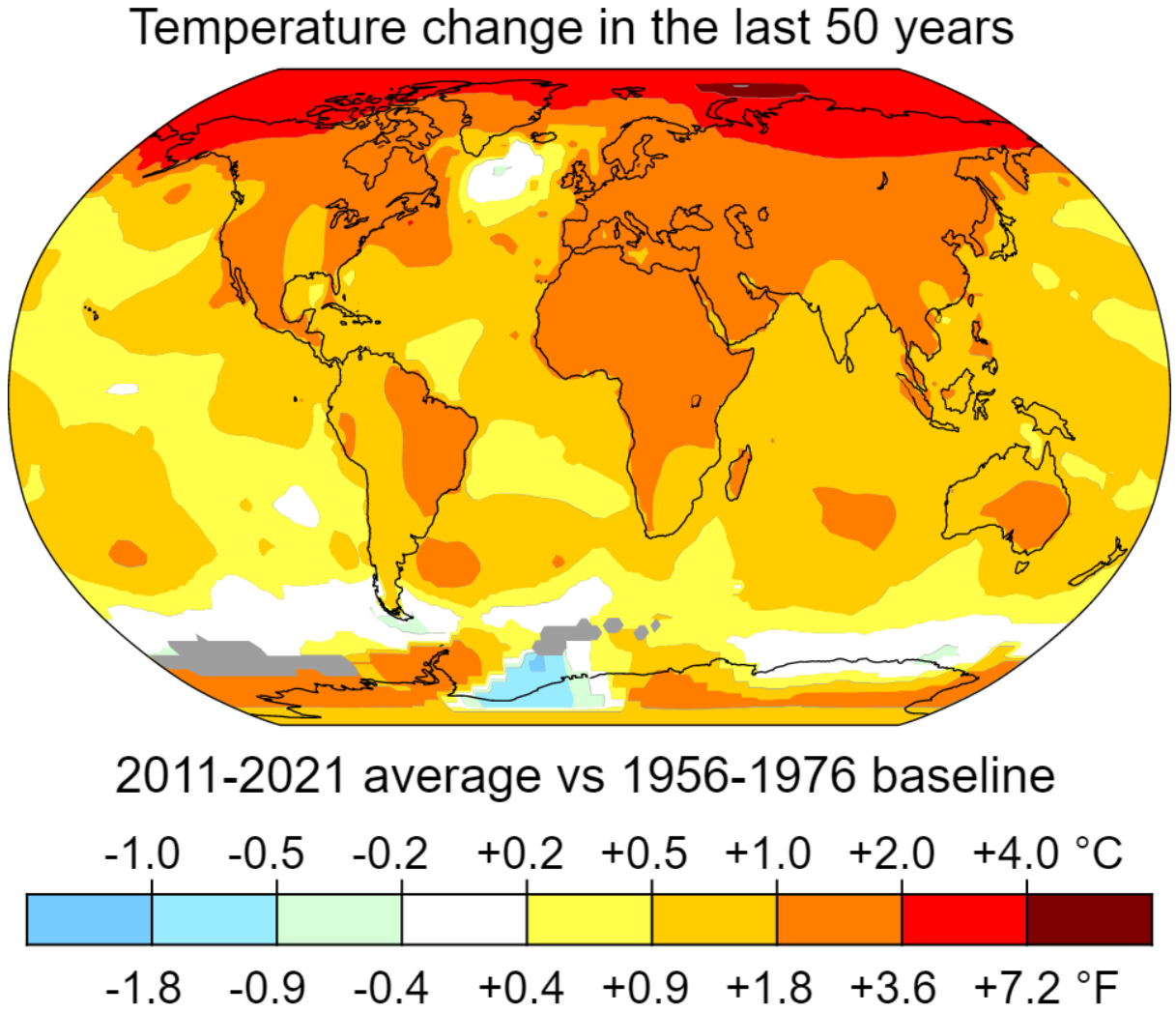
HYDROLOGY &
HYDRAULIC ENGINEERING
DEPARTMENT

An Open-source Python script to prepare the SWAT+gwflow inputs, calibrate and post-process

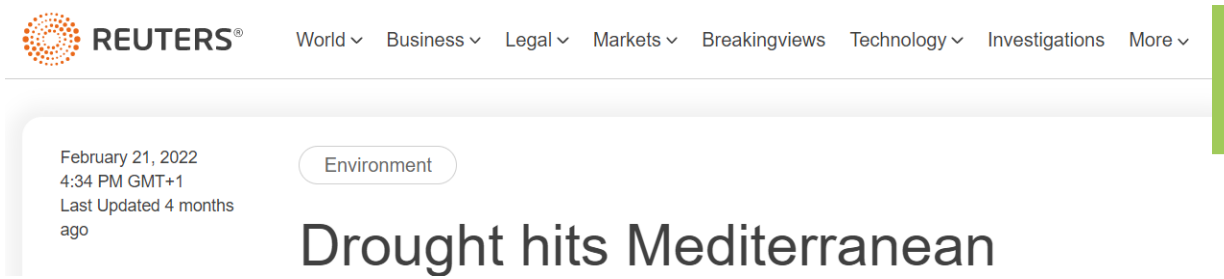
Estifanos Addisu Yimer, José Pablo Terán Orsini, Alula Girmay Kebedew, Lorenzo Villani, Alitane Abdenabi, Ammari Zakaria, Anandita Agarwal, Brian Omondi Oduor, Ann van Griensven, Jiri Nossent, and Ryan Bailey

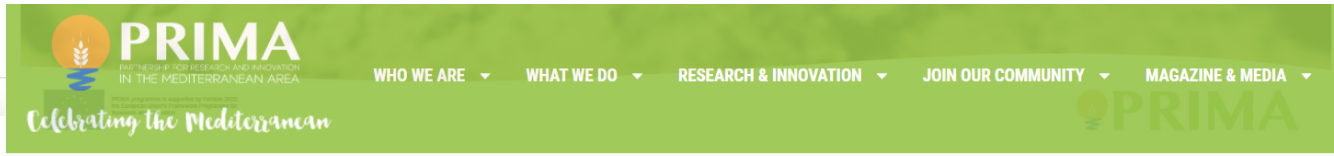
June 2023

Introduction and Problem statement



Introduction and Problem statement





Drought, the silent enemy of the Mediterranean

DATE

22.03.22

Looking for solutions to tackle water scarcity in agriculture

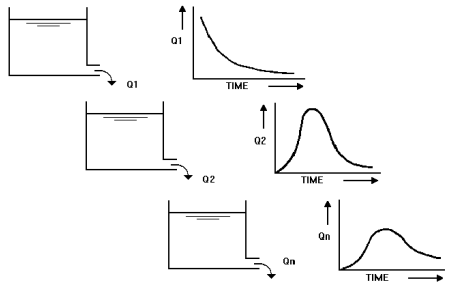
my.europe EUROPE NEWS

Belgian farmers struggle as drought and rising costs hit

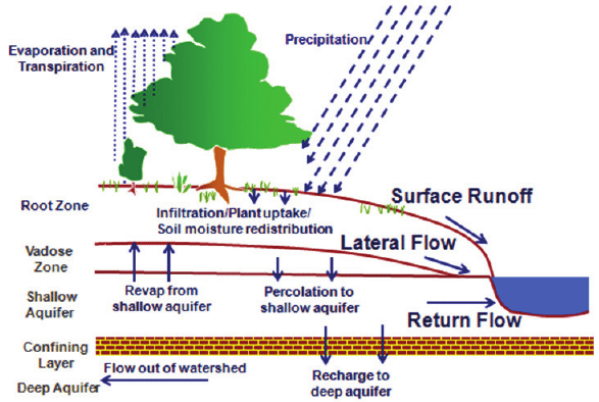
Introduction and Problem statement

How to assess the impact is the main question

Using conceptual models



Using distributed models



Coupled Surface-GW models

- SWAT with MODFLOW
- SWAT+ gwflow
  (Bailey et.al 2020)
  (Yimer et.al 2023)
  (Yimer et.al 2022)*

Separate models

Why SWAT+gwflow?

1. Cumbersome code modification is not required

2. Physically based and distributed model → contrary to the standalone SWAT+ model

3. Computation time is reduced

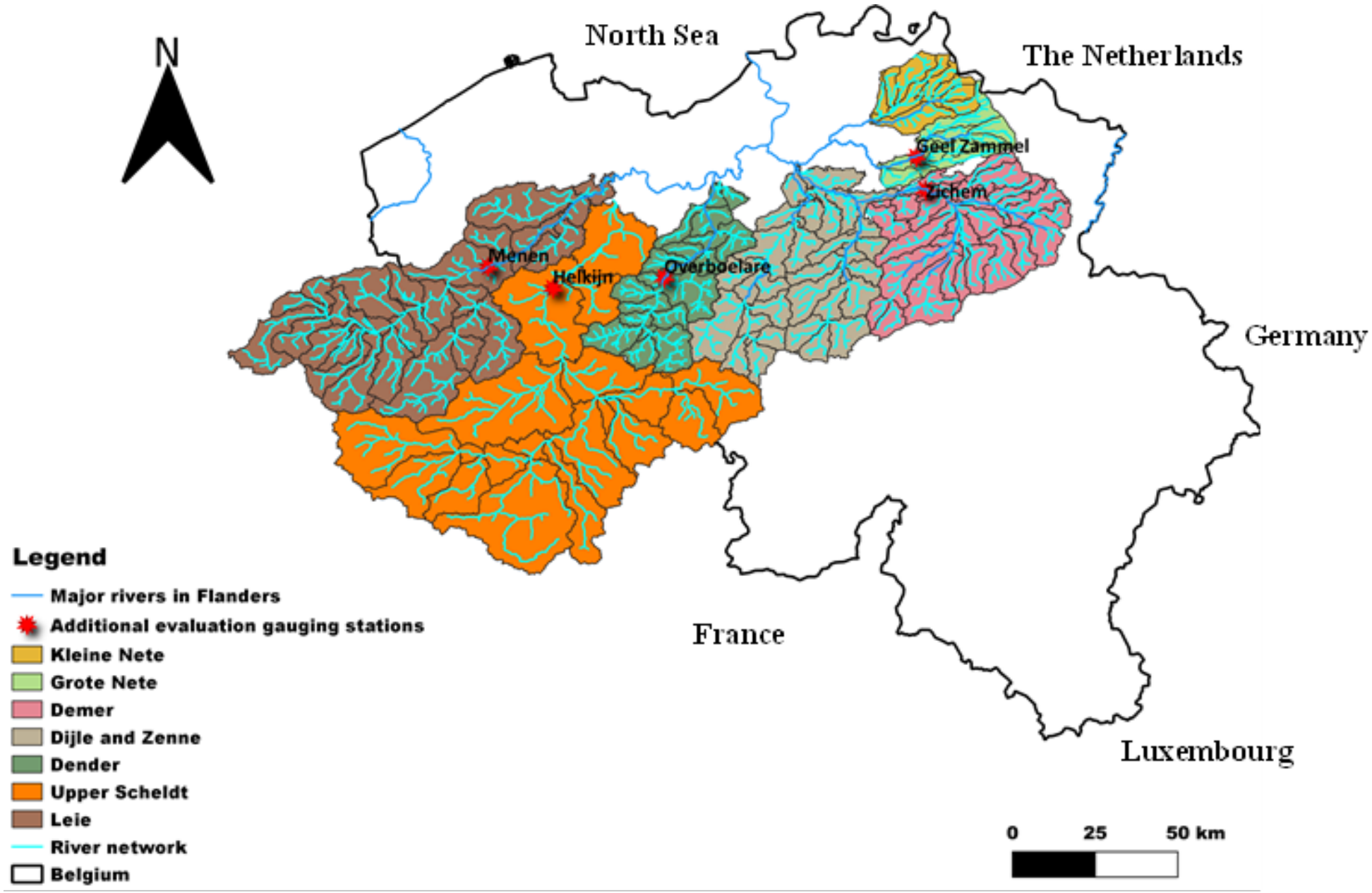
4. Easy to use → scripts to prepare the inputs and tutorial on how to develop the model exists.

But the python script used to prepare the inputs requires licensed package (Arcpy)

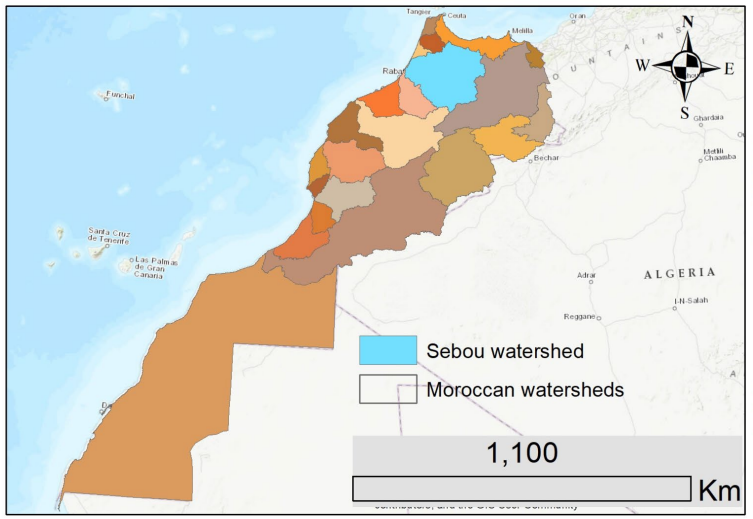
Packages used for the development

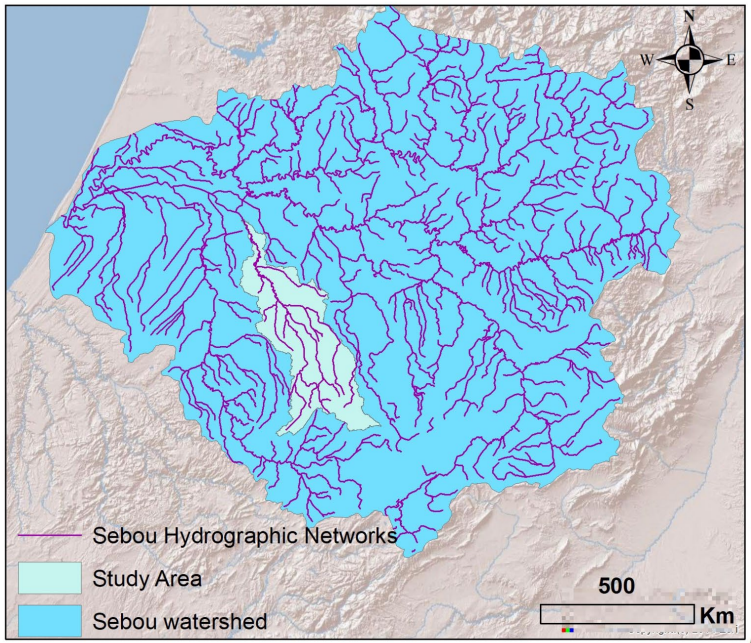
```
from osgeo import gdal,ogr,osr
from shapely import geometry
import pandas as pd
import geopandas as gpd
import numpy as np
import math
import matplotlib.pyplot as plt
from datetime import datetime
import os
import shutil
from matplotlib_scalebar.scalebar import ScaleBar
import matplotlib.patches as mpatches
```

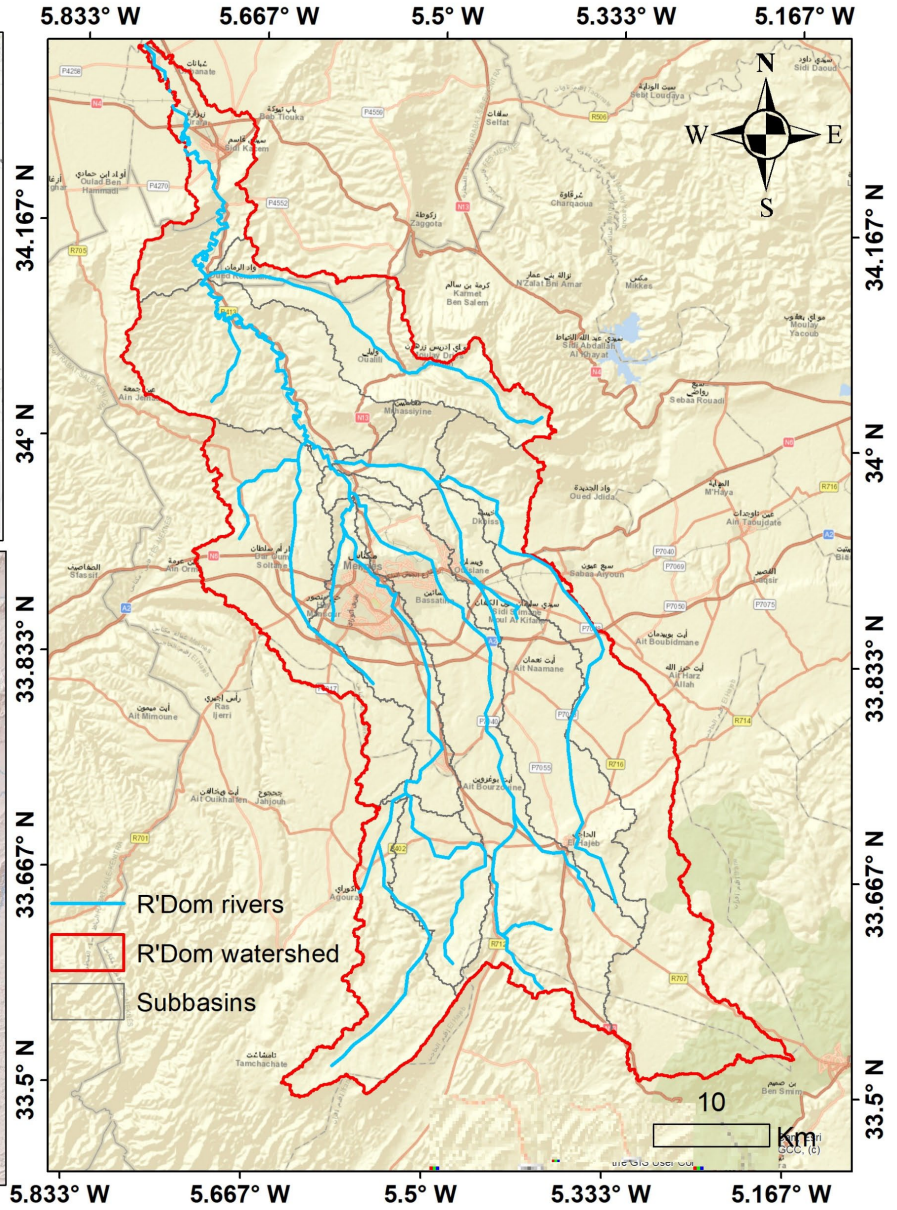
Study area 1


N
North Sea
The Netherlands
Germany
France
Luxembourg
Geel Zammel
Zichem
Menen
Helkijn
Overboelare
Legend
Major rivers in Flanders
Additional evaluation gauging stations
Kleine Nete
Grote Nete
Demer
Dijle and Zenne
Dender
Upper Scheldt
Leie
River network
Belgium
0
25
50 km

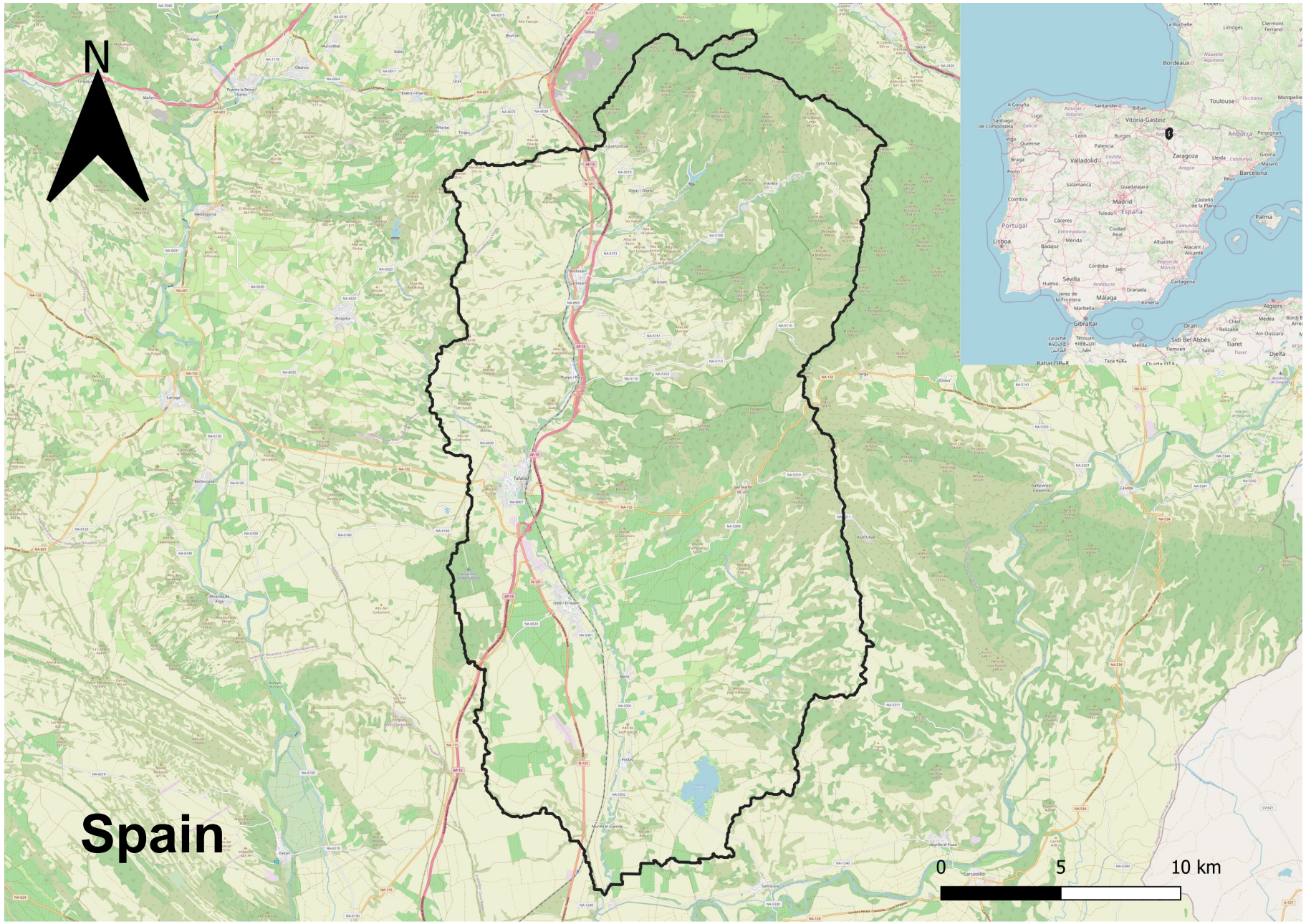
Study area 2


Sebou watershed
Moroccan watersheds
1,100
Km


Sebou Hydrographic Networks
Study Area
Sebou watershed
500
Km


5.833° W
5.667° W
5.5° W
5.333° W
5.167° W
34.167° N
34° N
33.833° N
33.667° N
33.5° N
R'Dom rivers
R'Dom watershed
Subbasins
10
Km

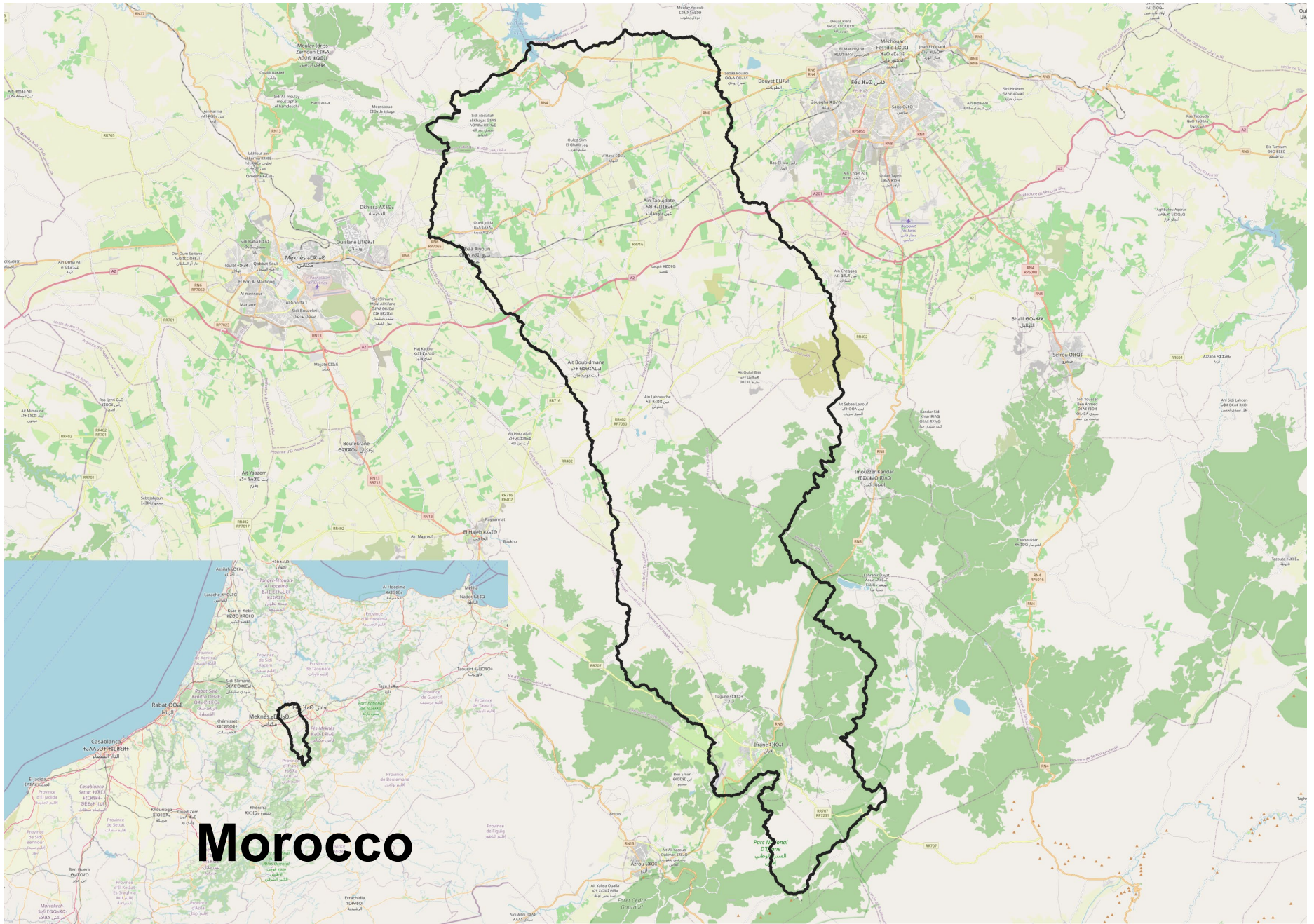
Study area 3



Study area 4


N
Denmark
0
10
20 km
Aarhus
Silkeborg
Horsens
Randers
Hedensted
Skanderborg
Odder
Tranbjerg
Beder-Malling
Brande
Hadsten
Hinnerup
Lystrup
Tilst
Ebeltoft
Bjerringbro

Study area 5

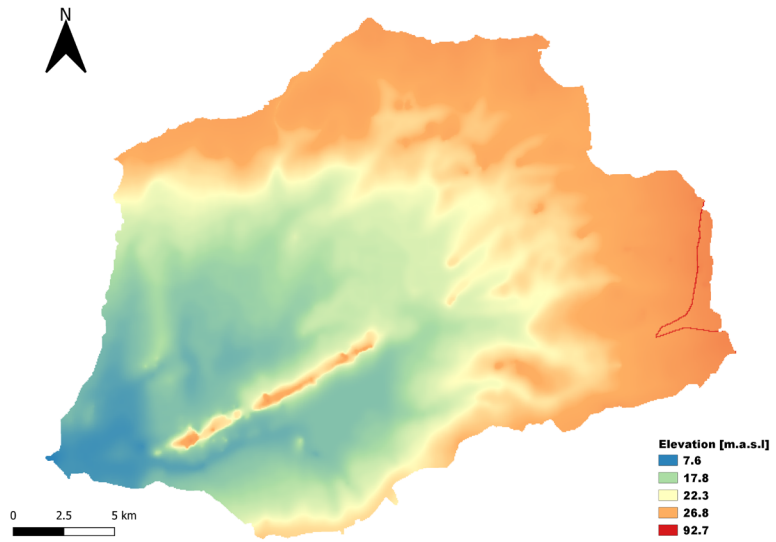


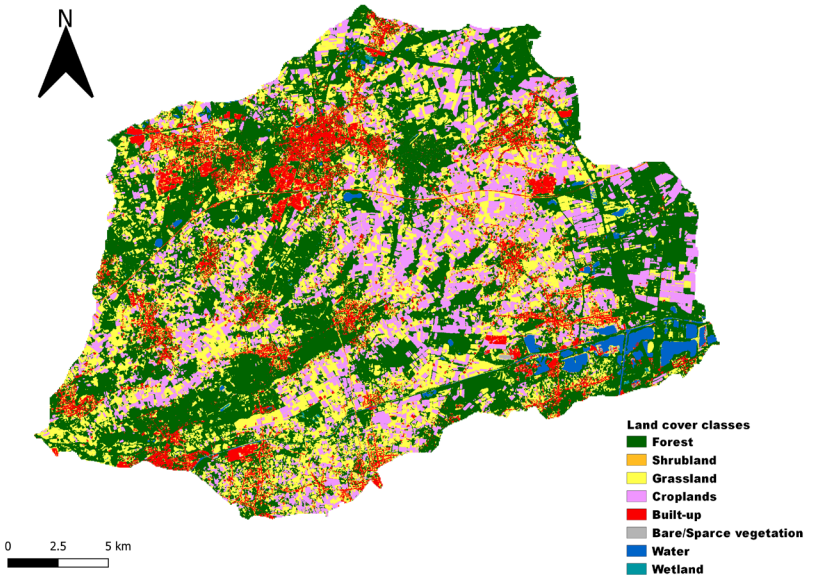
Methodology

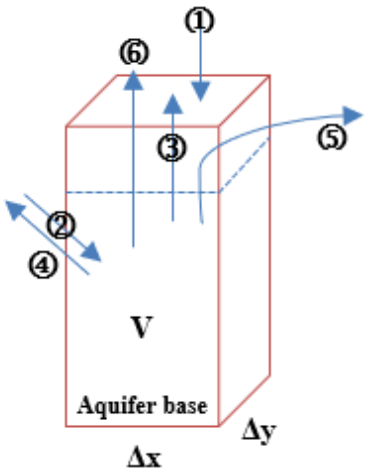
- Used SWAT+gwflow to model the catchments

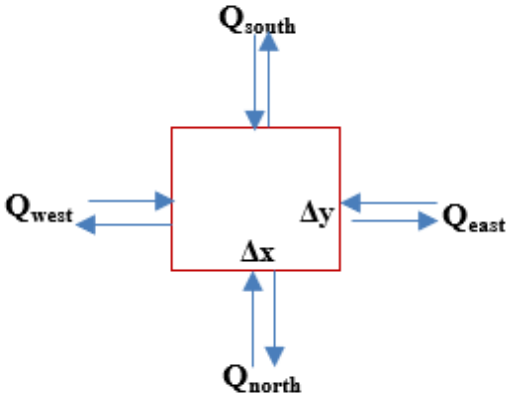
Data	Source	Resolution
	For SWAT+ model setup	
DEM	Accessed: 1 February 2022, https://viewer.nationalmap.gov, U.S. Geological Survey, National Elevation Data	30m
Land use	Accessed: 1 February 2022,https://remotesensing.vito.be/, VITO	10m
Soil map	Accessed: 1 February 2022, https://www.fao.org/land-water/en/	Vector polygon
	For SWAT+gwflow model setup	
Aquifer thickness (cm)	Accessed: 10 March 2022, https://soilgrids.org/	250m
Permeability zones (m/day)	Accessed: 10 March 2022, https://dataverse.scholarsportal.info/dataset.xhtml?persistentId=doi:10.5683/SP2/TTJNIU	Vector polygon

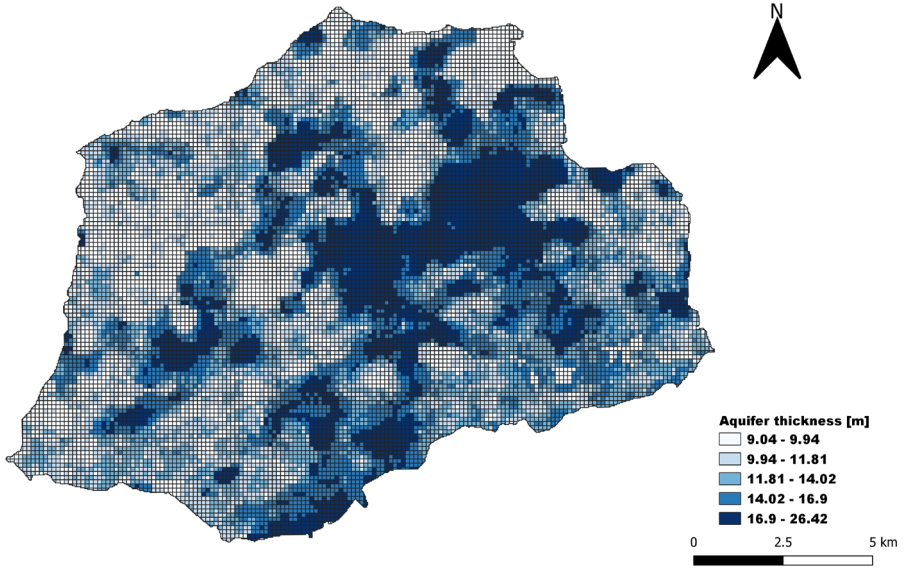
Methodology



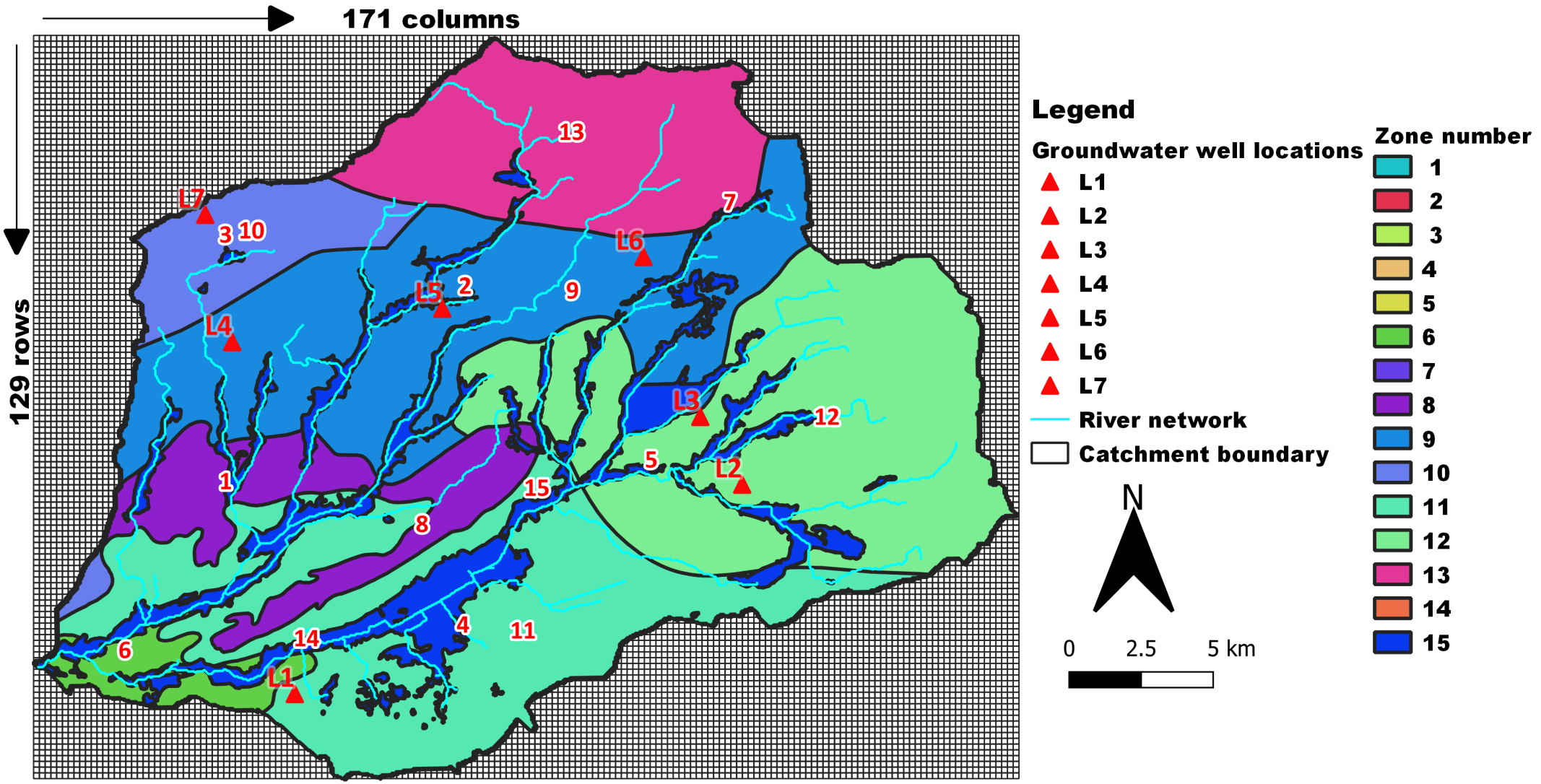


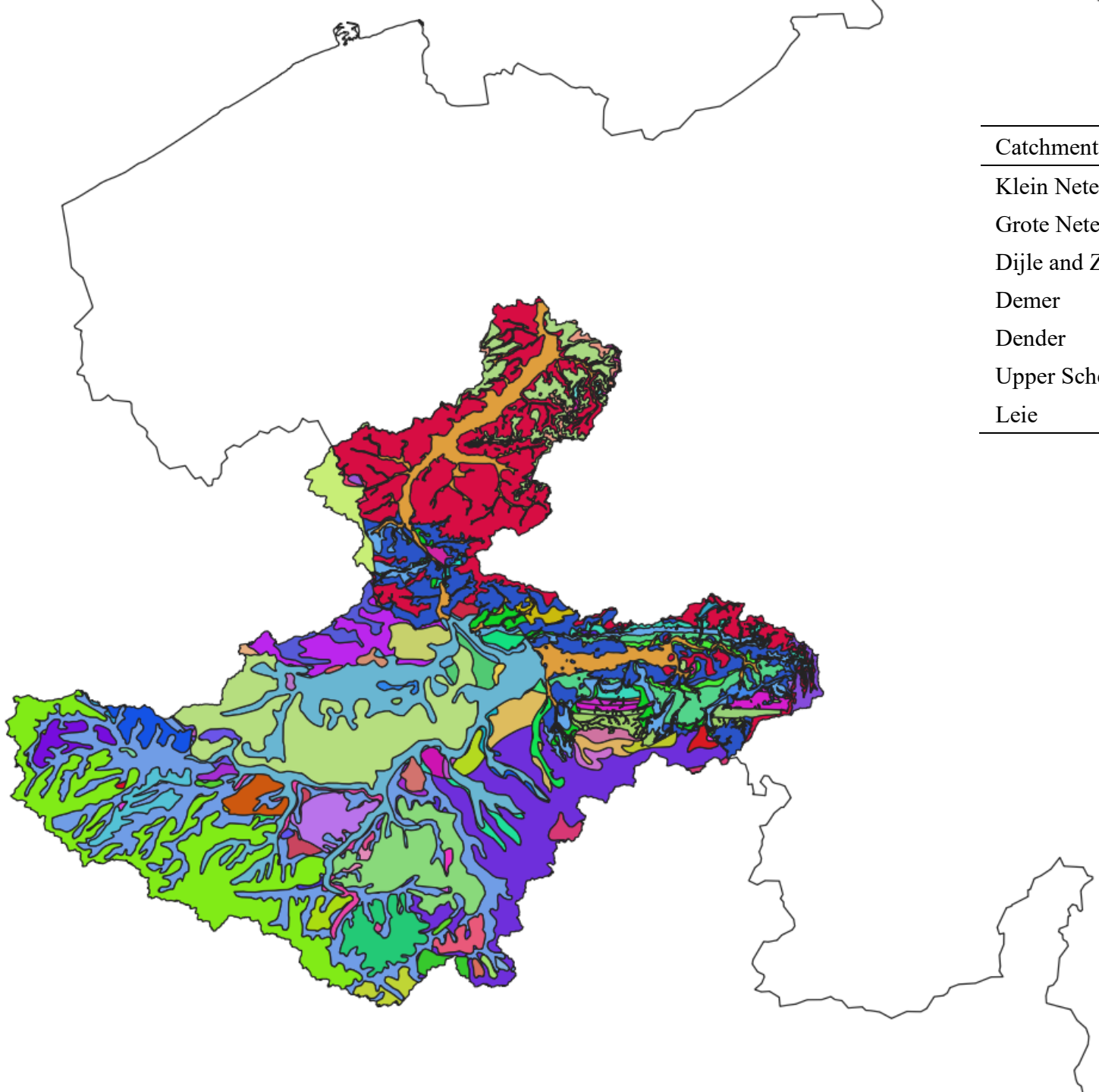






Methodology





Catchment name	Number of zones	Number of major zones
Klein Nete	15	7
Grote Nete	11	5
Dijle and Zenne	49	8
Demer	31	6
Dender	27	4
Upper Scheldt	165	10
Leie	107	13

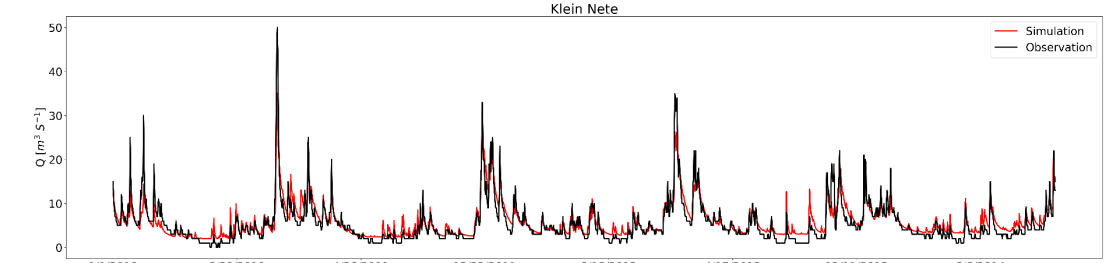
Case study area 1

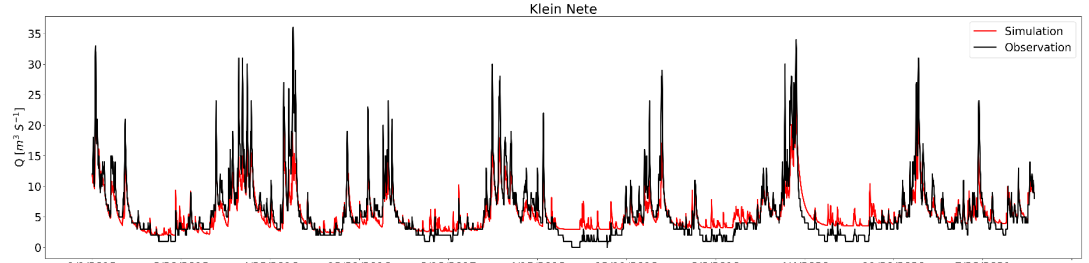
1. Calibration and validation at catchment outlet

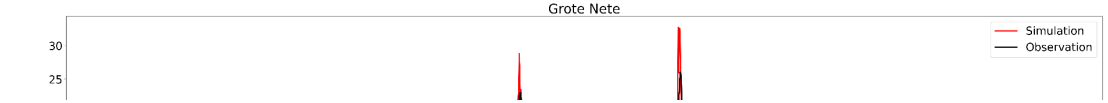
	For the main gauging station			
	Calibration		Validation	
Catchment name	Monthly	Daily	Monthly	Daily
Klein Nete	0.9	0.8	0.8	0.7
Grote Nete	0.9	0.8	0.8	0.7
Dijle and Zenne	0.8	0.7	0.8	0.7
Demer	0.9	0.8	0.8	0.8
Dender	0.9	0.6	0.9	0.7
Upper Scheldt	0.9	0.8	0.9	0.8
Leie	0.7	0.6	0.8	0.7

2. Validation using other gauging station data

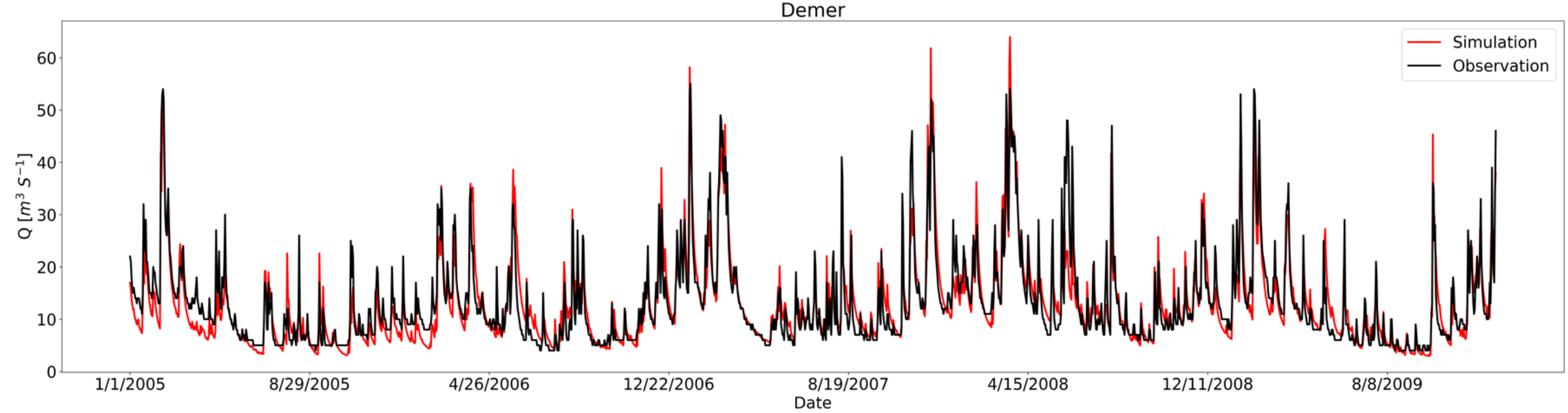
	Based on additional gauging station			
	Calibration		Validation	
Catchment name	Monthly	Daily	Monthly	Daily
Klein Nete	*	*	*	*
Grote Nete	0.5	0.5	0.8	0.7
Dijle and Zenne	*	*	*	*
Demer	0.8	0.8	0.9	0.8
Dender	0.7	0.5	0.9	0.8
Upper Scheldt	0.7	0.6	0.8	0.6
Leie	*	*	*	*

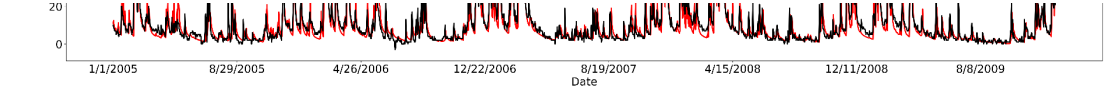

Klein Nete
Simulation
Observation
Q [m³ S⁻¹]
1/1/2010
8/29/2010
4/26/2011
12/22/2011
8/18/2012
4/15/2013
12/11/2013
8/8/2014
Date

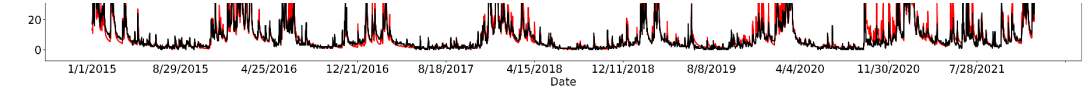

Klein Nete
Simulation
Observation
Q [m³ S⁻¹]
1/1/2015
8/29/2015
4/25/2016
12/21/2016
8/18/2017
4/15/2018
12/11/2018
8/8/2019
4/4/2020
11/30/2020
7/28/2021
Date

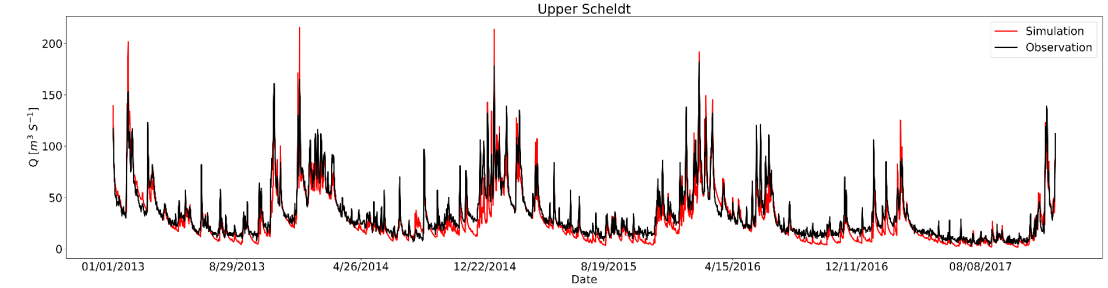

Grote Nete
Simulation
Observation

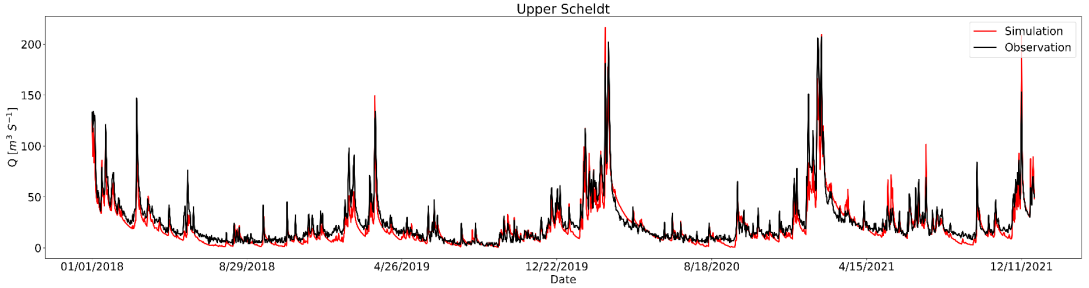

Grote Nete
Simulation
Observation


Demer
Simulation
Observation
Q [m³ S⁻¹]
1/1/2005
8/29/2005
4/26/2006
12/22/2006
8/19/2007
4/15/2008
12/11/2008
8/8/2009
Date

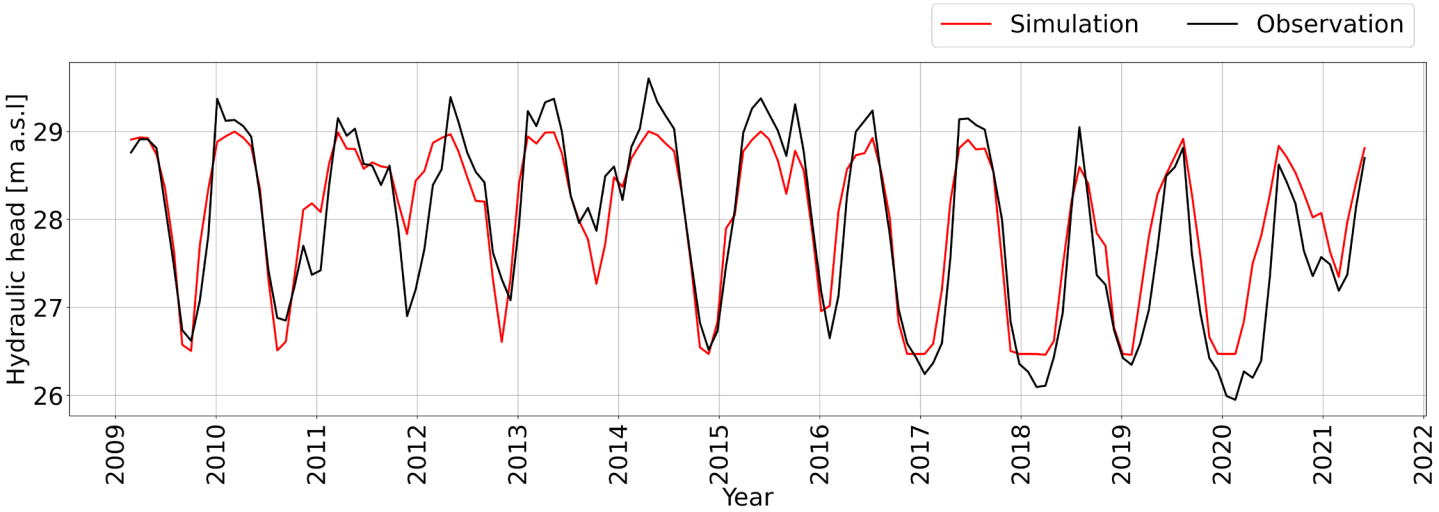

1/1/2005
8/29/2005
4/26/2006
12/22/2006
8/19/2007
4/15/2008
12/11/2008
8/8/2009
Date


1/1/2015
8/29/2015
4/25/2016
12/21/2016
8/18/2017
4/15/2018
12/11/2018
8/8/2019
4/4/2020
11/30/2020
7/28/2021
Date


Upper Scheldt
Simulation
Observation
Q [m³ S⁻¹]
01/01/2013
8/29/2013
4/26/2014
12/22/2014
8/19/2015
4/15/2016
12/11/2016
08/08/2017
Date


Upper Scheldt
Simulation
Observation
Q [m³ S⁻¹]
01/01/2018
8/29/2018
4/26/2019
12/22/2019
8/18/2020
4/15/2021
12/11/2021
Date

Case study area 1: Kleine Nete watershed



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Science of The Total Environment

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The impact of extensive agricultural water drainage on the hydrology of the Kleine Nete watershed, Belgium

Estifanos Addisu Yimer [a], Fatima-Ezzahra Riakhi [a], Ryan T. Bailey [b], Jiri Nossent [a c], Ann van Griensven [a d]

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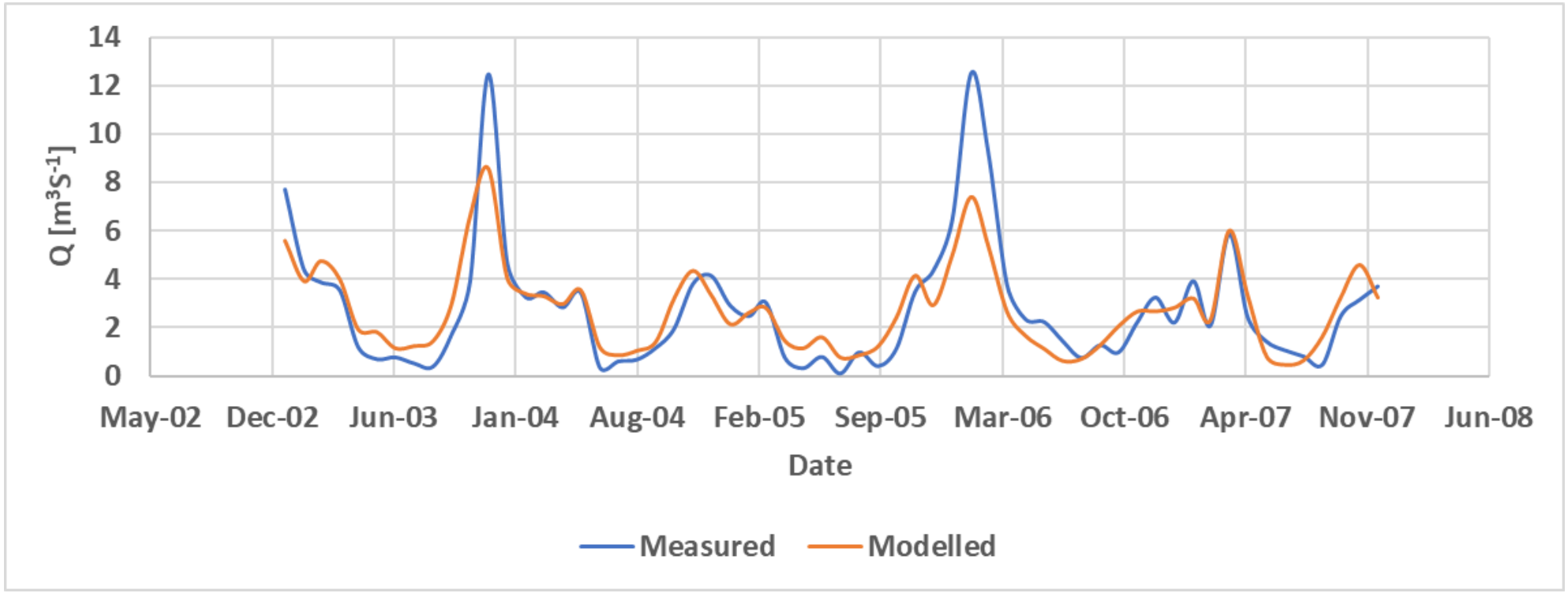
Highlights

- Water drained from agricultural fields is substantial.
- Coupled surface-groundwater modeling approach using SWAT+*gwflow*

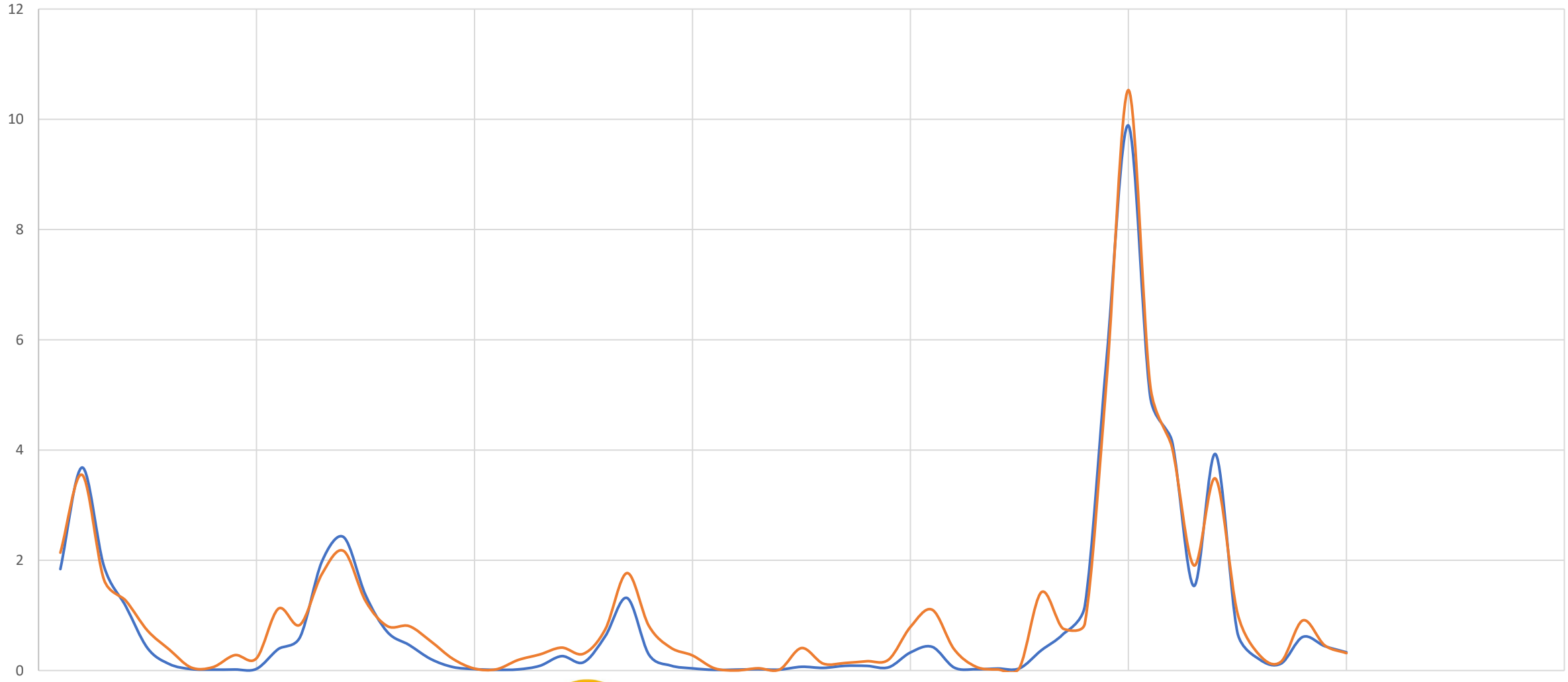
Case study area 2 (Morocco 1)

2. Calibration (monthly)



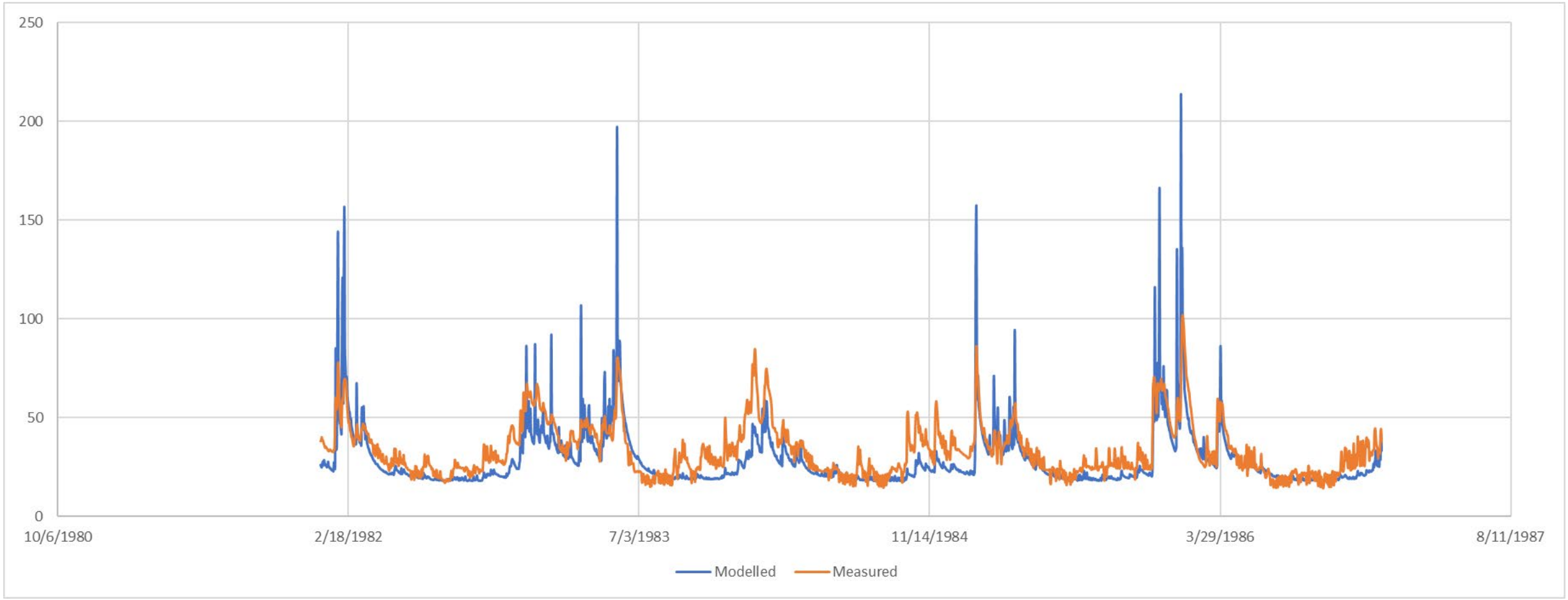
Nash-Sutcliffe efficiency of 0.75

Case study area 3 (Spain)

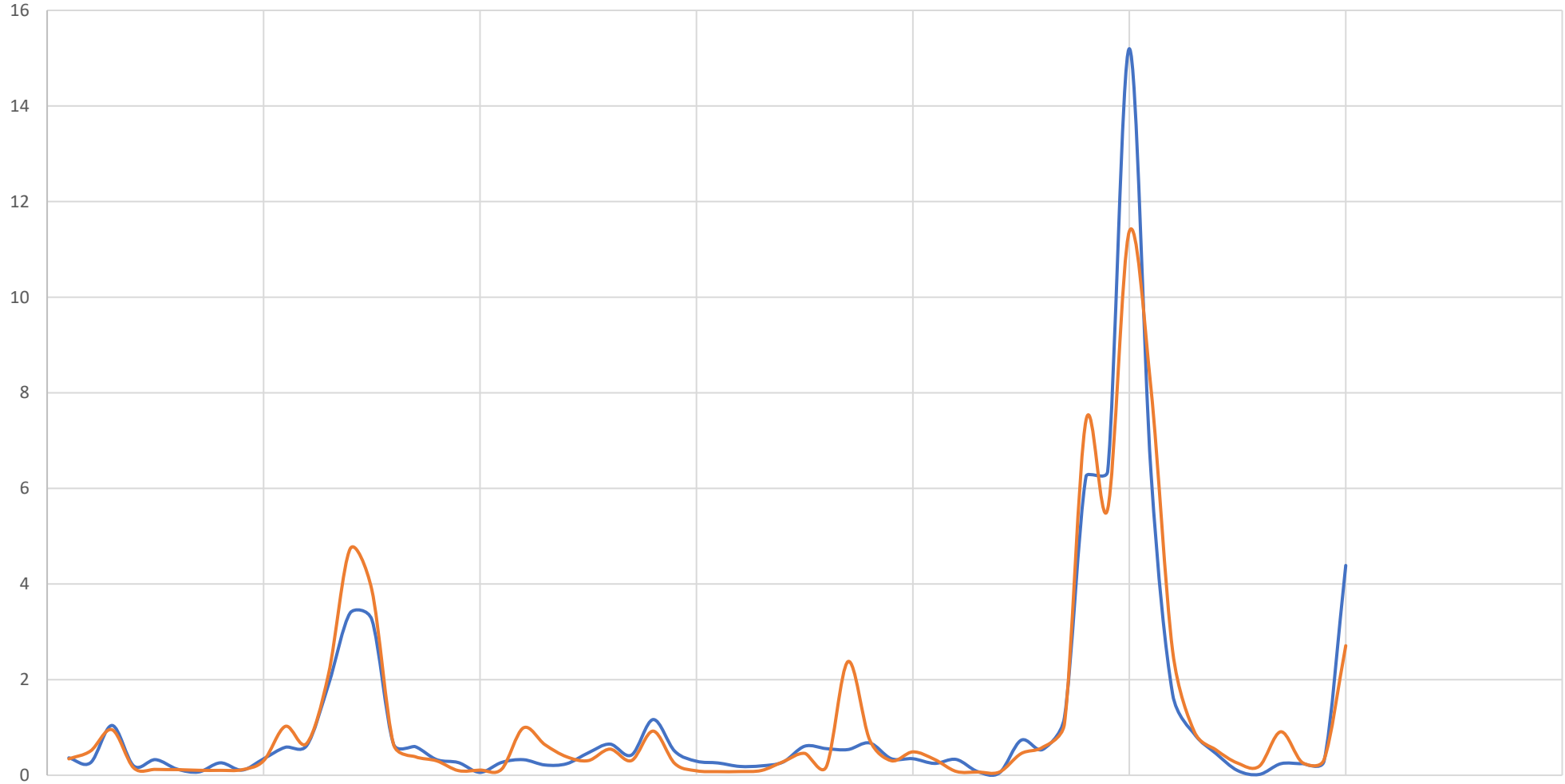


Nash-Sutcliffe efficiency of 0.97

Case study area 4 (Denmark)

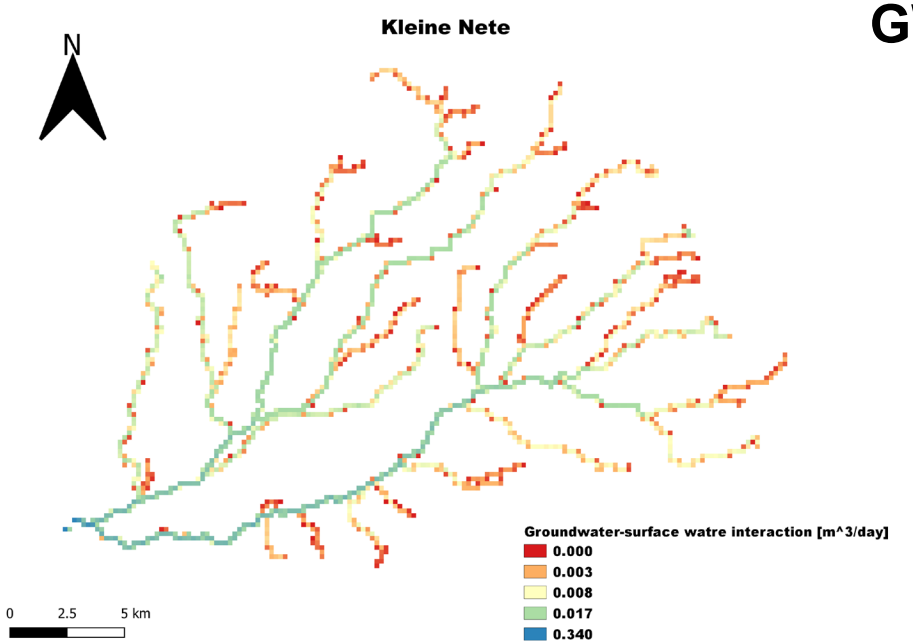


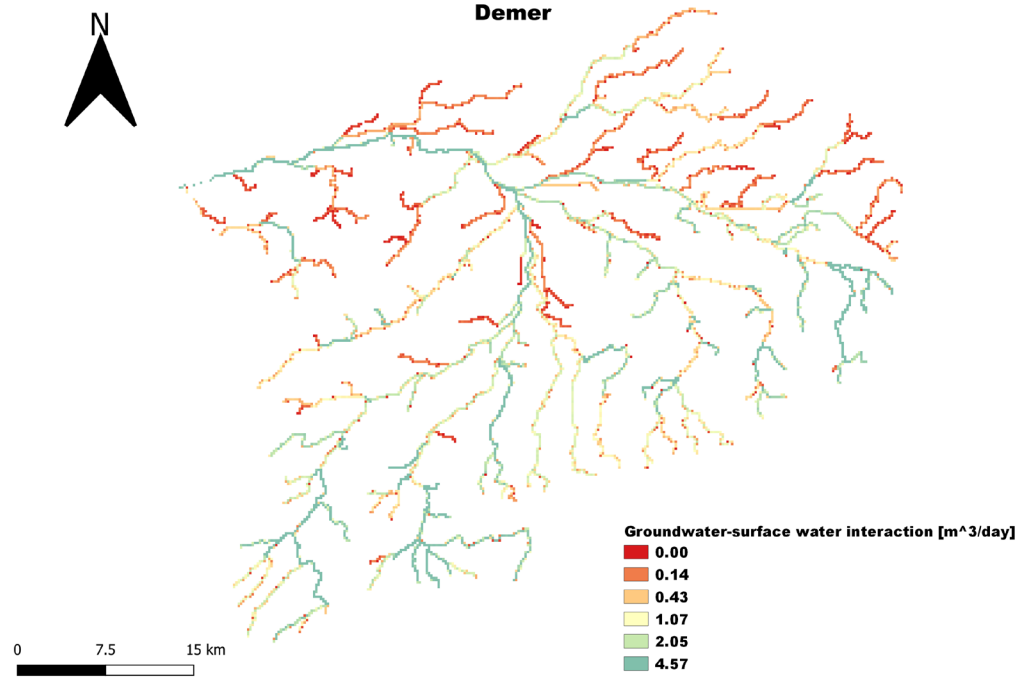
Case study area 5 (Morocco 2)

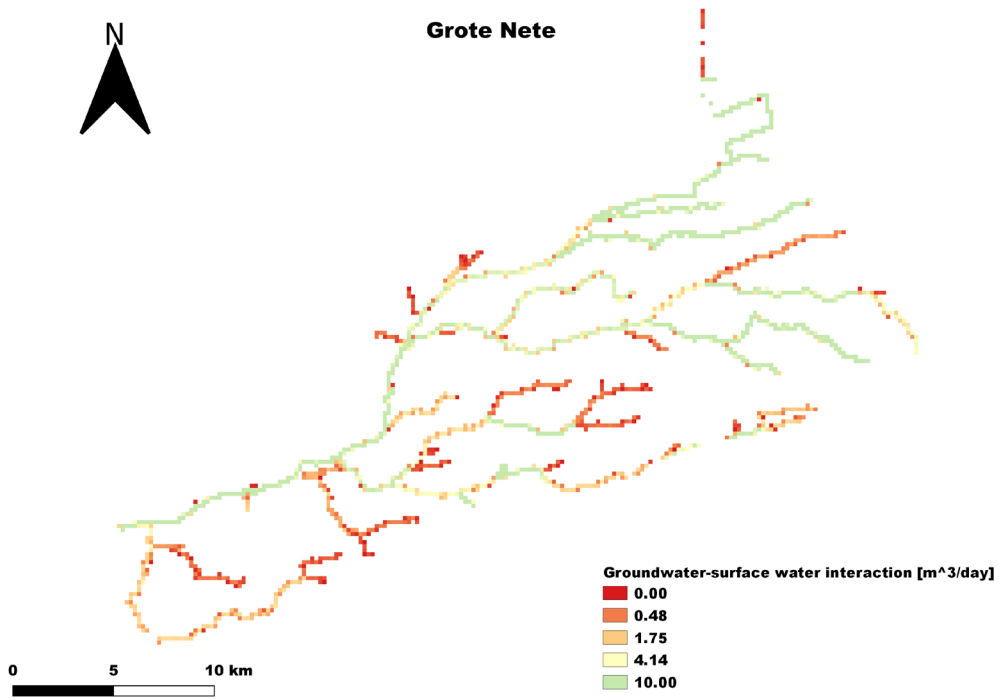


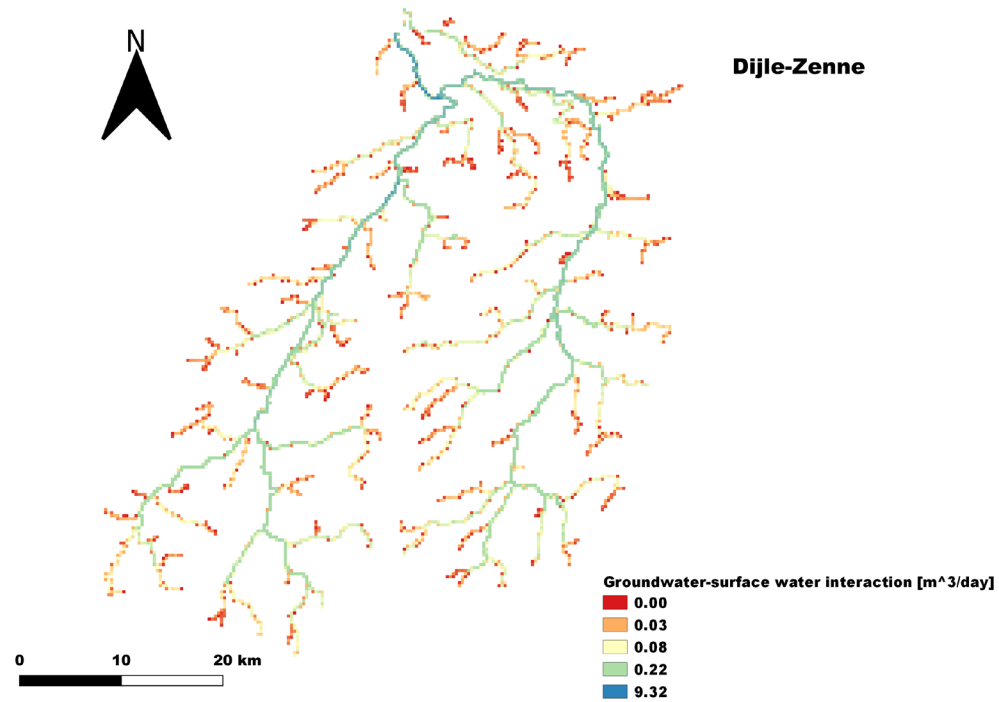
Nash-Sutcliffe efficiency of 0.91

GWSW


Kleine Nete
N
Groundwater-surface watre interaction [m^3/day]
0.000
0.003
0.008
0.017
0.340
0
2.5
5 km


Demer
N
Groundwater-surface water interaction [m^3/day]
0.00
0.14
0.43
1.07
2.05
4.57
0
7.5
15 km


Grote Nete
N
Groundwater-surface water interaction [m^3/day]
0.00
0.48
1.75
4.14
10.00
0
5
10 km


Dijle-Zenne
N
Groundwater-surface water interaction [m^3/day]
0.00
0.03
0.08
0.22
9.32
0
10
20 km

Conclusions

1. Open source packages made our life easy

2. Wide variety (catchment size, climate, land use, etc) of watersheds were able to be represented by the model

3. Post processing is still difficult, hence, further effort is needed


SWAT+gwflow
post processing?
Thank you for your time