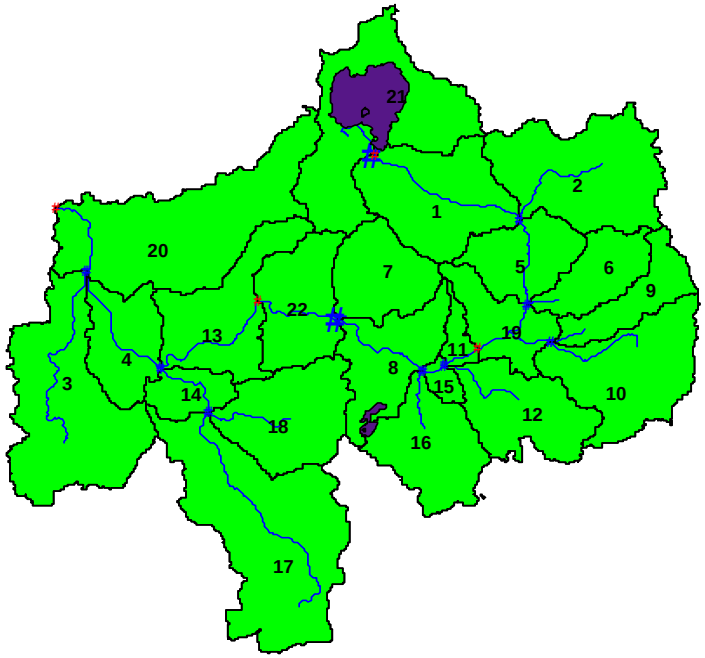
- File 1→ R002.out: Statistical Analysis of Daily Precipitation data. Directly used in userwgn.dbf
- File 2→mean_pcp.st: Average Daily precipitation in Month
- File 3→ totalpcp.sta: Total Monthly precipitation

Subbasin:

Input

- .sub: subbasin (area,…)
- .wgn: weather information (#gage or generate)
- .wus: water use
- .pnd: pond

Output: output.sub



HRU:

Input

- .hru: HRU information (area,…)
- .sol: sol data
- .chm: chemical composition soils
- .gw: groundwater
- .mgt: agricultural management (Curve number!)

Output: output.hru

River routing:

Input:

- .rte: river routing input (morphology, manning, …)
- .swq: stream water quality

Output: output.rte

SWAT i/o files:

../Project/scenarios/default/sim#/txtinout

../Project/scenarios/default/sim#/tablesin

../Project/scenarios/default/sim#/tablesout

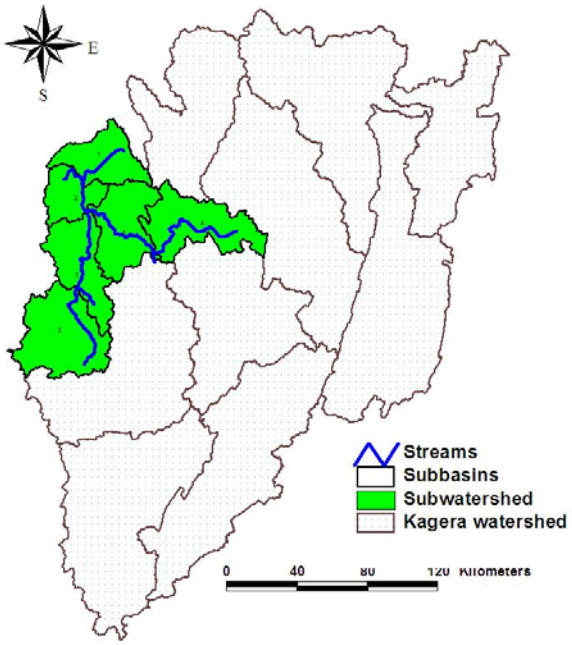
The use of SWAT within the Nile Basin

Dr. ir. Ann van Griensven
Department of Hydroinformatics and Knowledge Management
UNESCO-IHE, the Netherlands

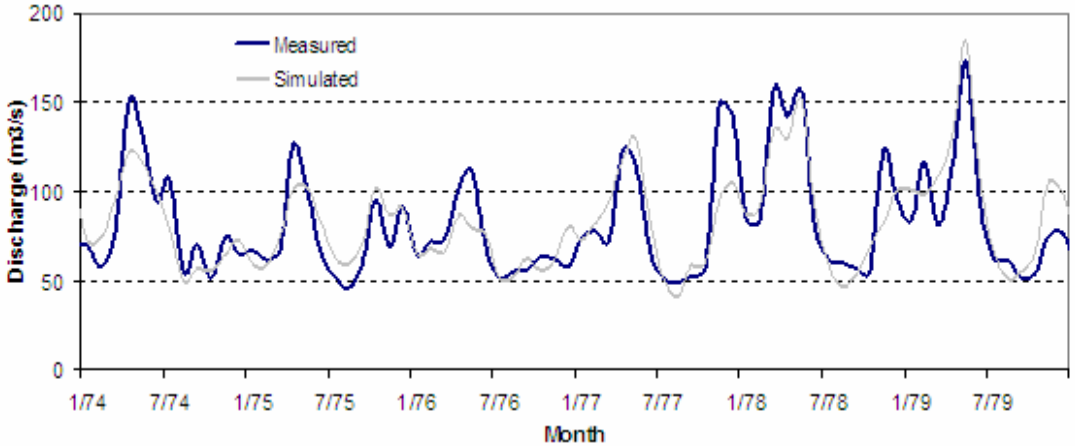
Dr. Preksedis .M. Ndomba
Department of Water Resources Engineering
UNIVERSITY OF DAR ES SALAAM, TANZANIA

Rainfall/runoff modelling

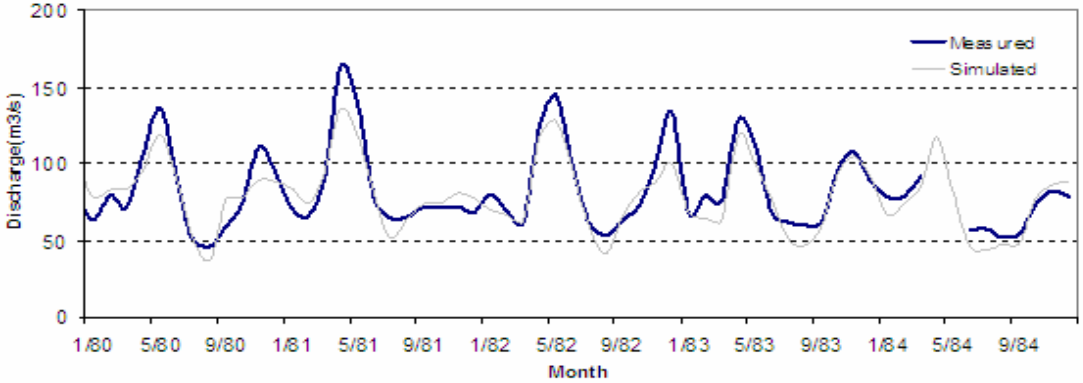
Rain gage data versus Satellite data: upper Kagera



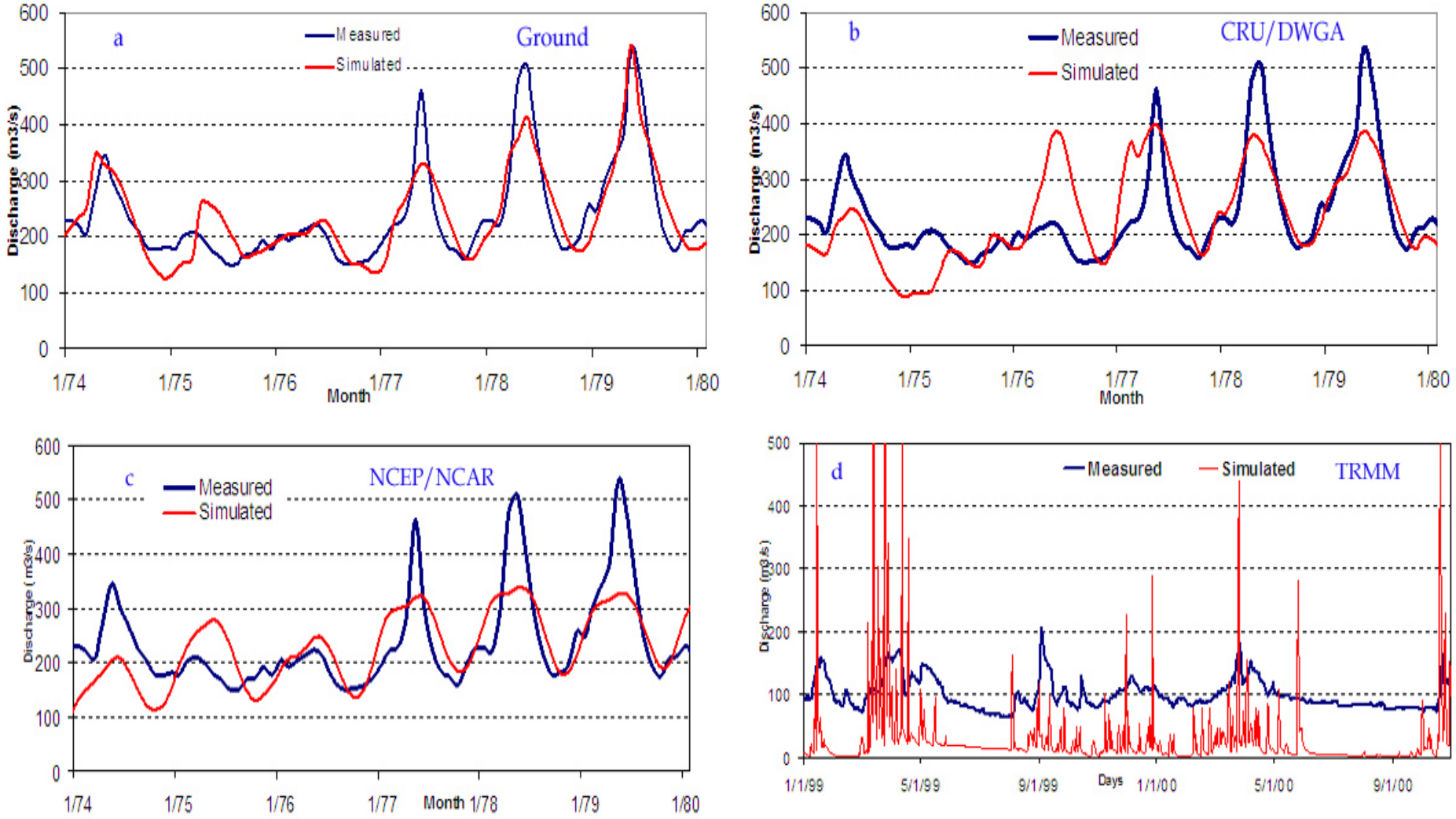
	Calibration	Validation
Ns	0.65	0.78
R^2	0.67	0.79
RMSE	23.05	11.94
Volume deviation	-2.34	-3.55



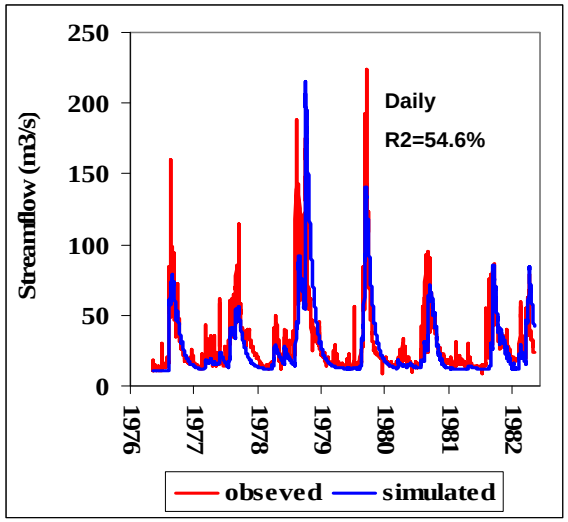
	Kagera watershed	Sub watershed
Area (Km^2)	8,393	8,393
Number of subbasins	3	6
Number of HRUs	15	36

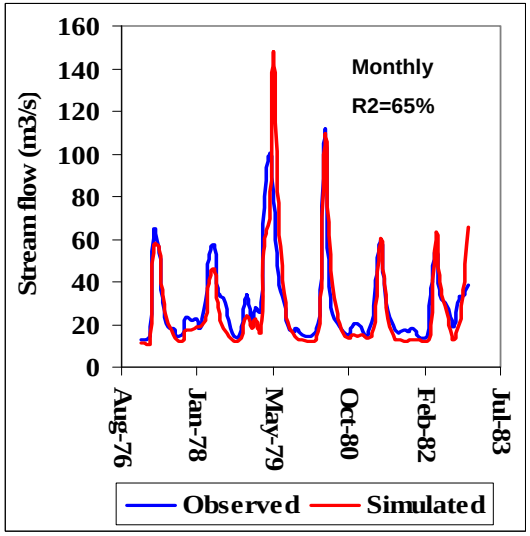


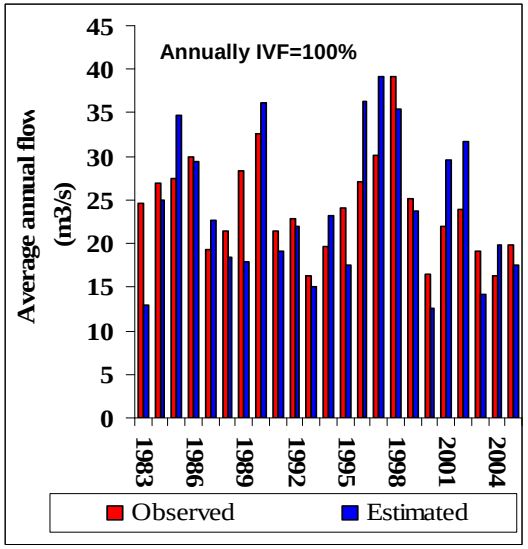
Rain gage data versus Satellite data: upper Kagera

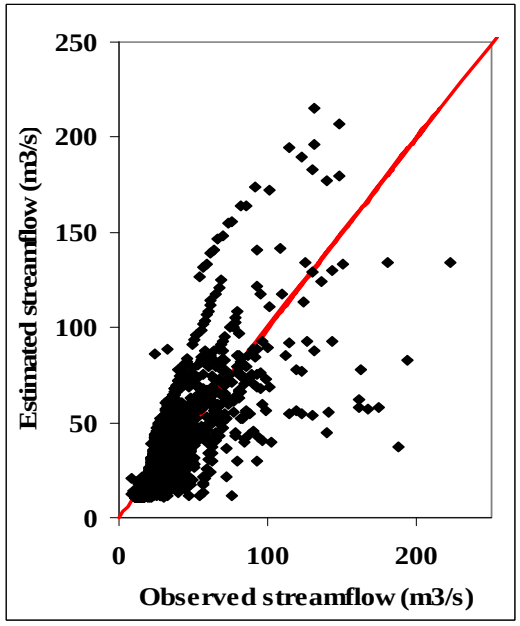


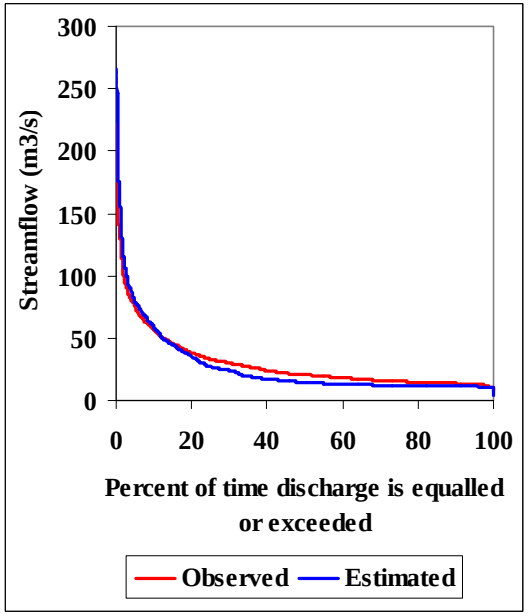
Pangani River Basin (Ndomba)

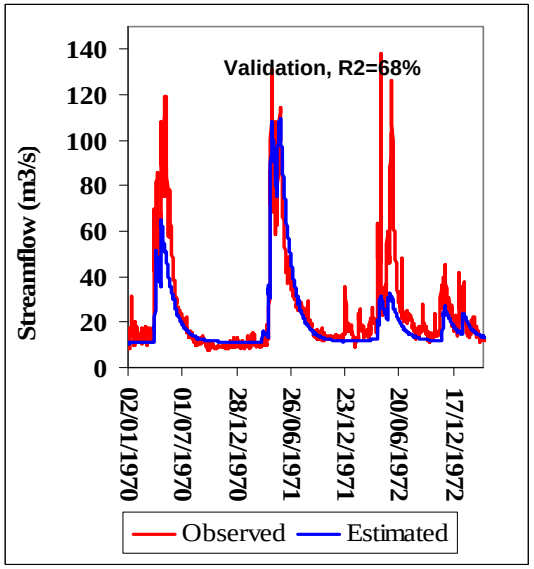








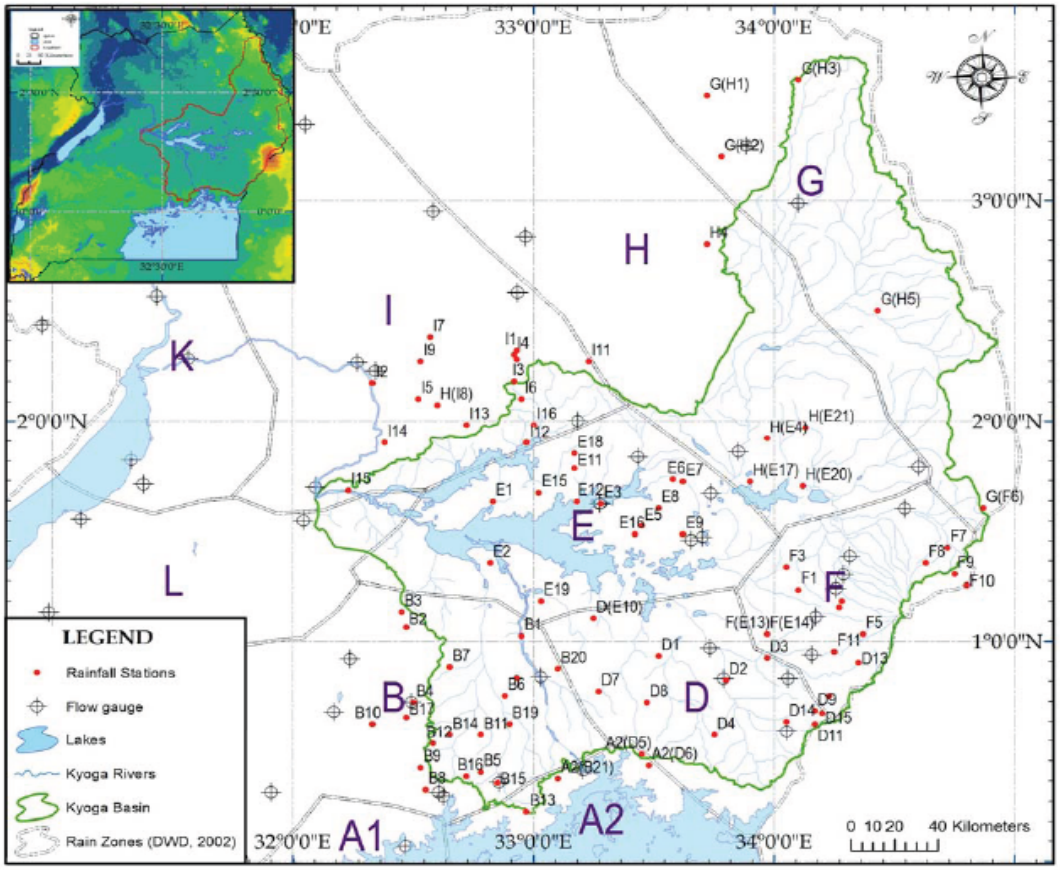




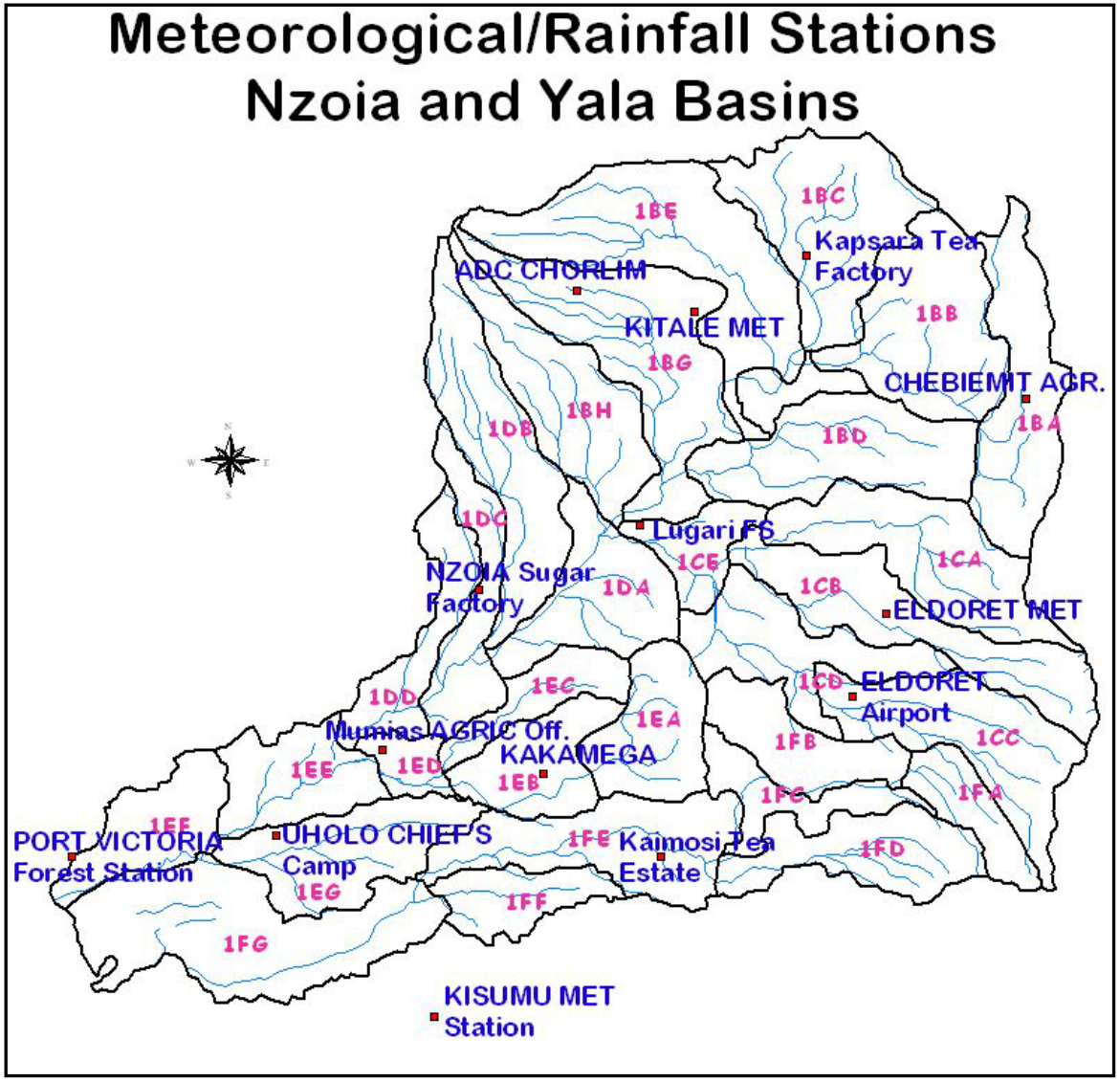
Stochastic rainfall modelling: Kyoga

Results

Kyoga Basin
Limited gauging

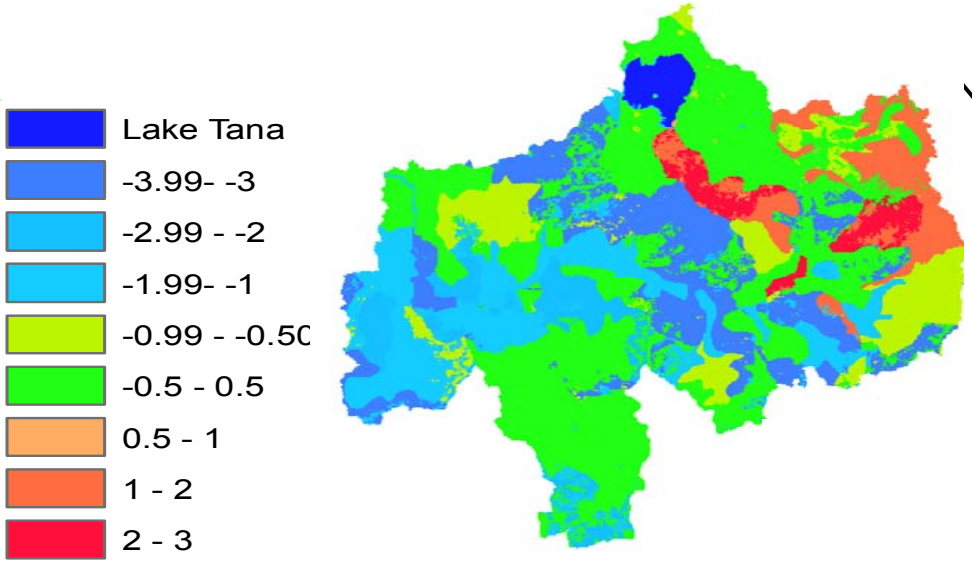


Rainfall interpollation: Nzoia



Water scarcity

Drought indexes: upper Blue Nile

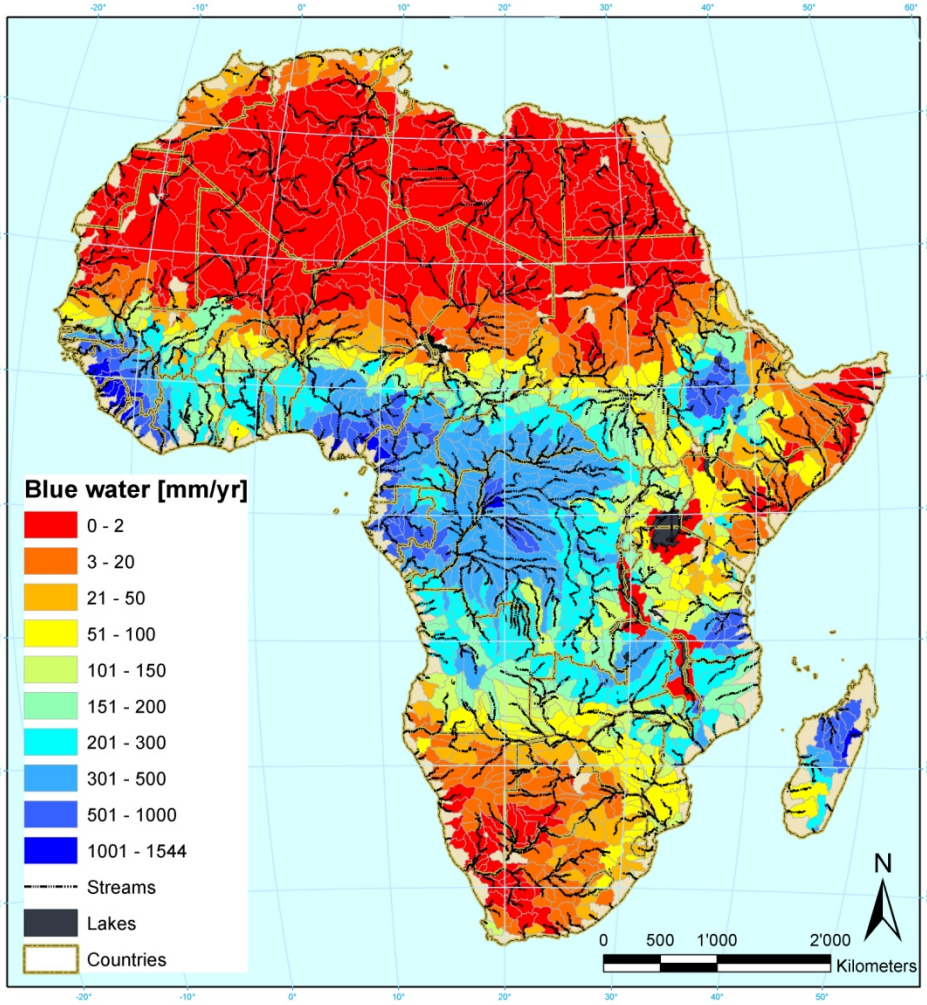


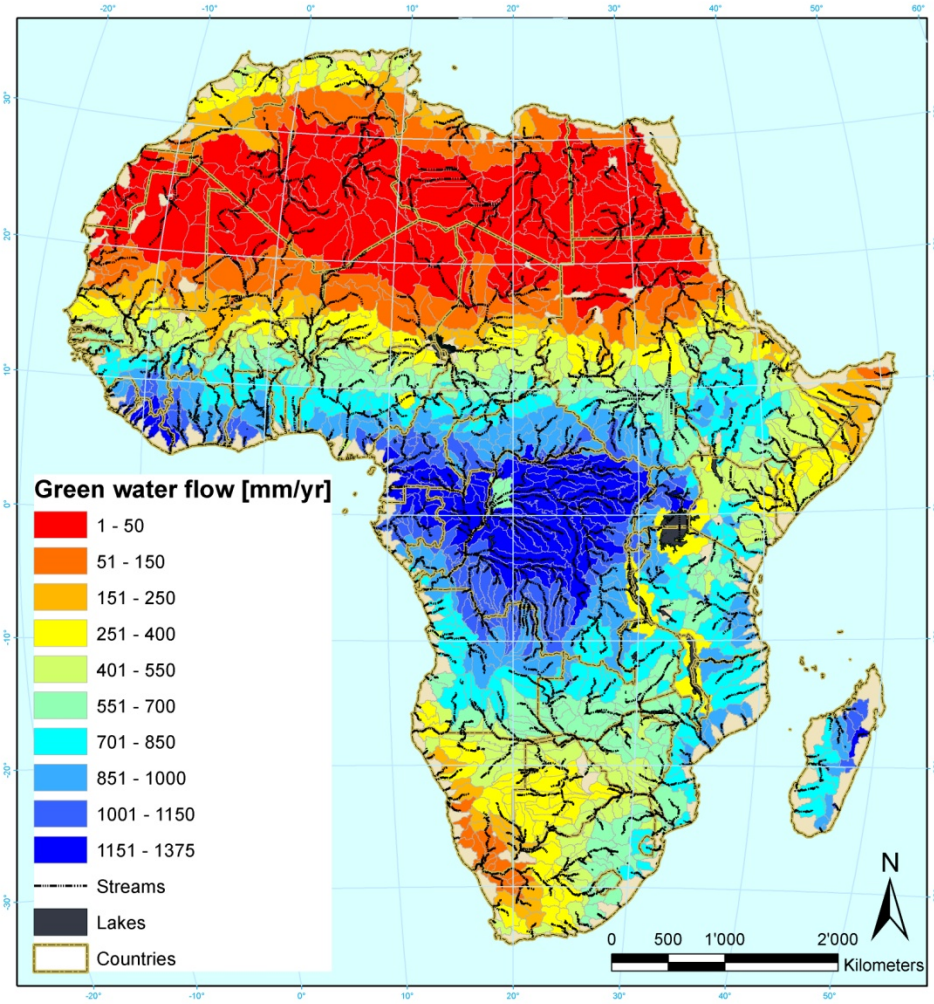
SMDI Jan, 2005

Water resources managament...

Jurgen Schuol & Karim Abbaspour

Blue water





Green water flow

Erosion/sediment transport

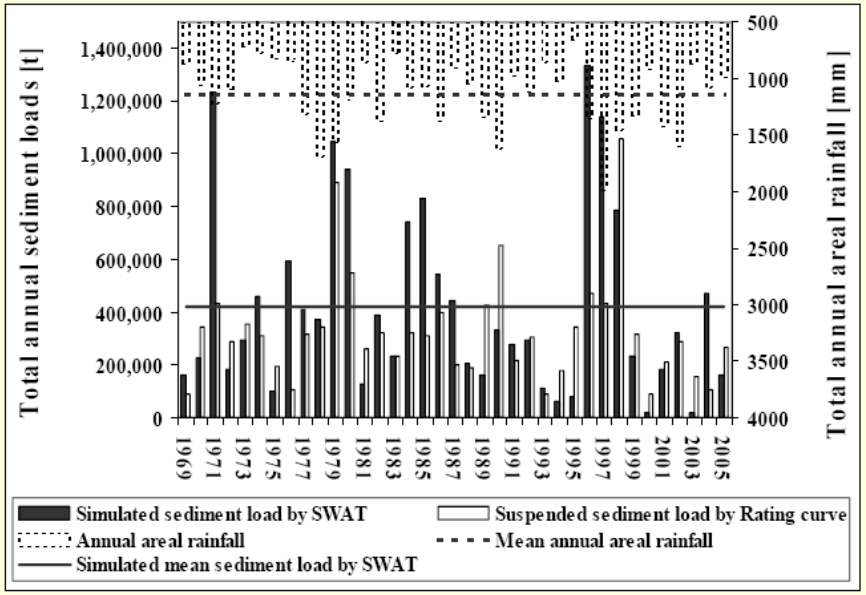
Erosion transport in Pangani (Ndomba)

RESULTS AND DISCUSSIONS

SWAT simulations Vs Rating curve-sediment loads at 1DD1 (Annually), **between January,1969 –December, 2005**

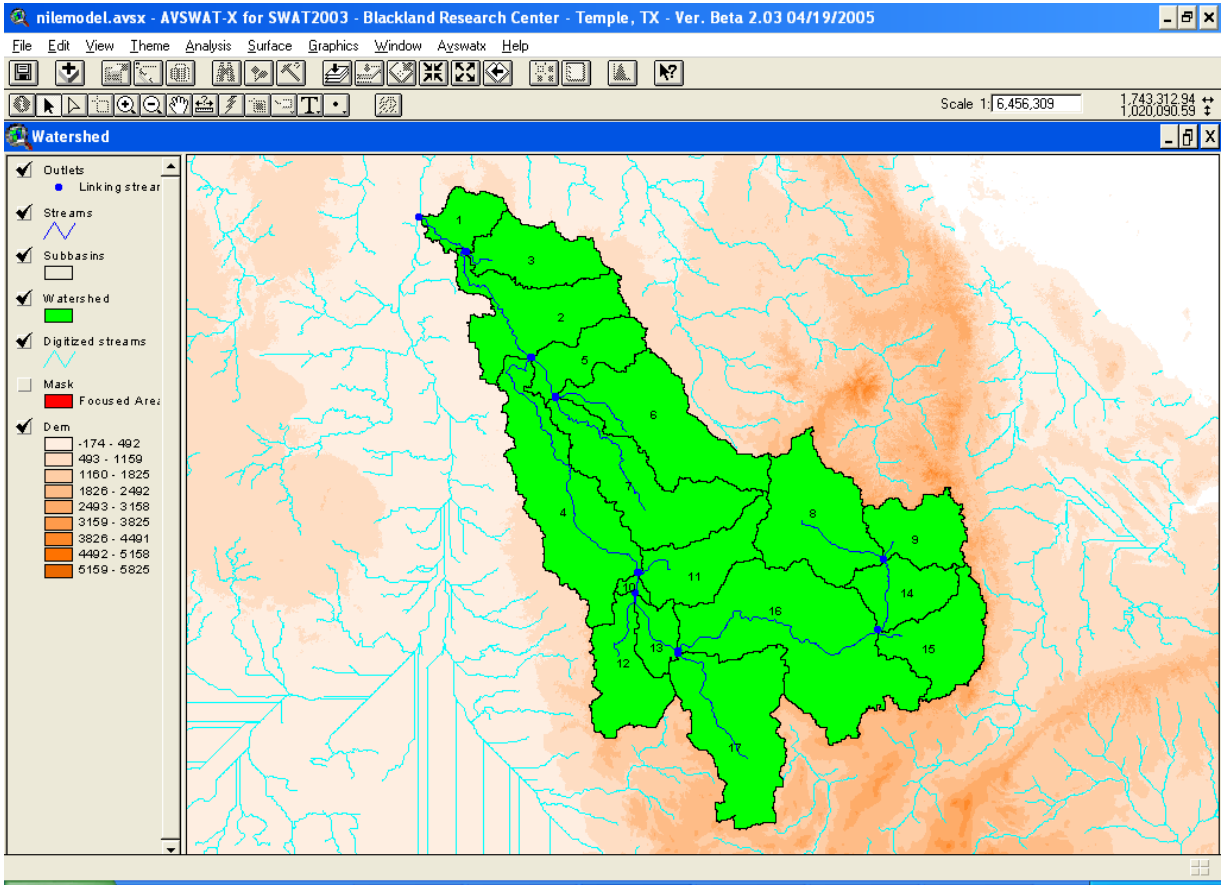
Performance (TMC=28.7%).

- Rating curve demonstrates linearity
- SWAT model demonstrates nonlinearity i.e. Not all rainfalls deliver sediment to outlet

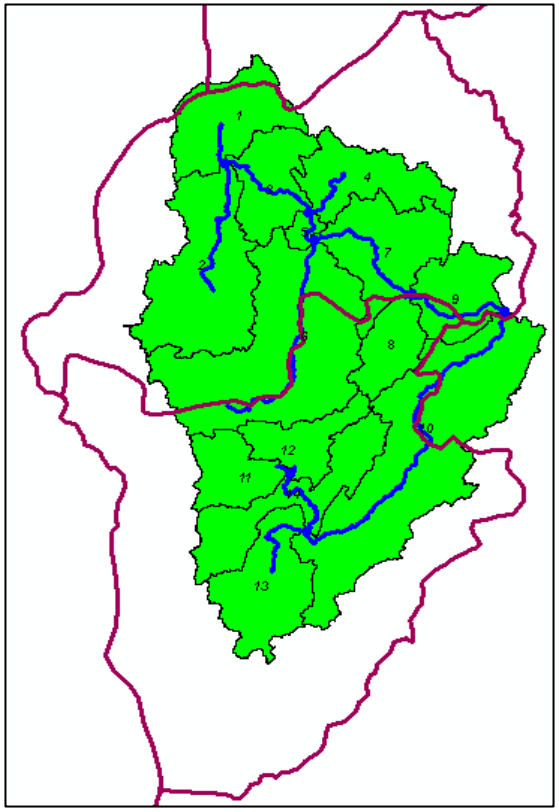


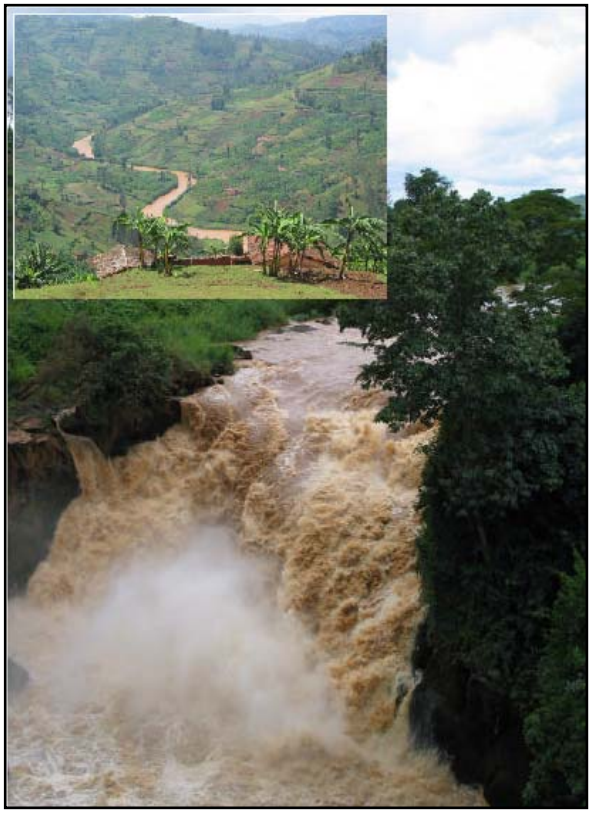
Blue Nile: Erosion transport
Getnet Dubale, UNESCO-IHE, 2009

- SWAT + SOBEK

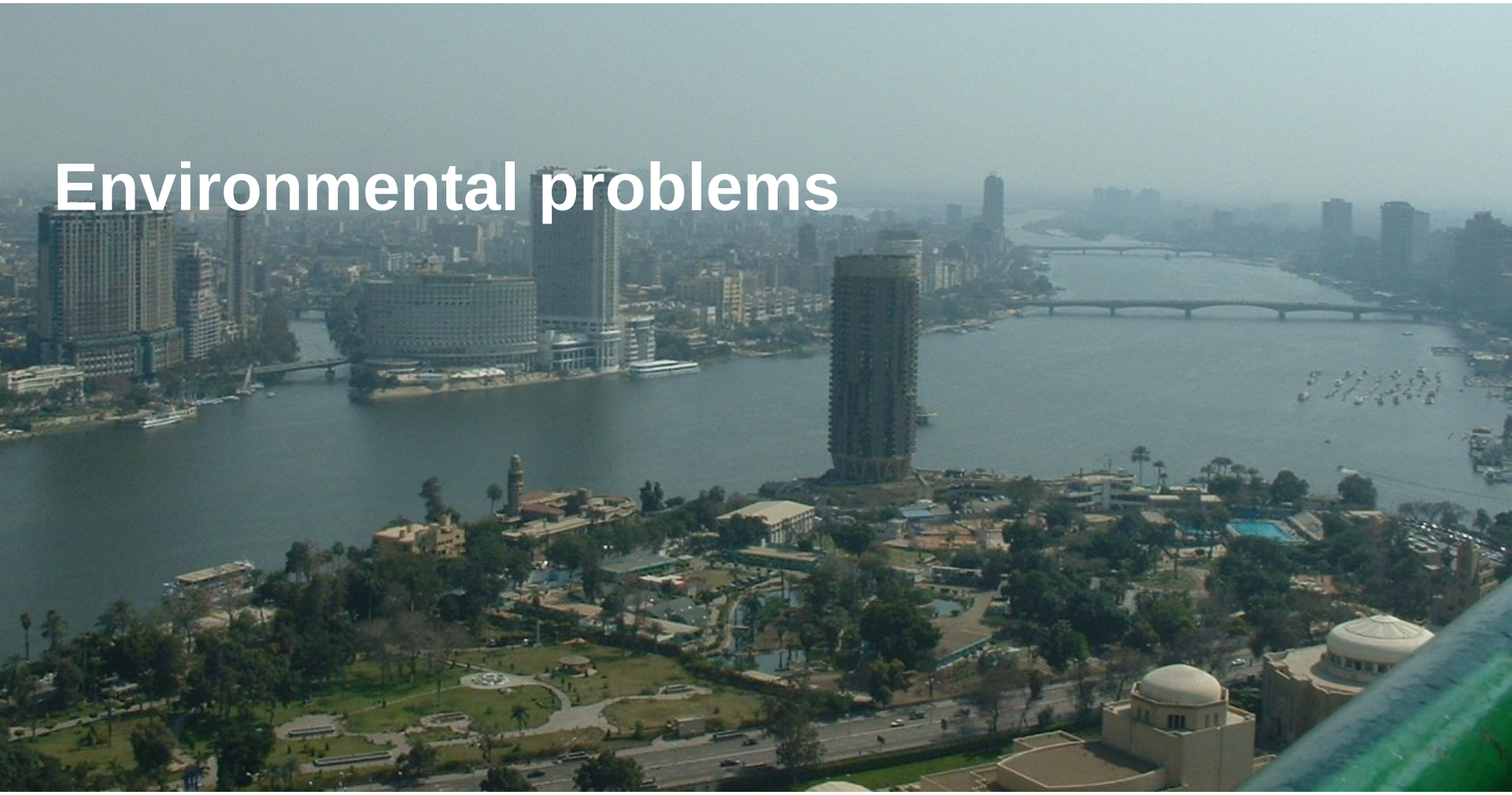


Upper Kagera river: erosion



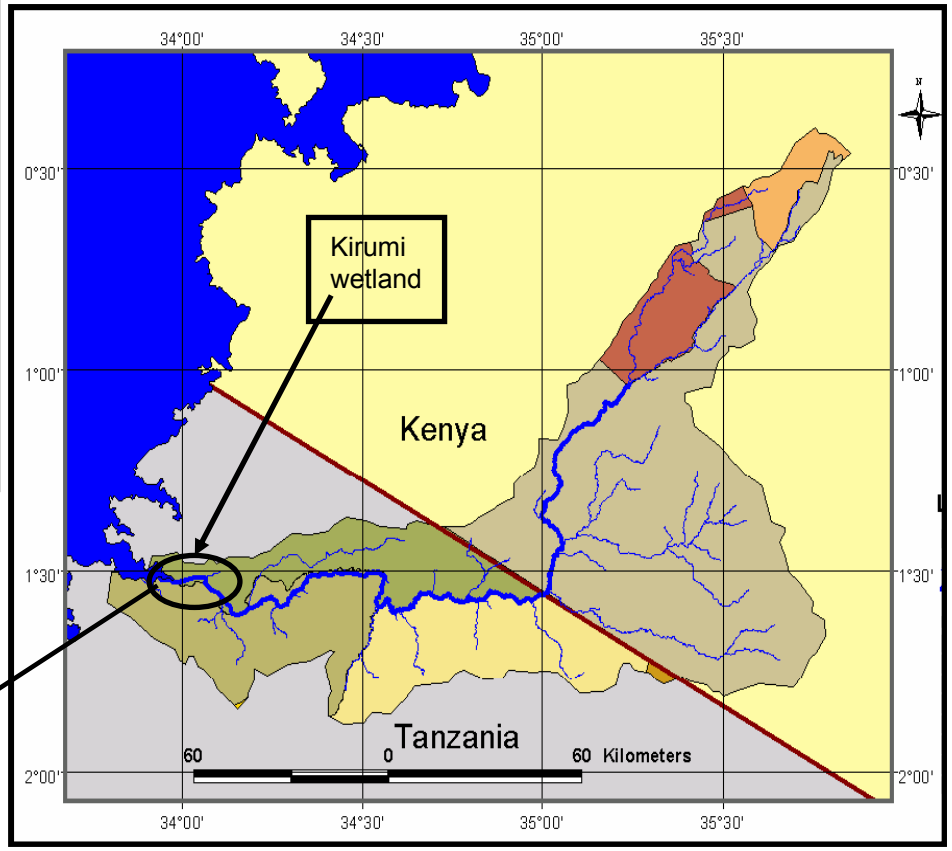


Environmental problems



Environmental Flow: Mara catchment

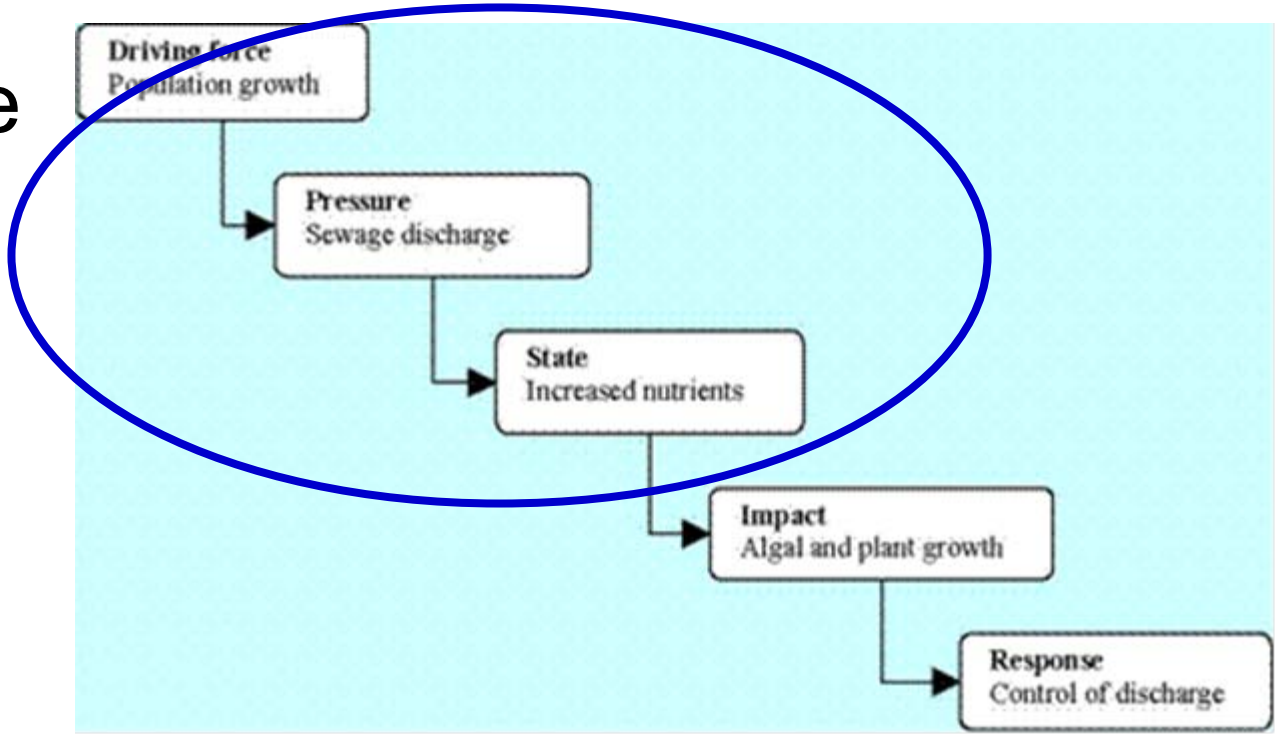
- Kirumi wetland
  - Important part of ecosystem, supports lives of about 6000 people
  - Situated on the lower end of the catchment
  - It is important to include the wetland in the EFA process



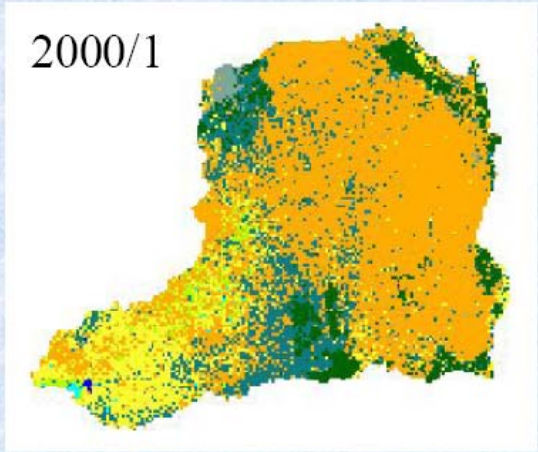
Scenario analysis

DPSIR

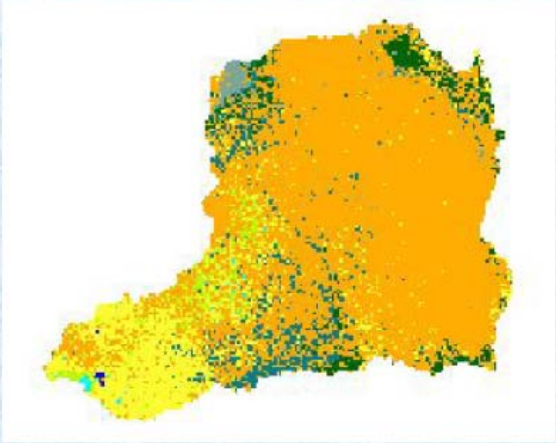
- Driving force
- Pressure
- State
- Impact
- Response



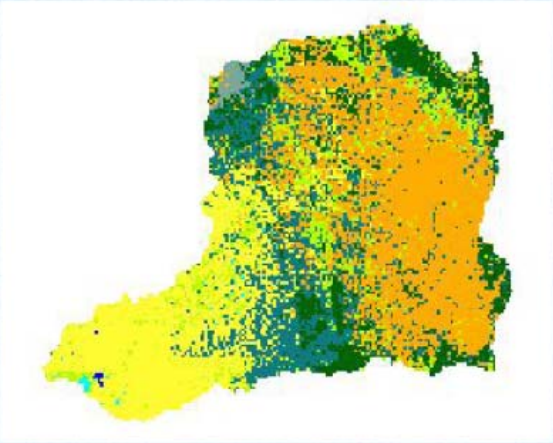
Climate change and land use change impacts



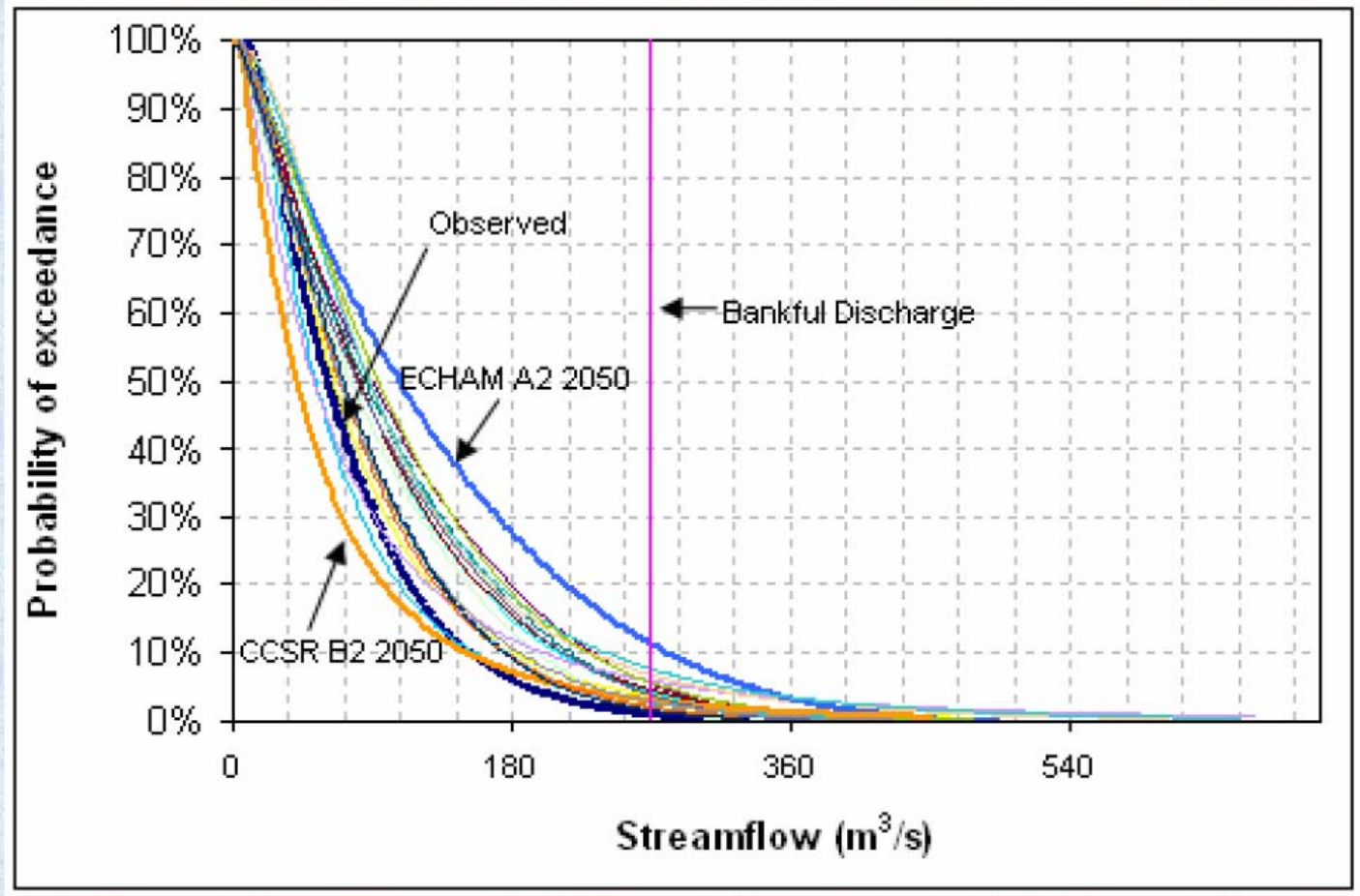
Scenario 1 –year 2020



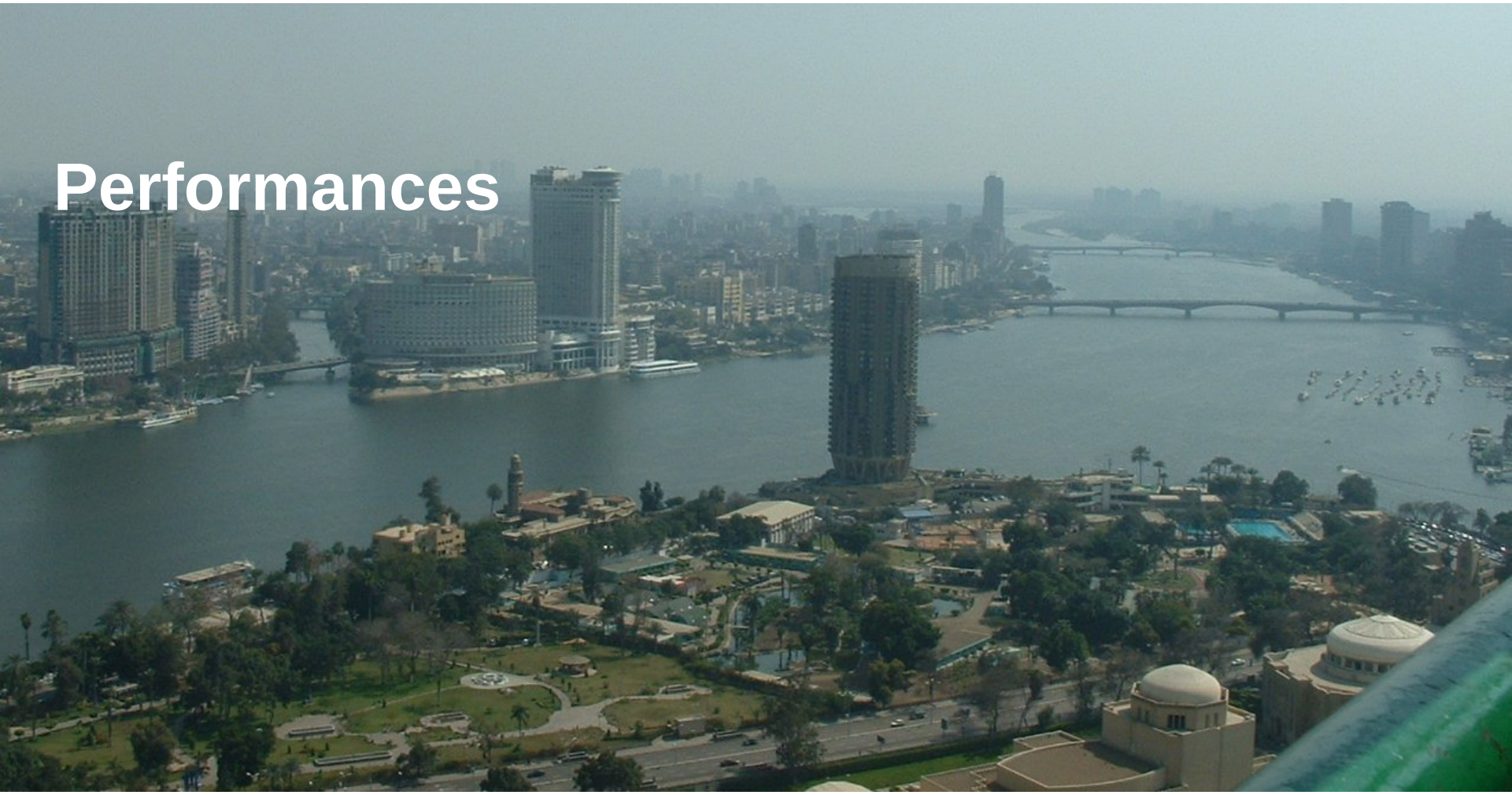
Scenario 2 –year 2020



Climate change and land use change impacts



Performances



Thank you!