Modelling the environmental impacts of FARMING PRACTICES

Possibilities and Limitations of AVSWAT2000

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Outline

- Context
  - Farming practices, policy response, policy performance, policy outcome
- Objectives
- Materials & Methods
- Results & Discussion
  - Parameterisation of FP
  - Simulated environmental effects of FP
- Conclusions and recommendations

Farming Practices (FP)

Choice of crops, crop varieties, crop succession

Nature and timing of:

- Land preparation (ploughing, manuring, fertilisation, irrigation, maintenance of hedges and pools, …)
- Sowing / Planting
- Management of growing crops (seasonal or perennial)
  - Fertilisation
  - Weed and pest management
  - Irrigation and drainage
  - Thinning
  - …
- Harvest
- Post-harvest land treatment (residue management, cover crop, …)

Tailored to the prevailing environmental conditions

- Long-term farmer's experience
- Agricultural science

FP in EU-Legislation

1st traces found in 1985 (797/85)

Nitrates Directive - cGAP

CAP (status 2003)

- 1st pillar (market organisation and income support) – GAEC-standards
- 2nd pillar (sustainable development of rural areas) - UGFP/cGFP

(Water Framework Directive)

…

GAEC-issues and GAEC-standards

Issues	Standards
Soil Erosion	Minimum soil cover
	Minimum Land Management
	Retention of Terraces
Soil Organic Matter	Crop Rotation
	Arable Stubble Management
Soil Structure	Appropriate Machinery Use
Minimum Maintenance	Min. stocking rate or regime
	Protection of permanent pasture
	Retention of landscape features
	No encroachment with unwanted vegetation

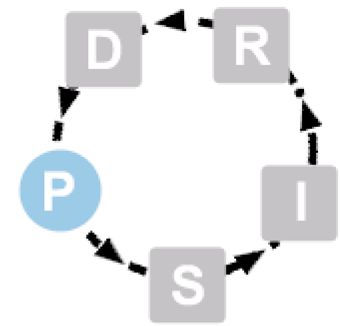
GAEC-standards: FP meant to reach GAEC-issues

(prevention of erosion and stand still of SOM, soil structure and habitat quality)

FP-related policies: Rationale

FP are Driving Forces possibly leading to

- Pressures on
- change of State of
- Impacts on the agri- and wider environment



Promotion/Prescription/Prohibition of environmentally (un)sound FP is a Policy Response

Assumption: Modification of the FP-related Driving Forces will

- (Contribute to) avoid/reduce undesired states and impacts
- (Contribute to) achieve/approach desired states and impacts

Policy performance & policy outcome

FP-related policy changes farmers' behaviour

- E.g. Increase of area under no-till or with cover crop
- Performance effect
- Reflected in 'common' agricultural and subsidy statistics

Is the changed behaviour likely to lead to environmental benefits ?

- E.g. Decrease of soil loss by erosion
- Outcome effect

Assessing outcome effects of FP-related policies

Environmental impacts are rather uncertain due to

- Complexity of and interaction between processes
- High spatio-temporal variability
- Lack of consolidated experience
- Uncertain uptake by farmers

Ex-post assessment

- Based on indicators and chains of indicators (e.g. DPSI-R)

Ex-ante assessment

- Integrated, spatially explicit modelling of the H_2O-, C-, N- and P-cycles and sediment displacement

What are the possibilities and limitations of the SWA-Tool, version 2000, under the ArcView GIS 3.2 user interface ?

- How are FP modeled and parameterised ?
- How does modeled output react to FP ?

Objectives

Assess possibilities and limitations of the SWA-Tool to assess the impacts of selected FP on

- River discharge
- Carbon stocks

FP of interest:

- Widening crop rotation
- Growing of cover crop
- No till
- Substitute mineral by organic fertiliser
- Convert arable land to pasture
- Convert pasture to arable land
- Afforest arable land
- Seal arable land

Materials (1)

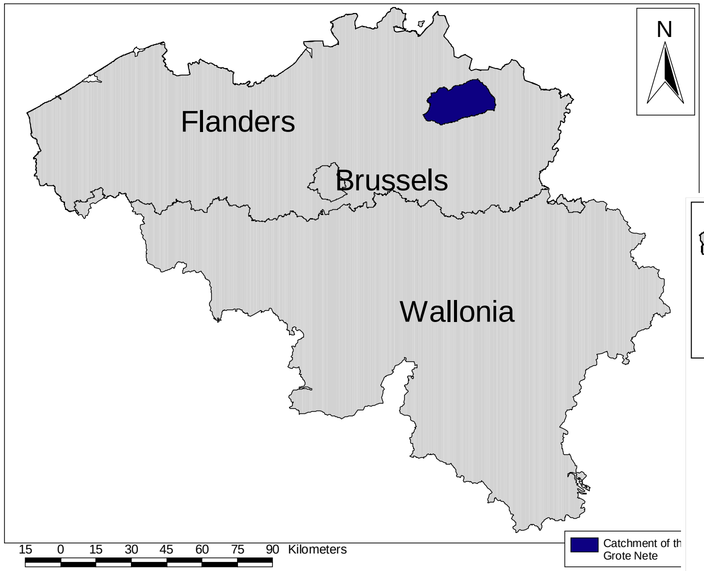
SWAT-2000 model, ArcView GIS 3.2 interface

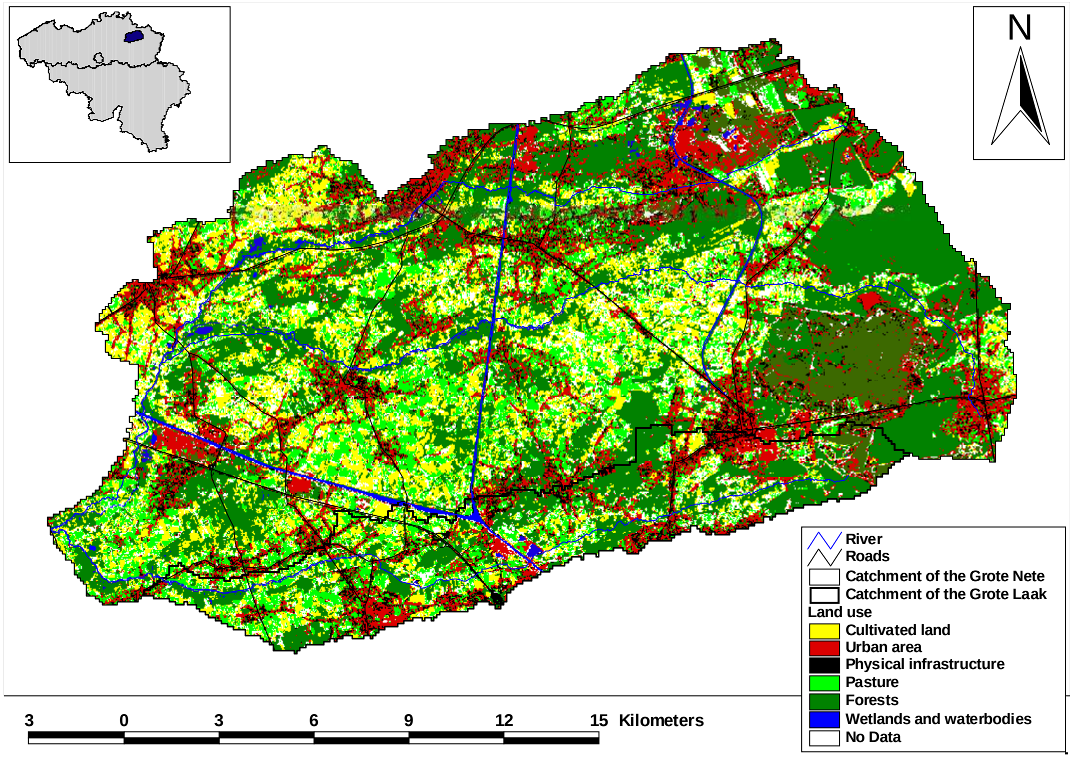
SWAT’s existing capabilities to handle FP

Code (MGT_OP)	Definition
1	Planting/beginning of growing season
2	Irrigation operation
3	Fertilizer application
4	Pesticide application
5	Harvest and kill operation
6	Tillage operation
7	Harvest only operation
8	Kill/end of growing season
9	Grazing operation
10	Auto-irrigation initialization
11	Auto-fertilization initialization
12	Street sweeping operation
13	Release/impound

Materials (2)

Study area = catchment "Grote Nete", Belgium – 383 km²





Materials (3)

- Measured river discharge data from specialised institutes (daily average values 1985-1995)
- Soil Carbon data from Lettens et al. (2005)
- Meteo data from RMI
- Input geodatasets from rSDI “GIS- Vlaanderen”
  - DEM
  - Soil association map
  - Land cover/use map
  - Rivers

Methods (1)

1. **Create baseline for further comparisons**
   - Detailed input data
   - Default farming practices
   - Calibrated for daily total river discharge and SOC

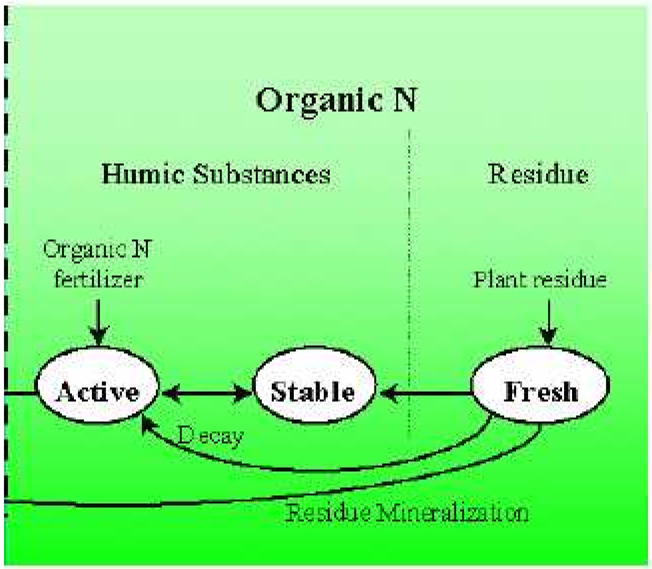
2. **Create scenarios by modifying FP and uptake ratio**

3. **Compare model output of (2) with (1)**

Methods (2)

Derive Soil Organic Carbon from Soil Organic Nitrogen

- Initialise SON based on SOC in .SOL-input/CN-ratio
- SON-balance
  SONi = SONi-1 + N_APP + N_GRZ + 0.2*F_MN – A_MN – ORGN
- Derive SOC from SON using CN-ratio (=14)
  SOCi = SONi * CN-ratio
- Spreadsheet developed
  for creation of annual time series of SOC from .SOL-input and .SBS-output files

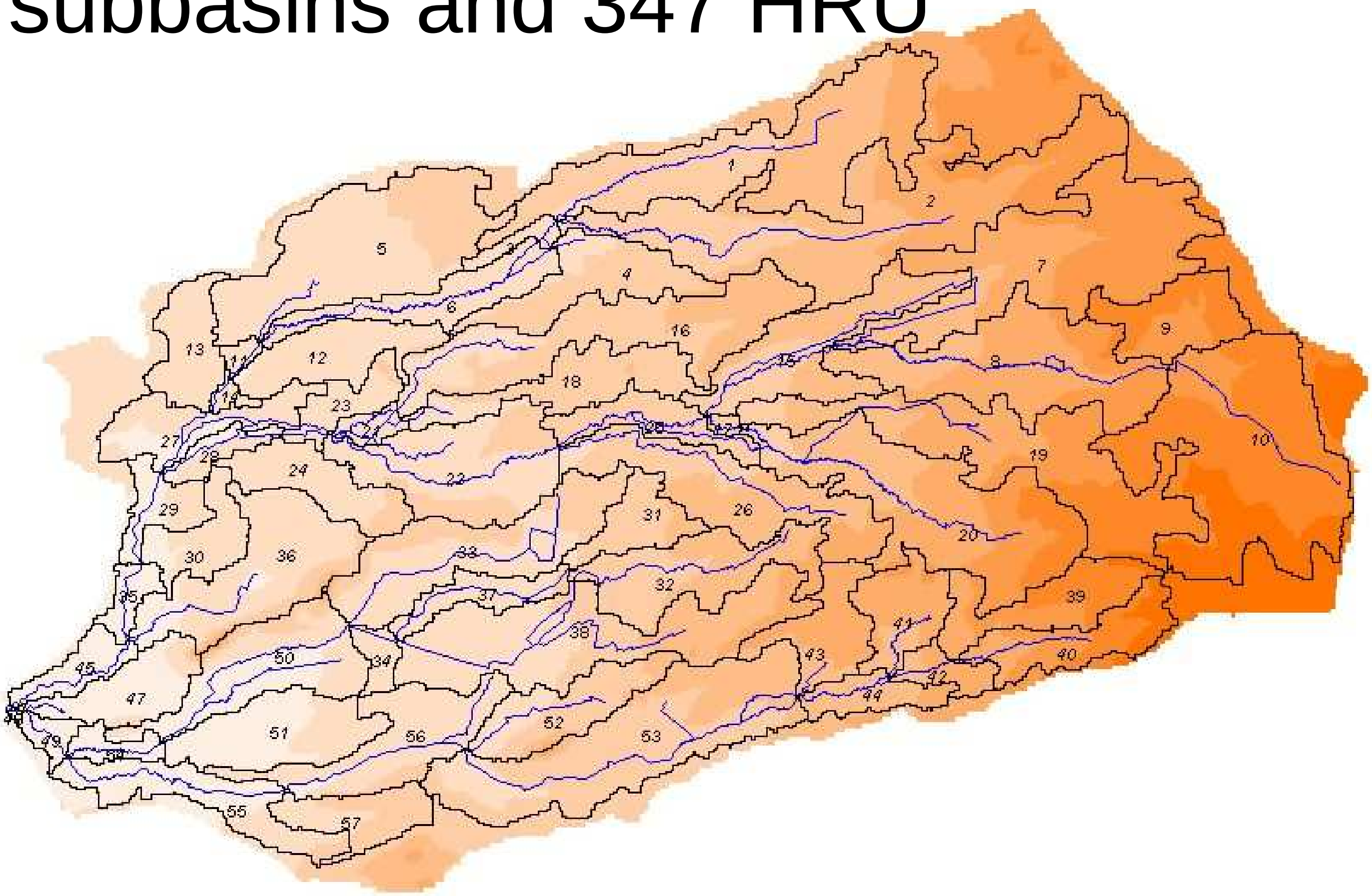


Results: Spatial model

- 348.5 km^2 – flat – light textured soils with alluvial clay strips
- 57 subbasins (300 hectares threshold)
- 347 HRU (land use class threshold = 10%; soil threshold = 20%)
- All soil units characterised by statistical profile with ploughed upper horizon
- All arable land = CSIL; all pasture land = WPAS (Fescue)

Results: Spatial model

- 57 subbasins and 347 HRU



Results – Baseline: Default FP for CSIL

#	Timing (fraction of total HU)	Practice
1	0.15 from 1-jan	Sowing
2	0.16 from 1-jan	Autofertilisation
3	1.2 from sowing	Harvest and Kill

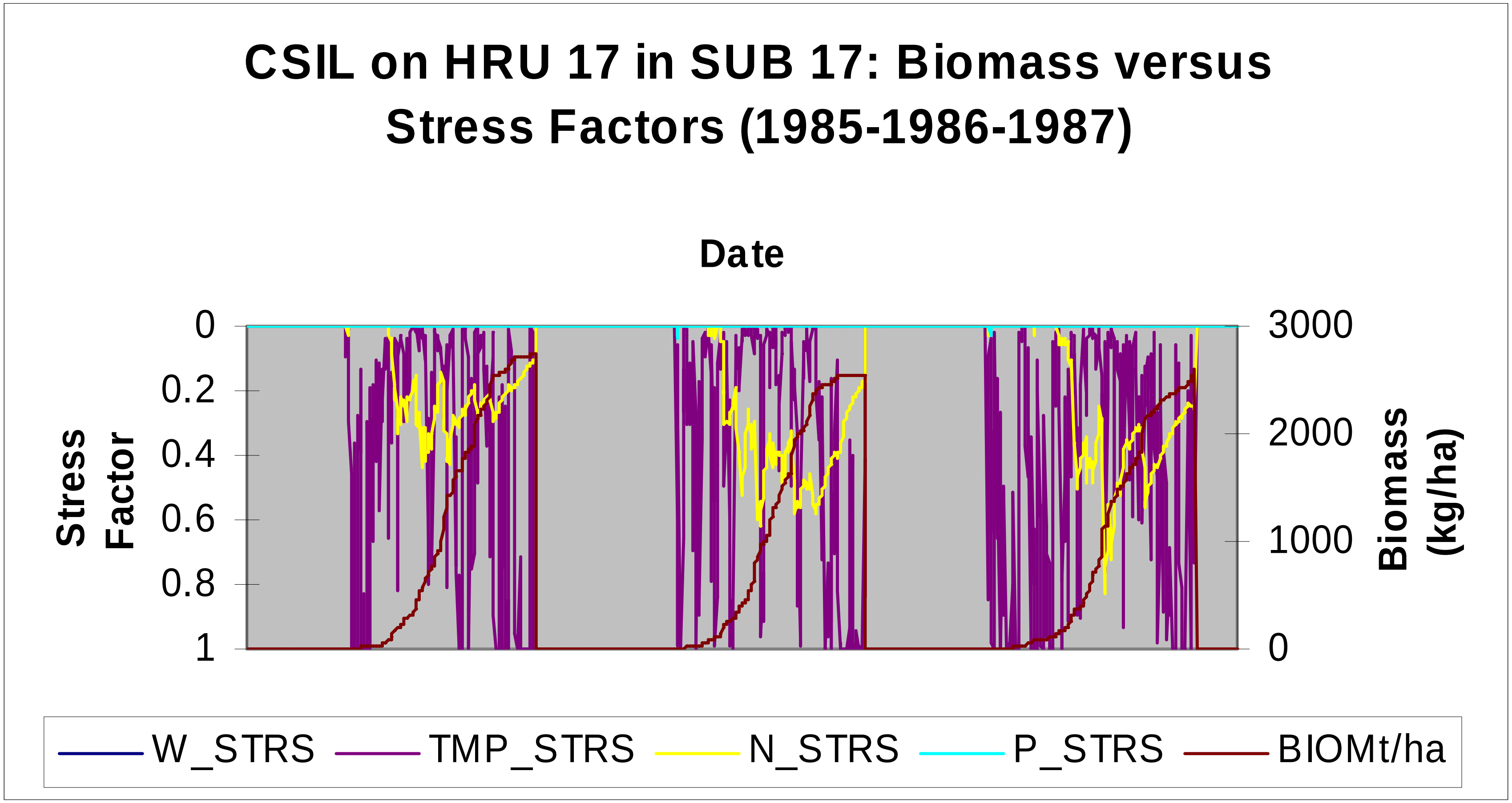
#	Timing	Practice
1	15-april	Tillage
2	11-may	Sowing
3	12-may	Autofertilisation
4	15-oct	Harvest and Kill

Results – Baseline: Default FP for WPAS

#	Timing	Practice
1	0.15 from 1-jan	Begin growing season
2	1.2 from sowing	Harvest and Kill

#	Timing	Practice
1	1-jan	Start of growing season
2	15-apr	Start of Autofertilisation
3	10-may	Harvest; 1^{st} cut
4	25-june	Harvest; 2^{nd} cut
5	10-august	Harvest; 3d cut
6	10-october	Harvest, 4^{th} cut
7	31-dec	Kill

Why change default FP ?



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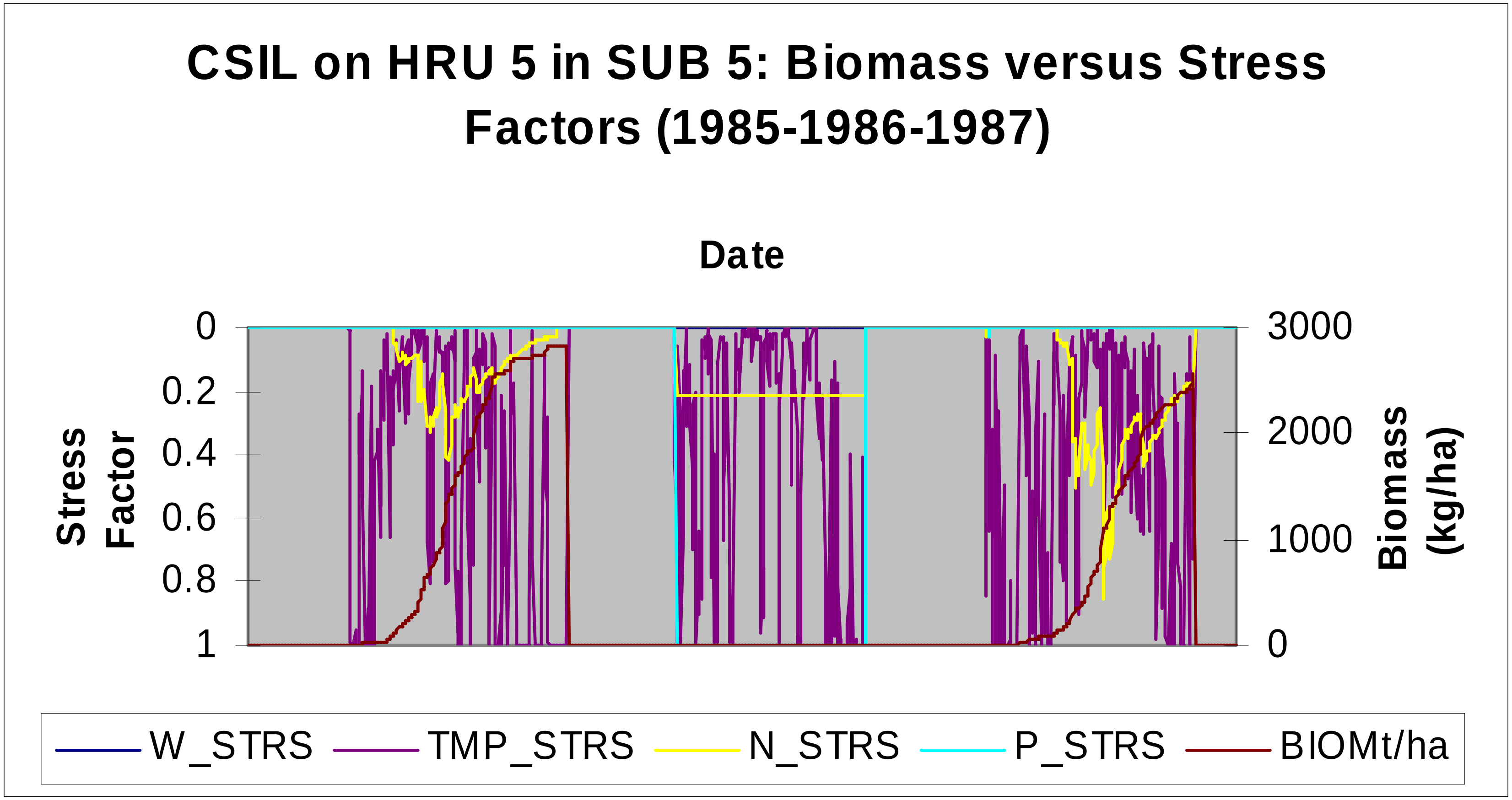

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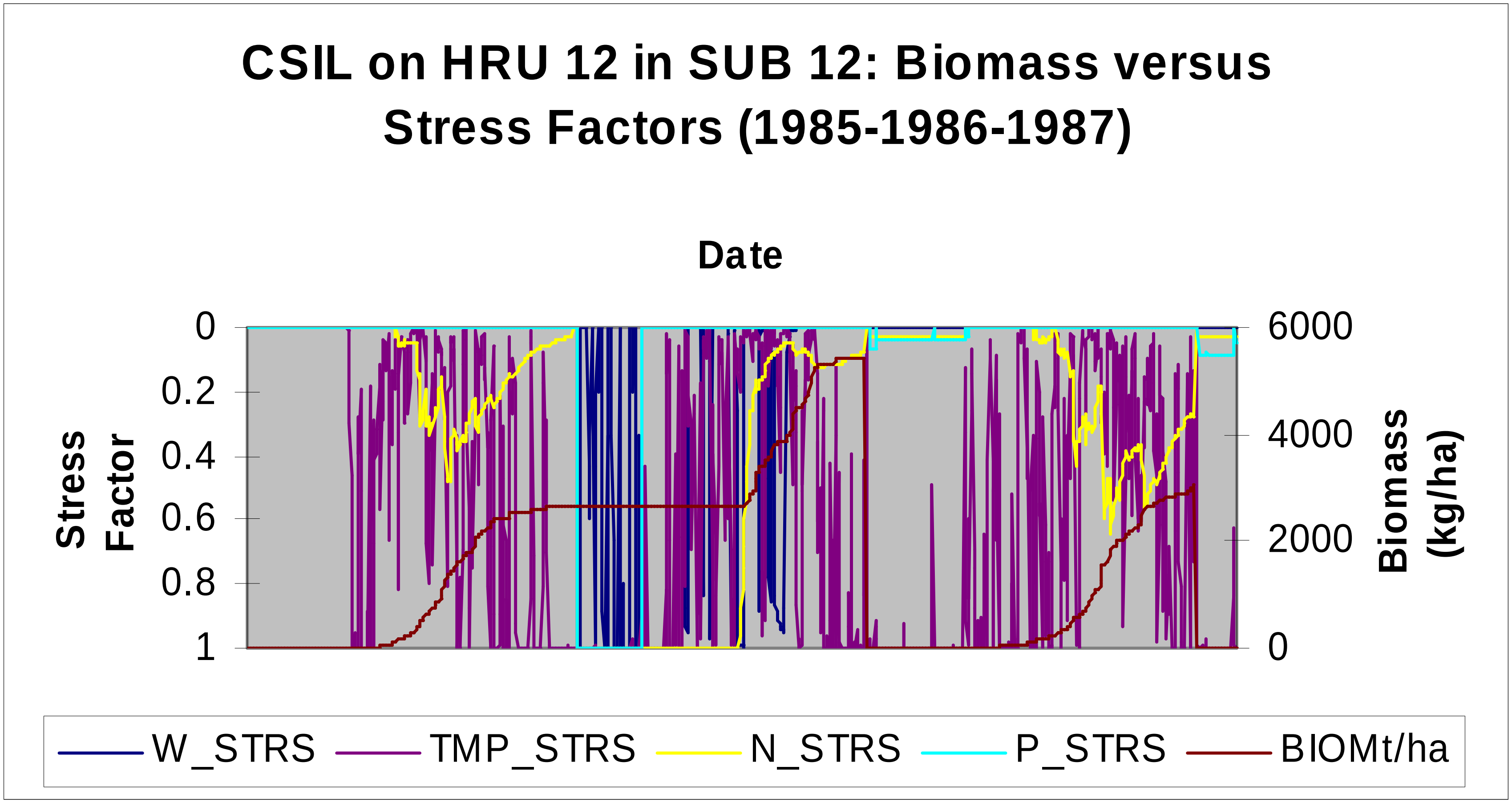
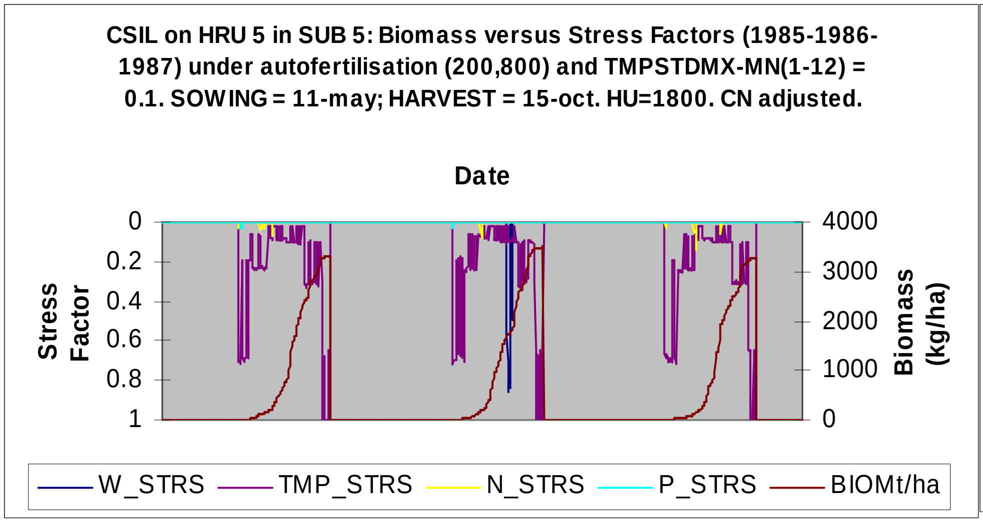


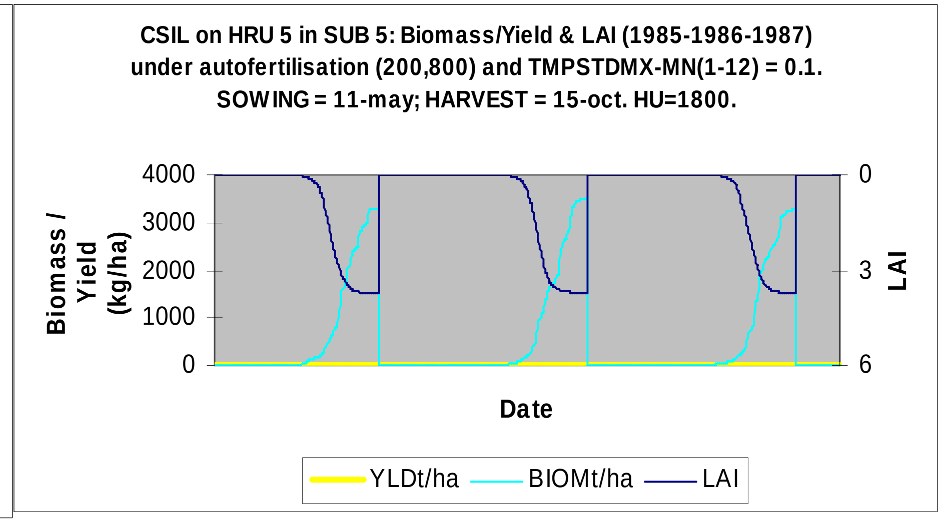
Change of FP-parameterisation

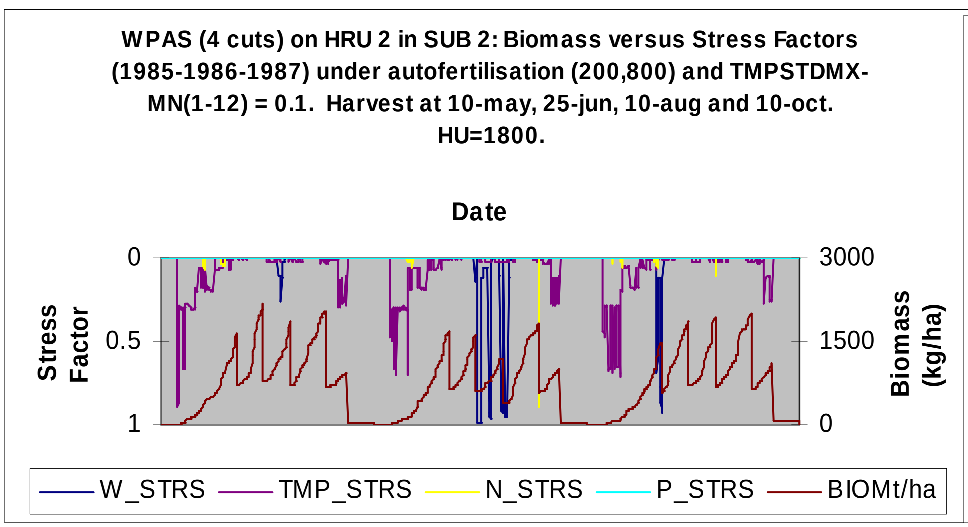
- Autofertilisation to reduce N-stress
- Make temperature stress less ‘unstructured’ by setting STD to min. allowed value
- From ‘schedule by Heat Units’ to ‘schedule by date’
- Default CN increased with ploughing and decreased during soil cover

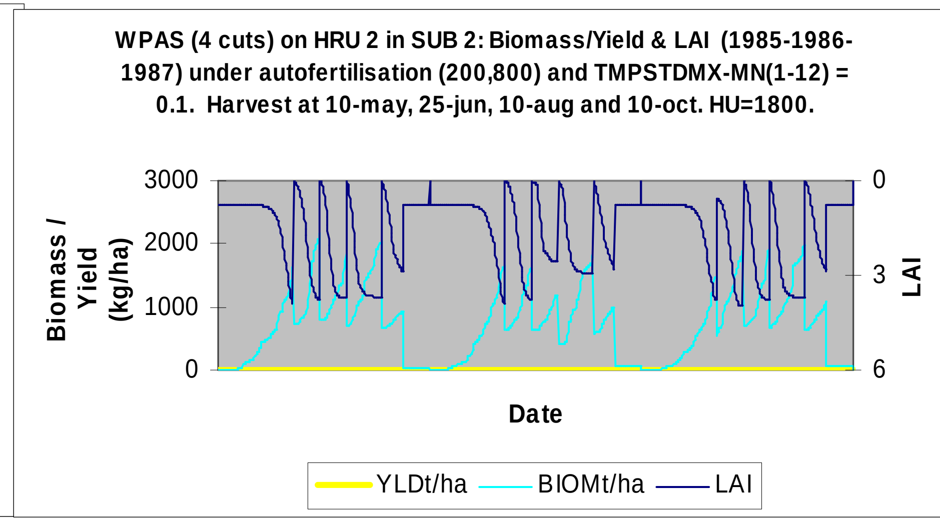
- Absolute values of simulated biomass & residue reamin too low !!!

With modified FP-parameterisation

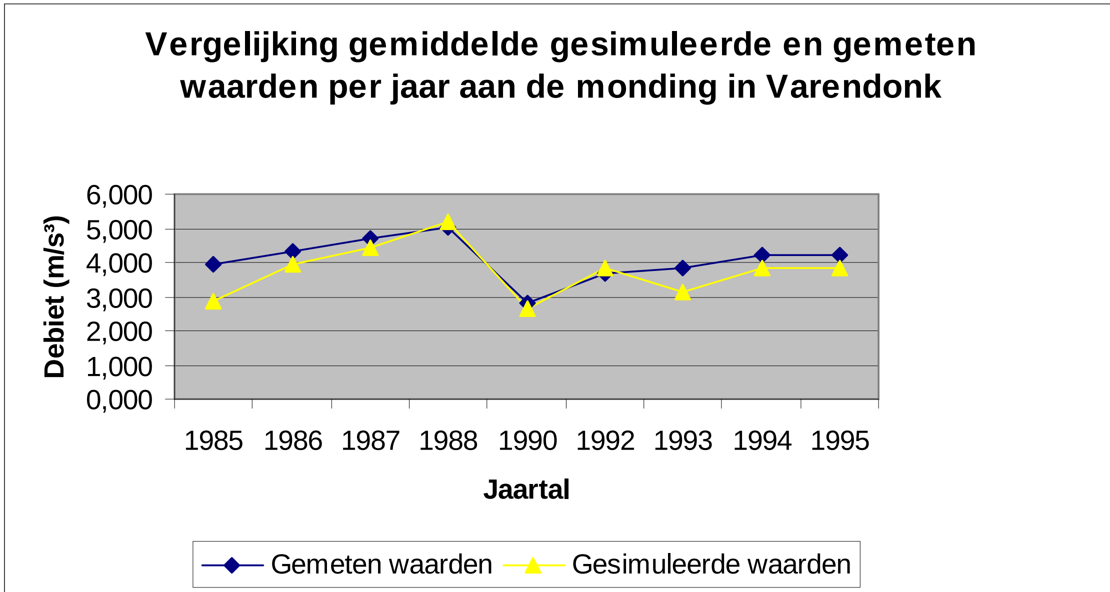








Results – baseline: Calibration-validation of river discharge



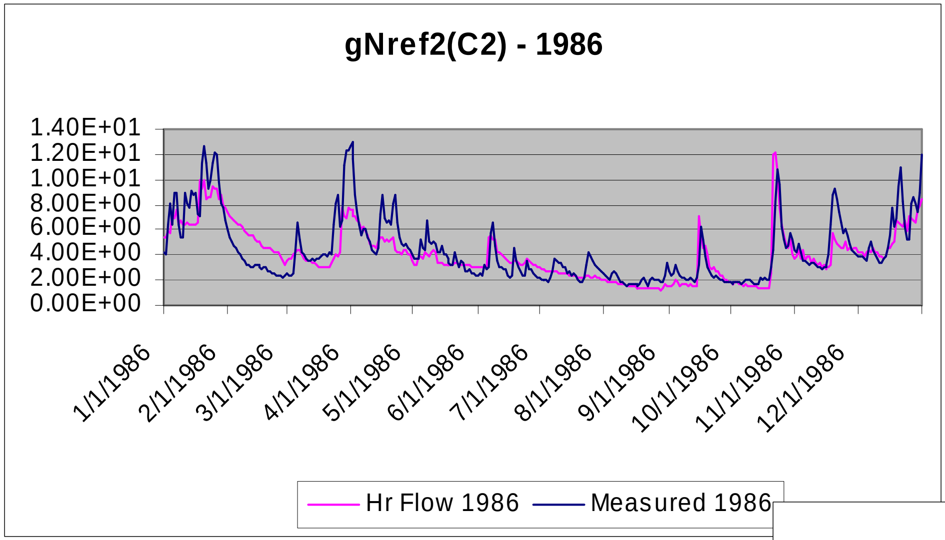
	Reference simulation	Measured values
Calibration (1986-1988)	**4,53 m³/s**	**4,70 m³/s**
Validation (1990, 1992-1995)	**3,45 m³/s**	**3,74 m³/s**
1986-1988, 1990, 1992-1995	**3,86 m³/s**	

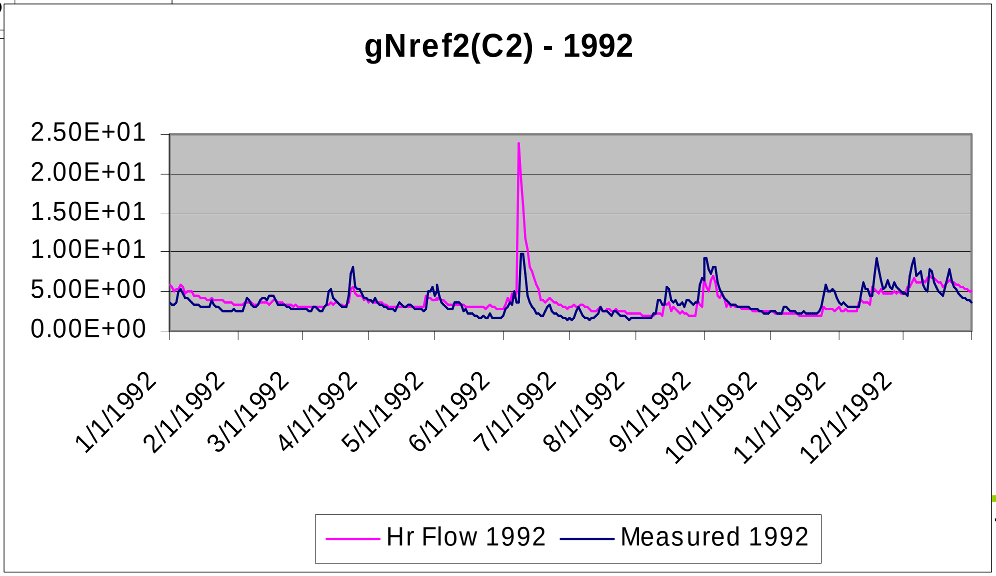
10-parameter set
after calibration for discharge

Quick flow	CN2 (dimensionless)	.mgt	Based on permeability, land use, management practices and antecedent soil moisture conditions	All CN increased by 2
	SOL_AWC (mm water/mm soil)	.sol	Based on soil characteristics	All AWC decreased by 0.01
	CH_N1 (dimensionless)	.sub	0.014	0.5
	SURLAG (days) .mgt	.bsn, to be set through the RunSwat menu	4	3

Slow flow	GW_REVAP (dimensionless)	.gw	0.02	0.14
	REVAPMN (mm)	.gw	1	1.1
	GWQMN (mm)	.gw	0	0.35
	ALFA_BF (days)	.gw	0.048	0.15
	GW_DELAY (days)	.gw	31	55
	RDHRG_DP (dimensionless)	.gw	0.05	0.25

Results – baseline:
Calibration-validation for river discharge



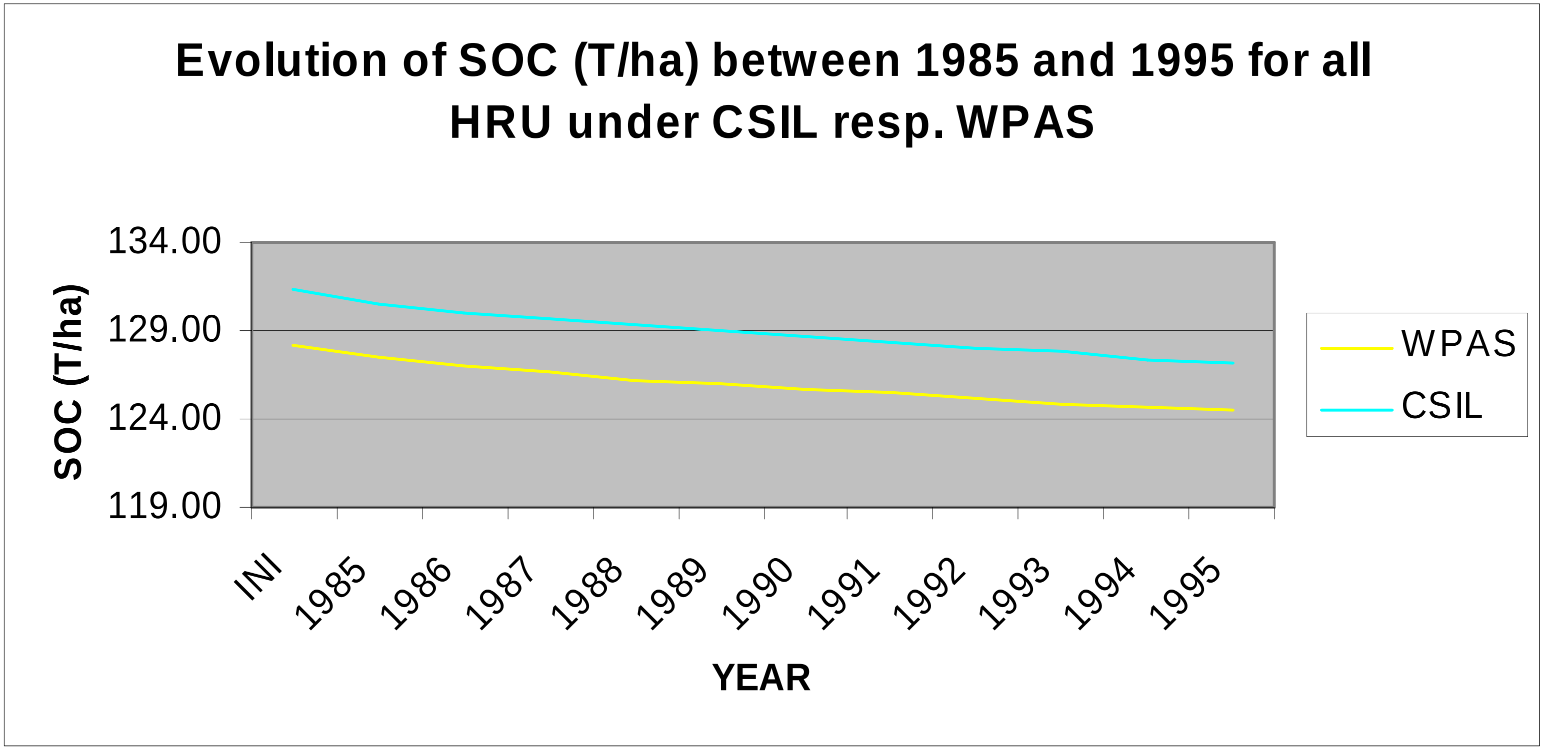


Results-baseline:
Estimated versus reference SOC-changes

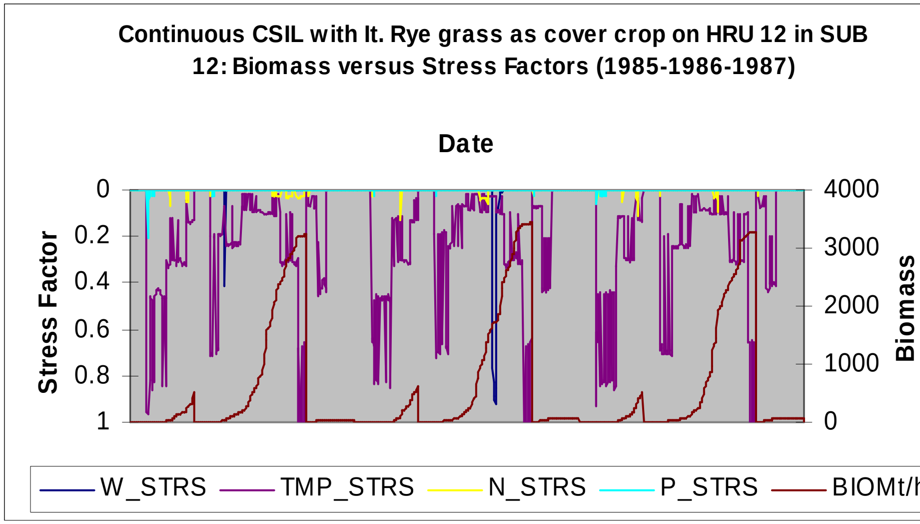
	SOC-changes 1990-2000 (T C / ha yr), 100 cm, Flanders, measured	SOC-changes 1985-1995 (T C/ ha yr), 100 cm, Grote Nete, simulated
Arable Land - CSIL	-0,73	-0,36
Grassland - WPAS	-0,82	-0,33

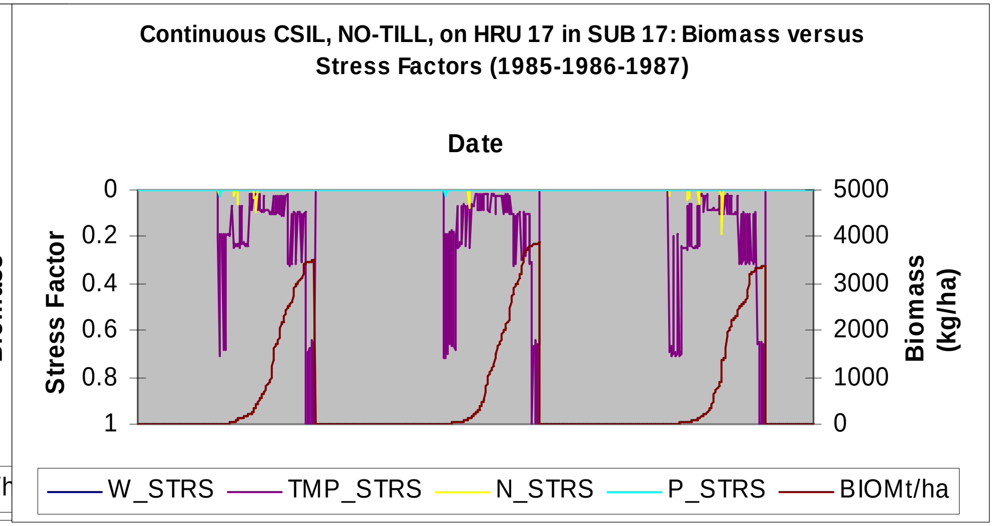
No calibration done; reference data too general

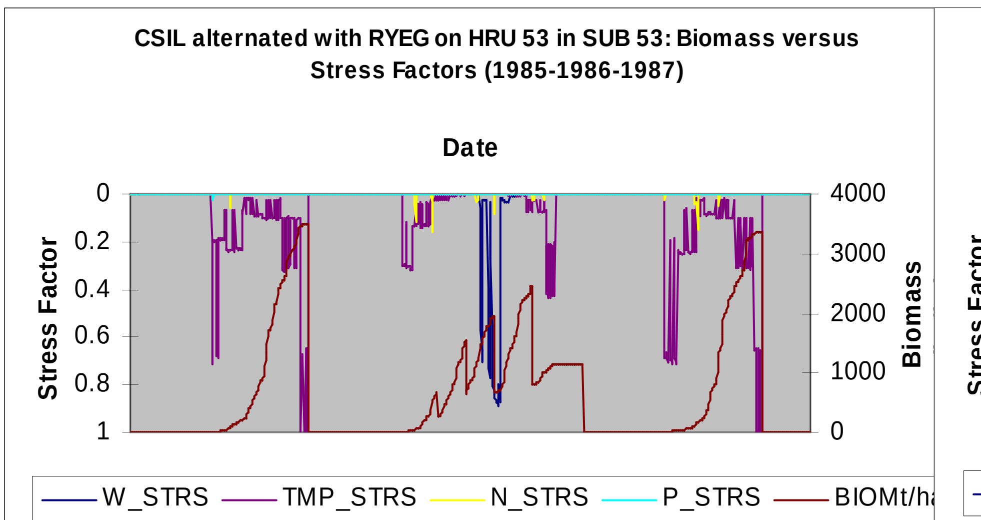
Results - baseline: Temporal SOC-profile

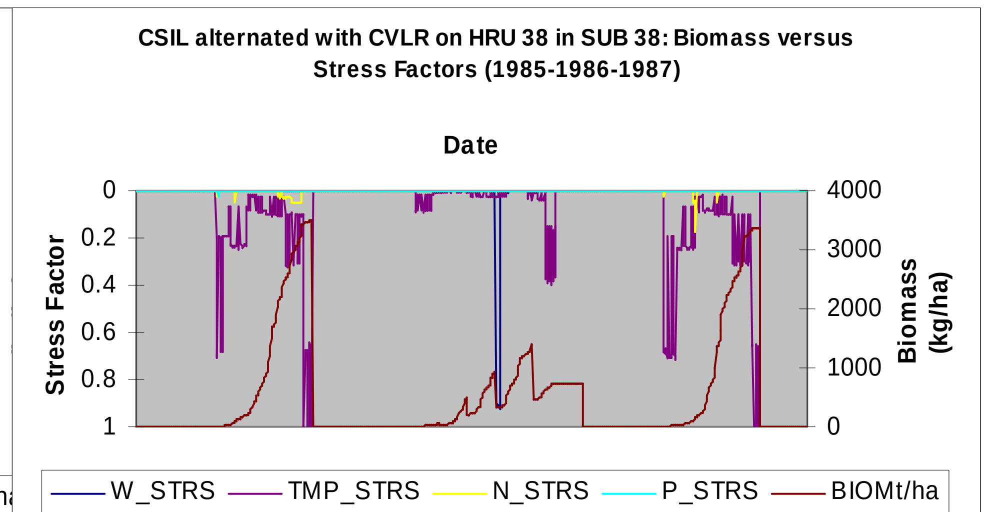


Results – scenarios









Results – scenarios

#	Acronym	Average daily discharge 1986-1988, 1990, 1992-1995 (m^3/s) at outlet	Contribution of surface runoff to total discharge at outlet (1986-1988, 1990, 1992-1995, m^3/s)	HRU under CSIL SOC Changes 1995-1985 (T C/ha/yr), 100 cm, Grote Nete, simulated
0	Baseline	3.86	0.69	-0.36
1	Sc1_CSILaRYEG	3.74	0.48	-0.34
2	Sc1_CSILaCLVR	3.79	0.49	-0.35
3	Sc1_CSILaFLAX	3.86	0.64	-0.36
4	Sc2_CSILcover	3.80	0.49	-0.30
5	Sc3_CSILnoTill	3.85	0.69	-0.36
6	Sc4_CSILorgfert	3.86	0.69	+0.38
7	Sc5_CSIL2cWPAS	3.69	0.49	-0.34
8	Sc5_WPAS2cCSIL	3.98	0.84	-0.36
9	Sc6_CSIL2cPINE	3.77	0.35	-0.40
10	Sc7_CSIL2cSEAL	3.99	1.37	-0.38
11	Sc8_CSILrandom	3.79	0.54	-0.25

Discussion

Environmental effects of simulated FP

- Surface runoff & peak discharges
  - decrease with increasing length and density of soil cover
  - are very sensitive to extent of sealed areas
- SOC
  - Organic fertilisation turns HRU from source to sink of CO_2
  - OC-input from residue is important
- No-till scenario: expectations are not confirmed
  - No noticeable influence on surface runoff, river discharge, SOC-stocks
- Randomisation scenario
  - Possibility to include uptake behaviour of farmers in the simulations

Discussion

Shortcomings in parameterisation of FP

- Biomass development
  - Crop residue production
- Crop succession
  - From one calendar year to the next
  - Shift from annual to permanent crops
- Tillage
  - Is more than the mixing of residue and nutrients
- SOC-balance computation
  - C/N=14: questionable
  - Deserves a proper module

Conclusions & Recommendations

- AVSWAT2000 potentially usable for ex-ante FP-related policy assessment
- Land management module is not fully operational

- More basins must be studied (meta-analysis)
- More recent versions of SWAT to be tested
- Be aware of pseudo-equivalent calibrated parameter sets
- Calibrate SOC-balance based on more detailed reference data