A SWAT model setup requires multiple input data, including a DEM (digital elevation model), a soil map (with soil properties), climate data, a land use map, as well as data on field management operations. Table 1 provides an overview of these input data sources for the Melk and Zaya catchments.

Table 1. Input data for the SWAT model.

|  |  |  |
| --- | --- | --- |
| **Data** | **Description** | **Source** |
| Digital Elevation Model | Terrain elevation, 10 m resolution | Digitales Geländemodell Österreich (www.geoland.at) |
| Soil type | Soil types based on six standard depth intervals at 250 m resolution | SoilGrids (https://soilgrids.org); |
| Soil characteristics | 1 km resolution of soil properties, i. e. organic carbon content | European soil data center (https://esdac.jrc.ec.europa.eu/) |
| Land cover | Land cover based on 44 classes. Shape file. | European Environmental Agency (EEA) 2012  CORINE Land Cover (https://land.copernicus.eu/pan-european/corine-land-cover); |
| Agricultural land use | Agricultural crops for 2017. Polygon file. | INSPIRE data. INVEKOS Schläge Österreich 2017 (https://www.data.gv.at/katalog/dataset/e21a731f-9e08-4dd3-b9e5-cd460438a5d9); |
| Precipitation data | Daily data from gauging stations | eHYD hydrographischen Daten, BMNT (https://ehyd.gv.at/); |
| Temperature, solar radiation and wind speed | Daily data from weather stations | Zentralanstalt für Meterologie und Geodynamik (ZAMG)( https://www.zamg.ac.at/cms/de/aktuell) |
| Fertilizer application | N applied kg / ha | Landwirtschaftliche Fach- und Berufsschulen Niederösterreich (https://lako.at/versuche/)  ÖPUL Programm (https://www.bmlrt.gv.at/land/laendl\_entwicklung/oepul.html). |
| Crop management practices | Field data for planting, fertilizing, harvest and tillage. | Landwirtschaftliche Bildung in Niederösterreich (https://www.lako.at/) |
| Crop yields | 1993-2018 | https://j1dev.agrarforschung.at/index.php?lang=de |

The detailed input information on the soil classes are provided in Table 2-3. Stations for measuring climate data are listed in Table 4.

Table 2. The setup of different soil classes in the SWAT model for the Melk catchment.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Soil class | HYDGRP | Soil texture | SOL\_Z | SOL\_BD | SOL\_AWC | SOL\_K | SOL\_CBN | Clay (%) | Silt (%) | Sand (%) | Rock (%) | SOL\_ALB |
| 1 | C | Silt-loam | 300 | 1.37 | 0.17 | 7.09 | 2.12 | 23.91 | 45.46 | 30.64 | 7.18 | 0.26 |
| 2 | C | Silt-loam | 300 | 1.24 | 0.18 | 3.91 | 5.01 | 25.73 | 43.53 | 30.72 | 13.92 | 0.08 |
| 3 | C | Silt-loam | 300 | 1.37 | 0.17 | 6.44 | 2.58 | 23.43 | 47.86 | 28.78 | 7.62 | 0.21 |
| 4 | C | Silt-loam | 300 | 1.35 | 0.18 | 6.76 | 2.84 | 22.43 | 43.46 | 34.13 | 8.35 | 0.19 |
| 5 | C | Silt-loam | 300 | 1.16 | 0.19 | 3.89 | 6.04 | 24.7 | 42.81 | 32.54 | 17.43 | 0.05 |
| 6 | C | Silt-loam | 300 | 1.25 | 0.19 | 5.77 | 4.78 | 18.75 | 36.93 | 44.39 | 11.98 | 0.09 |
| 7 | C | Silt-loam | 300 | 1.28 | 0.19 | 4.4 | 4.58 | 24.11 | 45.09 | 30.84 | 11.63 | 0.1 |
| 8 | C | Silt-loam | 300 | 1.37 | 0.17 | 6.03 | 2.45 | 25.22 | 46.99 | 27.85 | 7.65 | 0.23 |
| 9 | C | Silt-loam | 300 | 1.3 | 0.18 | 5.25 | 3.64 | 22.81 | 43.09 | 34.17 | 11.24 | 0.14 |
| 10 | C | Silt-loam | 300 | 1.21 | 0.19 | 4.8 | 5.22 | 21.49 | 40.84 | 37.71 | 13.97 | 0.07 |
| 11 | C | Silt-loam | 300 | 1.29 | 0.18 | 4.57 | 3.77 | 24.31 | 44.61 | 31.08 | 11.66 | 0.13 |
| 12 | C | Silt-loam | 300 | 1.34 | 0.18 | 5.88 | 3.11 | 23.71 | 45.69 | 30.63 | 8.19 | 0.17 |
| 13 | C | Silt-loam | 300 | 1.31 | 0.18 | 6.91 | 3.22 | 20.38 | 39.56 | 40.05 | 9.79 | 0.17 |
| 14 | C | Silt-loam | 300 | 1.28 | 0.18 | 4.54 | 4.36 | 23.49 | 43.41 | 33.16 | 13.3 | 0.1 |
| 15 | C | Silt-loam | 300 | 1.25 | 0.19 | 4.73 | 5.1 | 22.75 | 42.66 | 34.66 | 13.7 | 0.08 |

Abbreviation: HYDGRP: soil hydrologic group. SOL\_Z: depth from soil surface to bottom of layer. SOL\_BD: moist bulk density. SOL\_AWC: available water capacity of the soil layer. SOL\_K: saturated hydraulic conductivity. SOL\_CBN: organic carbon content. SOL\_ALB: moist soil albedo.

Table 3. The setup of different soil classes in the SWAT model for the Zaya catchment.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Soil class | HYDGRP | Soil texture | SOL\_Z | SOL\_BD | SOL\_AWC | SOL\_K | SOL\_CBN | Clay  (%) | Silt  (%) | Sand  (%) | Rock  (%) | SOL\_ALB |
| soilclass1 | C | Clay loam | 300 | 1.34 | 0.16 | 6.31 | 2.10 | 28.7 | 50.4 | 20.9 | 9.71 | 0.26 |
| soilclass2 | C | Clay loam | 300 | 1.34 | 0.17 | 6.47 | 2.31 | 27.1 | 50.3 | 22.6 | 9.64 | 0.24 |
| soilclass3 | C | Clay loam | 300 | 1.35 | 0.16 | 7.96 | 2.17 | 29.8 | 41.3 | 29.0 | 8.67 | 0.25 |
| soilclass4 | C | Clay loam | 300 | 1.31 | 0.17 | 4.22 | 2.22 | 26.8 | 49.2 | 24.0 | 12.21 | 0.25 |
| soilclass5 | C | Clay loam | 300 | 1.34 | 0.17 | 5.56 | 2.19 | 28.6 | 54.0 | 17.4 | 11.41 | 0.25 |

Abbreviation: HYDGRP: soil hydrologic group. SOL\_Z: depth from soil surface to bottom of layer. SOL\_BD: moist bulk density. SOL\_AWC: available water capacity of the soil layer. SOL\_K: saturated hydraulic conductivity. SOL\_CBN: organic carbon content. SOL\_ALB: moist soil albedo.

Table 4. Stations for measuring climate data.

|  |  |  |  |
| --- | --- | --- | --- |
| **Melk catchment** | | **Zaya catchment** | |
| **Precipitation** | **Weather** | **Precipitation** | **Weather** |
| Grabenegg | Buchberg | Altllichtenwarth | Bruckneudorf |
| Leonhard | Krems | Ginzeresdorf | Brunn\_am\_Gebirge |
| Oberndorf | Langenlois | Mistelbach | Gaenserndorf\_Stadt |
|  | Lilienfeld | Schletz | Gross\_Enzersdorf |
|  | Melk | Wultendorf | Gumpoldskirchen |
|  | Oberndorf | Eichenbrunn | Hohenau |
|  | Poelten | Ernstbrunn | Laa |
|  | Wieselburg | | Langenlebarn |
|  |  |  | Leiser\_Berge |
|  |  |  | Mistelbach\_Zaya |
|  |  |  | Mistelbach |
|  |  |  | Poysdorf |
|  |  |  | Schoengrabern |
|  |  |  | Stockerau |
|  |  |  | Wolkersdorf |
|  |  |  | Zwerndorf |
|  |  |  | Wien\_Donaufeld |
|  |  |  | Wien\_Hohe\_Warte |
|  |  |  | Wien\_Hohe\_W |
|  |  |  | Wien\_Stadt |
|  |  |  | Wien\_Jubi |

For the land use map, to simplify the representation of crops in the SWAT model, the crops in the INSPIRE land use map were grouped according to similar crop types and management. For example, winter wheat representation in SWAT was the crop category that contains the following crops: winter rye, winter barley, winter triticale, winter spelt, winter rapeseed and winter oats (Tables 5, 6, and 7). The land use map with the grouped crops from INSPIRE in 2017 was applied to the SWAT model.

The INSPIRE crop data contains information on agricultural land use only, therefore, the CORINE data was used to fill in the land cover in the catchments (Table 1). The final land use/land cover map applied to SWAT included information on specific crops, forest and urban areas and it remained static for each year simulated.

Table 5. Crop classification into groups for the setup of the Melk catchment (M1).

|  |  |  |  |
| --- | --- | --- | --- |
| **SWAT code** | **Crops** | **SWAT code** | **Crops** |
| **WWHT** | Silage rye | **BARL** | Summer barley |
|  | Silage rye/ corn |  | Summer wheat |
|  | Winter rye |  | Summer spelt |
|  | Winter barley |  | Caraway |
|  | Winter durum |  | Summer oats |
|  | Winter beets |  | Oat and mixed grains |
|  | Winter triticale |  | Poppy |
|  | Winter wheat |  | Rape seed |
|  | Einkorn/ Emmer |  | Triticale |
|  | Winter spelt |  | Flax |
|  | Winter rye and meslin |  | Buckwheat |
|  | Winter caraway |  | Camellia |
|  | Winter rapeseed |  | Quinoa |
|  | Winter oats | **PAST** | Permanent pasture |
|  |  |  | Bioenergy grasses |
| **CORN** | Corn / Beans in separated rows |  | 20 years fallow |
|  | Corn CORN-COB-MIX (CCM) |  | Alpine pasture |
|  | Grain corn |  | Mountain pasture |
|  | Millet |  | Blue lupine |
|  | Sorghum |  | Pasture (once mowed) |
|  | Sunflowers |  | Forage grasses |
|  | Sweet corn |  | Fallow pastureland |
|  |  |  | Herding pasture |
| **SOYB** | Soybeans |  | Pasture with two uses |
|  | Broad beans- grain mix |  | Pasture with three or more uses |
|  | Broad bean |  | Turf grass |
|  | Peas – grain mix |  | Other forage crops |
|  | Peas |  | Other pasture areas |
|  | Common vetch |  | Pasture for bedding |
|  | Hairy vetch |  |  |
|  | Lupine |  |  |
|  | Vetch – grain mix |  |  |
|  | Peavines |  |  |

Table 6. Crop classification into groups for the setup of the Melk catchment (M2).

|  |  |  |  |
| --- | --- | --- | --- |
| **SWAT code** | **Crops** | **SWAT code** | **Crops** |
| **FESI** | Pasture with three and more uses | **CORN** | Grain corn |
|  | Pasture with two uses |  | Corn CORN-COB-MIX (CCM) |
|  | Other forage crops |  | Sorghum |
|  | Forage grasses | **SOYB** | Soybeans |
|  |  |  | Broad bean |
| **WWHT** | Winter wheat |  | Peas |
|  | Winter barley |  | Broad beans – grain mix |
|  | Winter triticale |  | Flax |
|  | Winter rapeseed |  | Hemp |
|  | Sugar beet | **FESE** | Permanent pasture |
|  | Oil pumpkin |  | Pasture (once mowed) |
|  | Nuts (walnuts, hazelnuts, …) | | Herding pasture |
|  | Winter spelt |  |  |
|  | Winter rye |  |  |

The crops with small area not included in Table S6 were directly grouped into their neighbor main crops when we prepared the land use map.

Table 7. Crop classification into groups for the Zaya catchment.

|  |  |  |  |
| --- | --- | --- | --- |
| **SWAT code** | **Crops** | **SWAT code** | **Crops** |
| **WWHT** | Winter wheat | **BARL** | Summer barley |
|  | Winter rapeseed |  | Summer wheat |
|  | Winter barley |  | Summer wheat |
|  | Winter durum wheat |  | Summer oats |
|  | Winter triticale |  | Buckwheat |
|  | Winter spelt |  | Silage rye |
|  | Winter rye |  | Summer einkorn/ emmer |
|  | Winter vetch |  | Poppy |
|  | Einkorn/ Emmer | | Triticale |
|  | Winter poppy | | Summer rye |
|  |  |  |  |
| **SGBT** | Sugar beet | **CORN** | Grain corn |
|  | Oil pumpkin |  | Silage |
|  | Edible potatoes |  | Millet |
|  | Starch potatoes |  | Sorghum |
|  | Seed potatoes |  | Seed corn for propagation |
|  | Food potatoes | FESC | Fallow |
|  | Pumpkin |  | Pasture (once mowed) |
| **FESI** | Other forage crops |  | Herding pasture |
|  | Pasture with two uses | | Common vetch |
|  | Permanent pasture | |  |
|  | Forage grass |  |  |

The crops with small area not included in Table S7 were directly grouped into their neighbor main crops when we prepared the land use map.

Obtaining the types and amounts that farmers apply to their crops in the catchments for each year is almost impossible. Statistics are collected every 5 years at the district level [1], and guidelines are provided to farmers on fertilization regimes based on their soil nutrient levels [2], as well as subsidy programs exist in which farmers can obtain payments by adhering to the regulations [3]. Using this information, the SWAT model in the Melk catchment was setup with two N fertilizer input data. This was undertaken to examine uncertainties in the N fertilizer data input and the impact on the resulting simulated N2O emissions.

The first N fertilizer application input data (from here on referred to as “M1”) was based on field trials from 2013 conducted by the agricultural college in Lower Austria (Landwirtschaftliche Bildung in Niederösterreich, data available at [www.lako.at/versuche](http://www.lako.at/versuche)). Missing data was filled in from the best practices regulations for farmers to obtain subventions provided by the Austrian agro-environmental subsidy program called the ÖPUL (Österreichisches Programm für die Umweltgerechte Landwirtschaft). The ÖPUL program is part of the Austrian Rural Development Program 2014-2020 and to which 81.7% of agricultural land is registered and receives benefits. The M1 is an optimistic setup that most likely under represents the amount of fertilizer farmers apply to their fields. The N fertilizer type in M1 that is simulated in the SWAT model is input as NH4NO3.

The second N fertilizer application input data (from here on referred to as “M2”) was based on calculations of a national N balance for all of Austria subdivided and calculated at the municipal level [4]. All land use categories were kept the same as in M1, except that in the M2 land use map, pastureland was split into extensive (FESE) and intensively managed (FESI) pasture as these are fertilized separately. The N fertilizer types simulated are mineral N in the form NO3- and organic N. The amounts and types of applied N fertilizer in M2 are an attempt to represent the actual N fertilization regimes of farmers.

For the Zaya catchment, the SWAT model was only setup with the same N fertilization input data as from Melk M2 that was based on the N balance.

References

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