Modelling nutrient fate from agriculture: an integrated framework

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International Swat Conference
Framework of FATE

Europe-wide Harmonized Geographical Database

Assessment procedures (nested approach)

Scenario analysis (agricultural practices)

Results, reports, maps, recommendations

Policy Questions:

- Nitrate Directive
- Water framework directive
- Environmental indicators - IRENA
- The Soil Thematic Strategy

Policy Support

STAT > SWAT > EPIC
European DEM

- Source: CCM SWU- JRC
  (Catchment characterisation and modelling)

DEM 250 m x 250 m

e.g. Po Valley - basin delineation
River and catchments Database

• Source: CCM SWU - JRC
  • Digital River Network
  • Catchments

• DEM and River network used to delineate basins

e.g. Po Valley - basin delineation
Soil parameters

- Source: ESB (European Soil Bureau)
- Soil Geographical Database of Europe
- Scale: 1:1,000,000

- Topsoil / subsoil parameters
  - Clay, sand and silt - content (%)
  - Depth to rock (cm)
  - Organic carbon (%)
  - Bulk density (g/cm³) (packing density)
  - pH (base saturation)

e.g. Po Valley - Soils
From Landcover to Landuse

• CORINE landcover 100 m x 100 m grid
  (COoRdinate INformation on the Environment)

- 44 landcover classes for 1990 and 2000
- Source: European Environment Agency (EEA) - ETC/TA
**Meteorological data**

- **Source:** The Monitoring Agriculture and Regional Information Systems (MARS) - JRC
- Derived from more than 1500 weather stations across Europe
- Interpolated onto a 50 km x 50 km grid
- MARS database daily meteorological data

<table>
<thead>
<tr>
<th>Climate parameter</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum air temperature</td>
<td>°C</td>
</tr>
<tr>
<td>Maximum air temperature</td>
<td>°C</td>
</tr>
<tr>
<td>Precipitation</td>
<td>mm</td>
</tr>
<tr>
<td>Mean windspeed (at 10m height)</td>
<td>m/s</td>
</tr>
<tr>
<td>Mean vapour Pressure</td>
<td>hPa</td>
</tr>
<tr>
<td>Calculated potential evaporation</td>
<td>mm</td>
</tr>
<tr>
<td>Calculated global radiation</td>
<td>KJ/m²</td>
</tr>
</tbody>
</table>

- Data extracted: 1990-2003
- Weather generator used to fill data gaps in the MARS data.
Atmospheric Deposition

- **Source:** EMEP

- Data derived from the Precipitation Chemistry Database of the Co-operative Programme for the Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe

- The data are based on the Eulerian acid deposition model available on a 50 km x 50 km EMEP grid
Population Density

- Population density GISCO - cmec91/01

- 1991 and 2001 population density linked to comune (NUTS 5) polygons

- Eurostat data - population linked to treatment plants.
## MODELLING TOOLS

### The STAT model

<table>
<thead>
<tr>
<th>Model Type</th>
<th>Statistical model</th>
<th>Process-based model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model Type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data requirement</td>
<td>• DEM &amp; river network</td>
<td>• DEM &amp; river network</td>
</tr>
<tr>
<td></td>
<td>• Diffuse and point sources</td>
<td>• Soil map + soil characteristics</td>
</tr>
<tr>
<td></td>
<td>• Rainfall</td>
<td>• Land use map + agricultural practices</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Point sources</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Daily precipitation, Max/min temperature, Weather generator</td>
</tr>
<tr>
<td>Model outputs</td>
<td>• N and P river export (annual)</td>
<td>• N and P river export (daily)</td>
</tr>
<tr>
<td></td>
<td>• N and P diffuse losses</td>
<td>• N and P diffuse losses (pathways)</td>
</tr>
<tr>
<td></td>
<td>• Source apportionment</td>
<td>• Source apportionment</td>
</tr>
<tr>
<td></td>
<td>• N and P retention</td>
<td>• N and P retention</td>
</tr>
</tbody>
</table>

*Annual water flow and water quality*  
*Daily water flow and water quality*
The STAT model

Load = \((PS \times Q) + (DS \times B \times Q)\)

- **point source river reduction;** \(Q = f(\text{river length})\)
- **diffuse source basin reduction:** \(B = f(\text{Precipitation})\)

2 model parameters
Presentation of the Vilaine Catchment

Area (Km²): 10530
Rainfall (mm): 630-1000
Water Flow (m³/s): 70
Arable land (%): 74
Fertiliser (kgN/ha): 125
Application of the statistical model to the Vilaine catchment (10530 km²)

Calibration results:

- Measured NO3 load (tonN/yr)
- Predicted NO3 load (tonN/yr)

Nitrogen

NO3 calculated emission

(KgN/ha)
- < 5.00
- 5.00 - 10.00
- 10.00 - 15.00
- 15.00 - 20.00
- 20.00 - 25.00
- 25.00 - 30.00
- 30.00 - 35.00
- > 35.00
Application of the SWAT model to the Vilaine

Water flow

Nitrate concentration

<table>
<thead>
<tr>
<th>Date</th>
<th>Measured concentration NO3-N (g/l)</th>
<th>Predicted concentration NO3-N (g/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/1/90</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>1/1/91</td>
<td>0.005</td>
<td></td>
</tr>
<tr>
<td>1/1/92</td>
<td>0.010</td>
<td></td>
</tr>
<tr>
<td>12/31/92</td>
<td>0.015</td>
<td></td>
</tr>
<tr>
<td>12/31/93</td>
<td>0.020</td>
<td></td>
</tr>
<tr>
<td>12/31/94</td>
<td>0.025</td>
<td></td>
</tr>
<tr>
<td>12/31/95</td>
<td>0.030</td>
<td></td>
</tr>
<tr>
<td>12/30/96</td>
<td>0.040</td>
<td></td>
</tr>
<tr>
<td>12/30/97</td>
<td>0.050</td>
<td></td>
</tr>
<tr>
<td>12/30/98</td>
<td>0.060</td>
<td></td>
</tr>
<tr>
<td>12/29/99</td>
<td>0.070</td>
<td></td>
</tr>
<tr>
<td>12/29/00</td>
<td>0.080</td>
<td></td>
</tr>
</tbody>
</table>
Pathways of water and sediment losses

Surface runoff

Groundwater flow

Sediment losses
**SWAT:** Average N load in streams

- **Sediment-bound org-N**

- **Nitrates in runoff**

<table>
<thead>
<tr>
<th>ORGN_KG/HA</th>
<th>0.000 - 0.200</th>
<th>0.201 - 0.400</th>
<th>0.401 - 0.600</th>
<th>0.601 - 0.800</th>
<th>0.801 - 1.000</th>
<th>1.001 - 1.200</th>
<th>1.201 - 1.400</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO3-N_KG/H</td>
<td>&lt; 0.600</td>
<td>0.601 - 0.800</td>
<td>0.801 - 1.000</td>
<td>1.001 - 1.200</td>
<td>1.201 - 1.400</td>
<td>1.401 - 1.600</td>
<td>1.601 - 1.800</td>
</tr>
</tbody>
</table>
SWAT: NO3 loss pathway

Nitrate load

- measured NO3-N
- total predicted NO3-N
- subsurface NO3-N

NO3-N load (tons)

Jan-92 Jan-93 Jan-94 Jan-95 Jan-96 Jan-97 Jan-98 Jan-99 Jan-00
**EPIC**: simulation of a catch crop
Derived input data for the STAT model
Nitrogen Diffuse Emissions
SWAT Application Seine basin

LandUse/Soil THRESHOLDS: 5 / 10 [%]
Number of HRUs: 1343
Number of Subbasins: 83
$r^2 = 0.69 \quad E = 0.45$
$r^2=0.83 \quad E=0.65$
$r^2 = 0.81 \quad E = 0.62$
$r^2 = 0.87$  \quad E = 0.76
$r^2 = 0.87 \quad E = 0.61$
SWAT Application Seine Basin

Marne - NOISIEL

Seine - ORLY

Concentration NO3_N (mg/L)

Measured
Simulated

0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0
Jan-97 May-97 Sep-97 Jan-98 May-98 Sep-98 Jan-99 May-99 Sep-99 Jan-00 May-00 Sep-00 Jan-01 May-01 Sep-01 Jan-02 May-02 Sep-02

Concentration NO3_N (mg/L)

Measured
Simulated

0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0
Jan-97 May-97 Sep-97 Jan-98 May-98 Sep-98 Jan-99 May-99 Sep-99 Jan-00 May-00 Sep-00 Jan-01 May-01 Sep-01 Jan-02 May-02 Sep-02
Conclusions

FATE Framework: from regional to farm scale

• A database necessary to evaluate the fate of nutrient across a wide range of scale (continental to field scale) has been gathered.

• A set of tools to assess the fate of nutrients as affected by various management practices have been linked to the database to perform various analysis on nutrient sources and fate.

SWAT is being used to assess the impact of agriculture at sub-basin level taking into account major loss pathways. It will be used to evaluate the efficiency of various agri-environmental measures in the framework of CAP (cross-compliance)

Future plans include the sep-up of SWAT for the major European river basin