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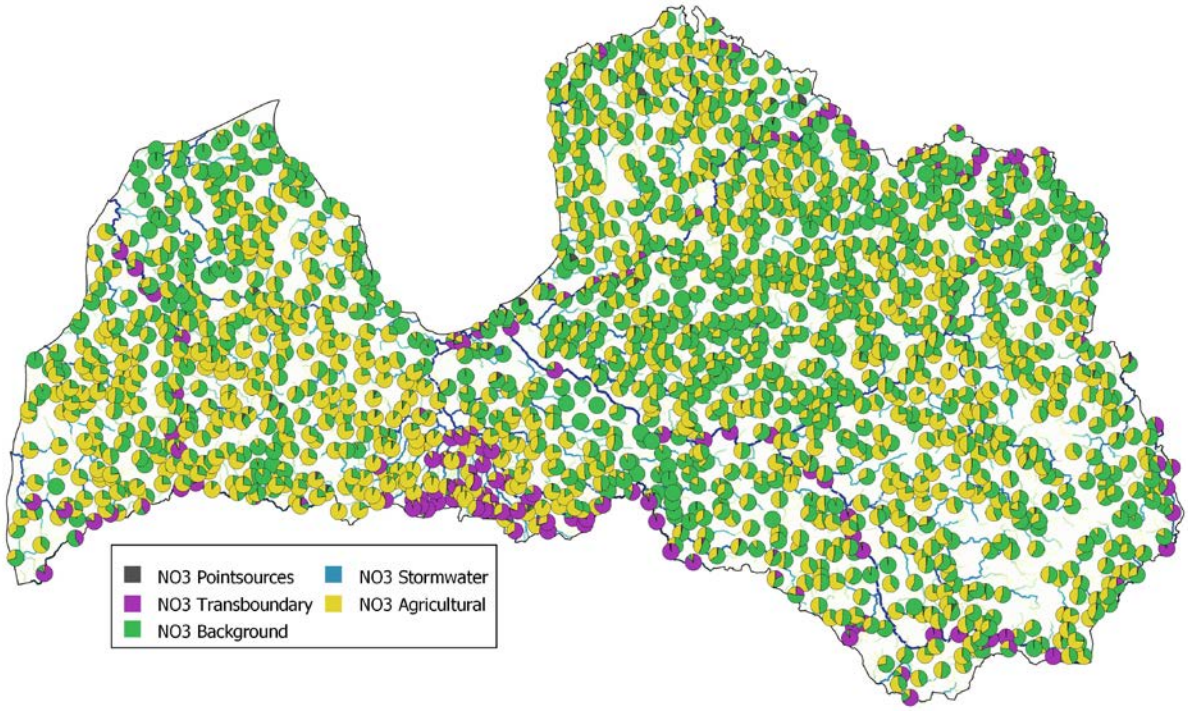
"Latvijas upju baseinu apsaimniekošanas plānu ieviešana laba virszemes ūdens stāvokļa sasniegšanai"

TECHNICAL REPORT ON DEVELOPMENT AND EMPLOYMENT OF SOURCE APPORTIONMENT

DELIVERABLE R6



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Technical report on development and employment of source apportionment

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Summary

This document is a technical report on the development of the source apportionment methodology and its employment in a Python script.

Document is written in English, it contains 14 pages, 2 figures, 3 tables and 6 references.

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Introduction

This document is a Technical report on the development of the source apportionment methodology and its employment in a Python script. It is Deliverable R6 within LIFE Goodwater project, activity C1.

The source apportionment tool may be used with the water quantity and quality modelling system delivered within Deliverable R5 “Complete modelling system – data, models, results” PAIC (2023b). This modelling system comprises of the

- data prepared within Deliverable R1 – Data base for model implementation, PAIC (2020);
- water quantity and quality modelling tools described in Deliverable R3 – Modelling results for Reference and Baseline scenarios, PAIC (2022b);
- model setups of the calibrated and validated modelling system for the water quantity and quality in the territory of Latvia delivered as Deliverable R2 – Calibrated and validated modelling system in PAIC (2022a);
- modelling results delivered as Deliverable R2 – Calibrated and validated modelling system in PAIC (2022a) and described in the Deliverable R4 – Documentation of development, calibration, validation and results of SWAT modelling system in PAIC (2023a).

The methodology of source apportionment is described in Chapter 1.

The Python script which realises this methodology is described in Section 2.1, while its output files in Section 3.2. Examples of source apportionment are given in Section 2.2.

1. Methodology of source apportionment

1.1. General principles

Source apportionment methodology relies on nutrient source separation on the level of model hydrological response units (HRUs).

After calculation by SWAT+ model, loads to the streams are divided into desired land use classes, and then each load portion is traced downwards through the river network, accounting also for riverine processes as retention and settling. This method guarantees that sum of all loads by apportionment classes is equal to the total modelled load at each point in the river network.

We assume that the riverine processes that change the concentrations of the nutrients in the streams are independent of the origin of the load. Thus, these processes are the same for all components of the total load of the given substance, e.g. proportional. This method does not require alternate model runs. It means that this effectively is the source apportionment by the resulting loads.

The proposed methodology of the nutrient source separation is in line with the guideline EuroHARP (2007).

1.2. Methodology

For the purposes of load apportionment, we group HRUs in several classes according to their land use code. We use two steps of aggregation (see Tables 1, 2) of land use classes. The different land uses are generalized in the first step (Table 1) and then further aggregated into five aggregated classes (Table 2).

Table 1. List of land use type ids for generalized land use type classification of the source apportionment script.

Generalized land use class id	Description
AGRICULTURAL	Loads from HRUs with agricultural crops
PASTURE	Loads from pasture HRUs
FOREST	Loads from all forest HRUs
BARREN	Loads from HRUs with landuse code *BARREN*
WETLAND	Loads from wetland HRUs
WATER	Loads from water HRUs (code *WATER*)
URBAN	Loads from HRUs of all urban landuse codes
POINTSOURCE	All loads from point sources
TRANSBOUNDARY	All transboundary loads, not specifying their sources. Those include both (a) loads inflowing directly through rivers and (b) loads from transboundary parts of catchments (*added areas*).

Table 2. Aggregation of land use types of the source apportionment script.

Aggregated land use class id	Generalized land use class ids
AGRICULTURAL	**AGRICULTURAL,PASTURE**
BACKGROUND	**FOREST,BARREN,WETLAND,WATER**
STORMWATER	**URBAN**
POINTSOURCE	**POINTSOURCE**
TRANSBOUNDARY	**TRANSBOUNDARY**

For each of the model catchments, we calculate yearly average amount of the load from each of the land use groups for a given time period and for each of the nutrients. The load assigned to the land use group is the sum of the loads from all of the HRUs with the land use code belonging to that particular group. The nutrients included are nitrate nitrogen (N-NO3), total nitrogen (N-tot), phosphate phosphorus (P-PO4), and total phosphorus (P-tot).

The methodology includes the following steps:

1. Model run - calculation by the water quality modelling system for the selected time period and calculation of the separated nutrient (N-NO3, N-tot, P-PO4, P-tot) loads from the considered sources (transboundary, background, agricultural etc., see Tables 1, 2) for each subbasin of the modelling system.

2. Building of the nutrient mass balance for each nutrient and each subbasin as

   $L_{in} + L_{catchment} - R = L_{out}$

   Here
   - L_{in} is the riverine nutrient flux into the subbasin. It is either the transboundary pollution if the river enters Latvia or it is zero at the very upstream subbasin or it is the load from the upstream catchment otherwise;
   - $L_{catchment}$ is the nutrient load from the catchment of the subbasin calculated in point 1;
   - R is the retention of the nutrients in the river stream calculated by SWAT+;
   - L_{out} is the riverine nutrient load flowing out of the subbasin. It either enters Baltic Sea, or leaves Latvia, or otherwise flows into downstream subbasin.

3. The relative retention rate (R%) is calculated for each nutrient and each subbasin as

   $R\% = L_{out} / (L_{in} + L_{catchment})$

4. The separation of the nutrient sources is performed for each nutrient in each of the subbasins under assumption that retention rate is the same for the same nutrients regardless of their source. Assuming that the source separation is available at the inflow L_{in} we calculate the source-separated loads at the outflow for i-th (i=1,2,3,4) source as

   $L_{out,i} = R\% * (L_{in,i} + L_{catchment,i})$

5. Propagating of the algorithm of points (2-4) through the river (or hierarchical subbasin) network produces the source apportionment of the riverine outflowing loads from each of the subbasins, and ultimately – for riverine loads entering Baltic Sea or leaving Latvia.

6. Calculate the retention of each particular i-th (i=1,2,3,4) source as

   $R_{,i} = (L_{in,i} + L_{catchment,i}) - L_{out,i} = (L_{in,i} + L_{catchment,i})(1 - R\%)$

2. Script for calculation of source apportionment

2.1. Script

The name of the script for calculation of the source apportionment name is *apportionment.py*. It is located in main script directory *Project/Setup/Scripts*, at the same location where *main.py* script is located.

The script is invoked similarly to the *main.py* script.

The results of the script execution are the MS Excel files for aggregated and detailed results, see Section 2.2. By default, these results are placed in the *Projects/GIS/apportionment* directory. User may modify the location of the result files in variables *output_file* and *output_file_detailed*. Those variables contain output *xlsx* filenames for aggregated and detailed results, respectively.

Start and end years of the apportionment calculation are determined by the variables *startyear* and *endyear*. The default time period for the source apportionment is from Year 2008 to Year 2018.

2.2. Contents of result files

After the execution of *apportionment.py* script, the apportionment results are written to two *MS Excel* (*.xlsx)* files. The apportionment script prepares results for *detailed* and *aggregated* land use type classification. Detailed source type classification is based on grouping of the HRUs into generalized land use classes, see Table 1. Aggregated source type classification aggregates some of the source classes, see Table 2.

Table 3: List and description of "substances" in the result files of the apportionment script

Substance	Description
A	Area in ha. For **catchmentloads** it corresponds to the area of the catchment, including its external area). For **apportionment** and **sumloads** it is the area of the basin upstream (and including) the catchment. For **retention** and **sumretention** it is redundant. Area is apportioned according to the respective source types it produces.
Q	Flow in m^3/s. For **catchmentloads** it corresponds to the water flow from the catchment, including its external area. For **apportionment** and **sumloads** it is a water outflow from the stream segment. For **retention** and **sumretention** it is redundant.
NO3	Load or retention of N-NO3 in kg/year. For **catchmentloads** it corresponds to the substance outflow from the catchment, including its external area. For **apportionment** it is outflow of the substance in the river segment. For **sumloads** it is the sum of catchment loads of the substance in the basin upstream (and including) the catchment. For **retention** it is the retention flux in the stream segment. For **sumretention** it is sum of retention flux in the basin upstream (and including) the catchment.
NTOTAL	Load or retention of total nitrogen in kg/year. See remarks at NO3.
PO4	Load or retention of P-PO4 in kg/year. See remarks at NO3.
PTOTAL	Load or retention of total phosphorus in kg/year. See remarks at NO3.

Both files contain the following sheets, here i stands for all considered nutrients (i=1,2,3,4):

1. Loads in the rivers apportioned by source at segments ($L_{out,i}$) is in the sheet **apportionment.**

2. Loads from catchments ($L_{catchment,i}$) are summarized in the sheet **catchmentloads.**

3. Amount of retention in each of the river segments ($R_{,i}$) is in sheet **retention.**

4. Sum of the loads of nutrients for all catchments upstream of the particular catchment (including load from that catchment) is in the sheet **sumloads.**

5. Sum of the retention in all river segments upstream of the particular segment (including retention in that segment) is in the sheet **sumretention.**

The first column of each of the spreadsheets contains the *id* of the catchment which equals to the segment corresponding to that catchment. This *id* can be joined to geospatial layers of catchments (on *catchmentid)* or segments (on *segmentid*) for the visualization purposes.

The rest of the columns in spreadsheets contain data. The column headers of each of the spreadsheets are in the form *substance_type*. List of substances and their description are given in the Table 3.

2.3. Illustration of results

The geospatial illustration of source apportionment is shown in Figures 1 and 2 for the percentage loads of different aggregated source types of, respectively, nitrate nitrogen and phosphate phosphorus. The results are shown at the outflows of river segments of the SWAT+ catchments.

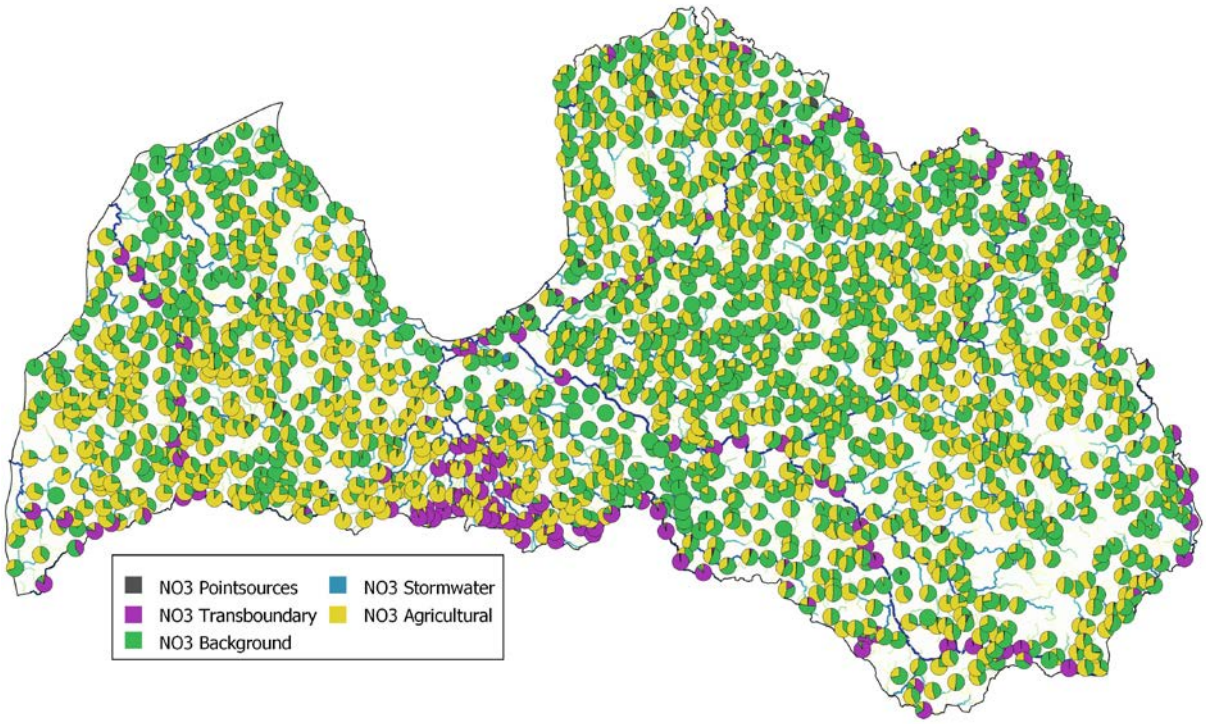

Figure 1. Source apportionment: the percentage loads of different aggregated source types of nitrate nitrogen at the outflows of river segments of the SWAT+ catchments.

The transboundary pollution dominates at the inflows of all rivers into Latvia, significant share of it remains in the major rivers (Daugava, Lielupe, Venta) up to their discharge into the sea.

The agricultural pollution is dominating in Zemgale as well as in agricultural lowland parts of Vidzeme, Kurzeme and Latgale.

Background pollution has dominant share in the highlands with lower agricultural activity and the forested areas.

The point source and stormwater shares are evident downstream the large towns; also in the smaller streams downstream the medium settlements.

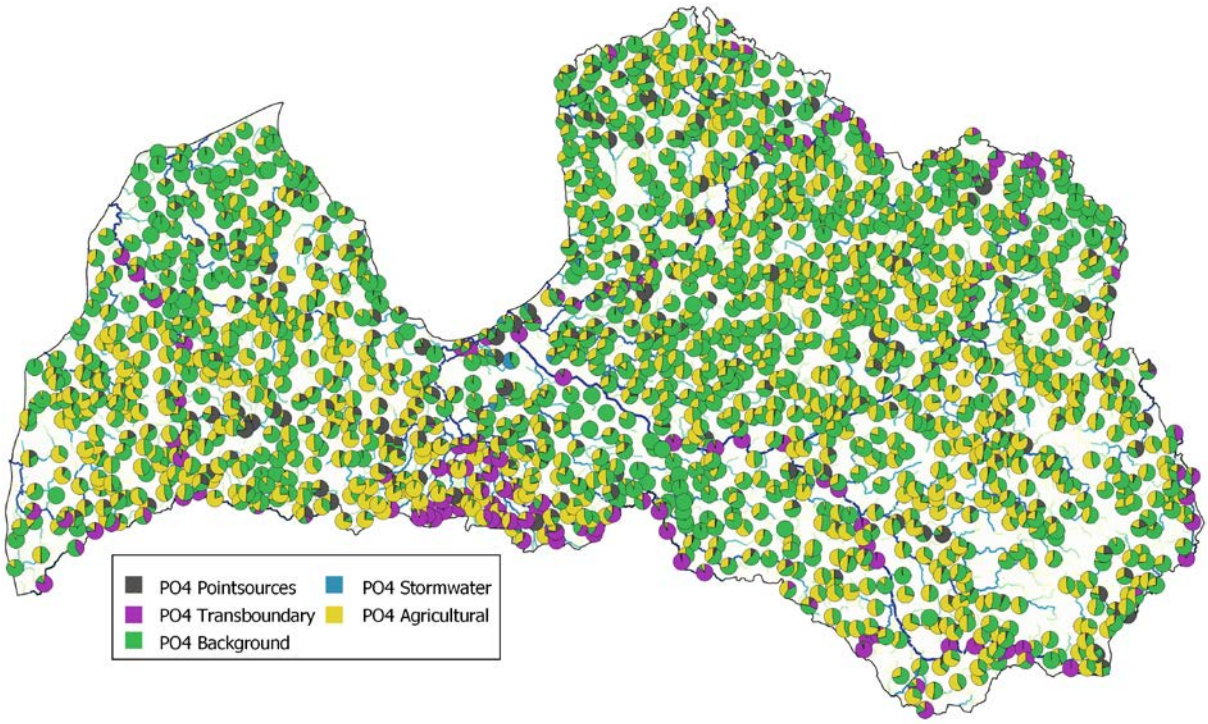

Figure 2. Source apportionment: the percentage loads of different aggregated source types of phosphate phosphorus at the outflows of river segments of the SWAT+ catchments.

References

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