Democratizing soil erosion modelling: A Jupyter Notebook approach

iMPAcT erosion

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EGU General Assembly 2024

April 2024

EGU General Assembly

European Commission

Marie Skłodowska-Curie Actions

Postdoctoral Fellowship

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Models are valuable tools to **help decision makers gain deeper insights into their system (e.g land)**

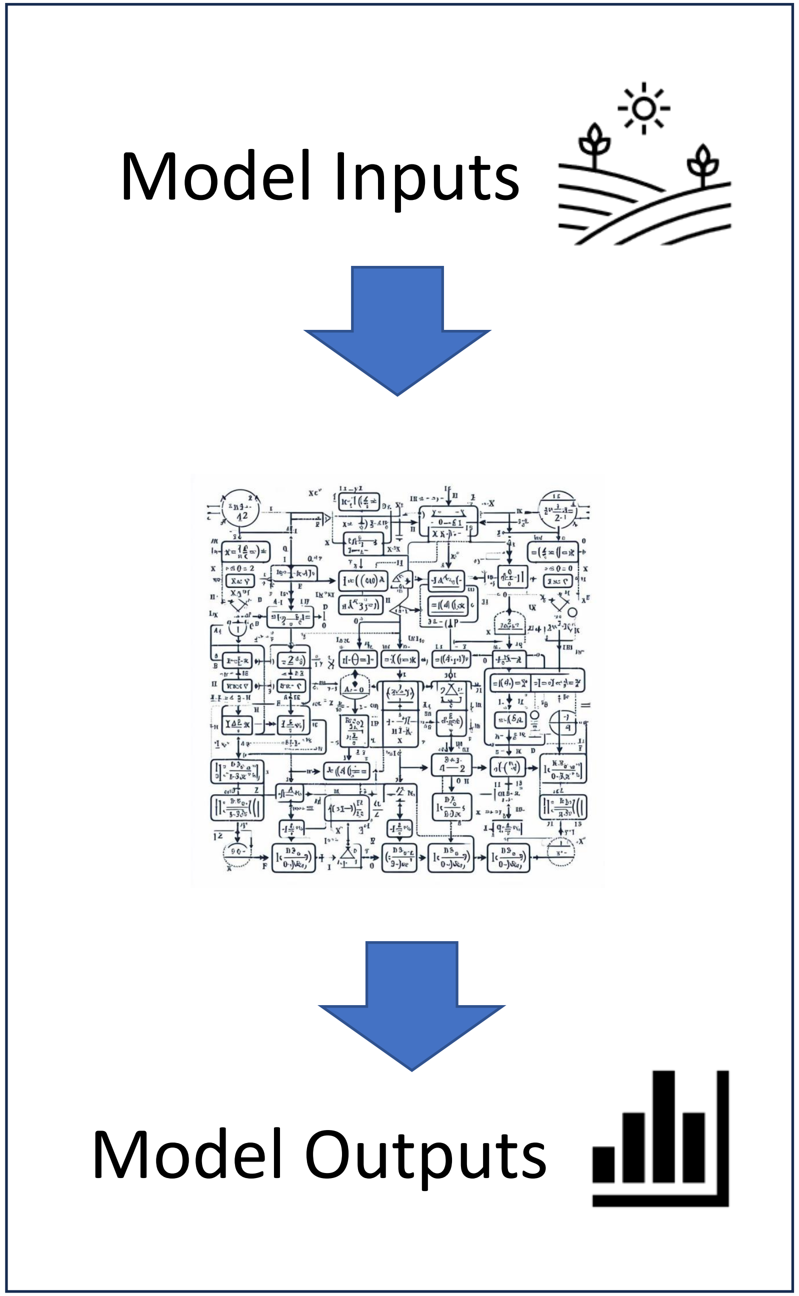
- Understanding a system takes time and real-world experimentation
- Models allow for rapid exploration of countless scenarios and conditions

No tillage /herbicides

Cover crop

New crop

But models are **complex** (to use and understand)



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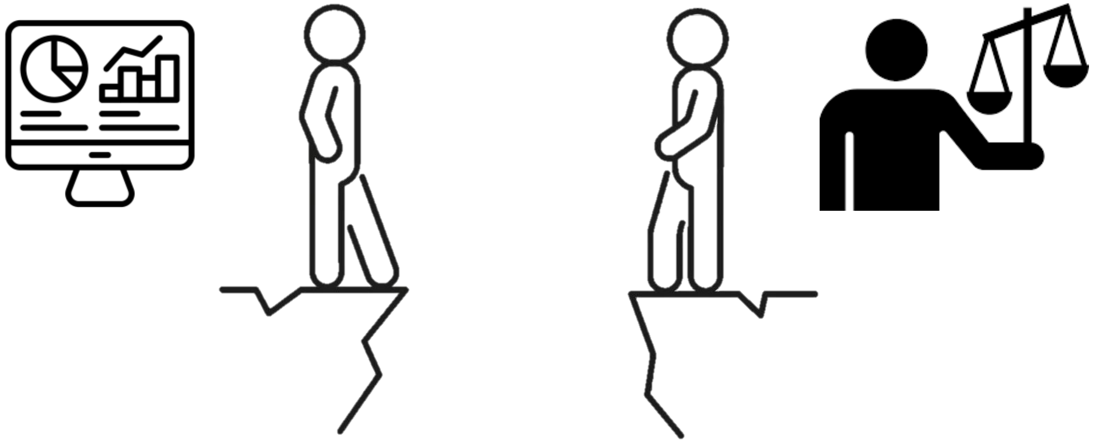
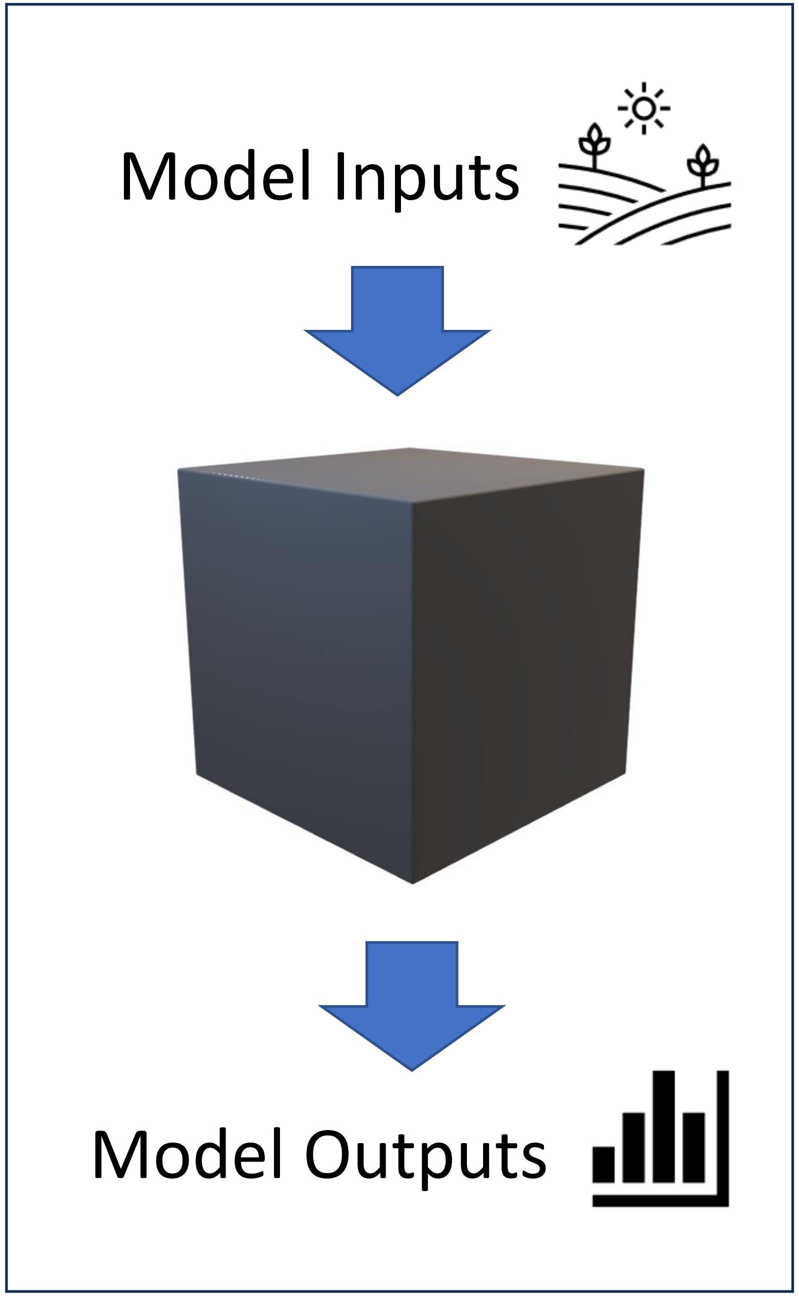
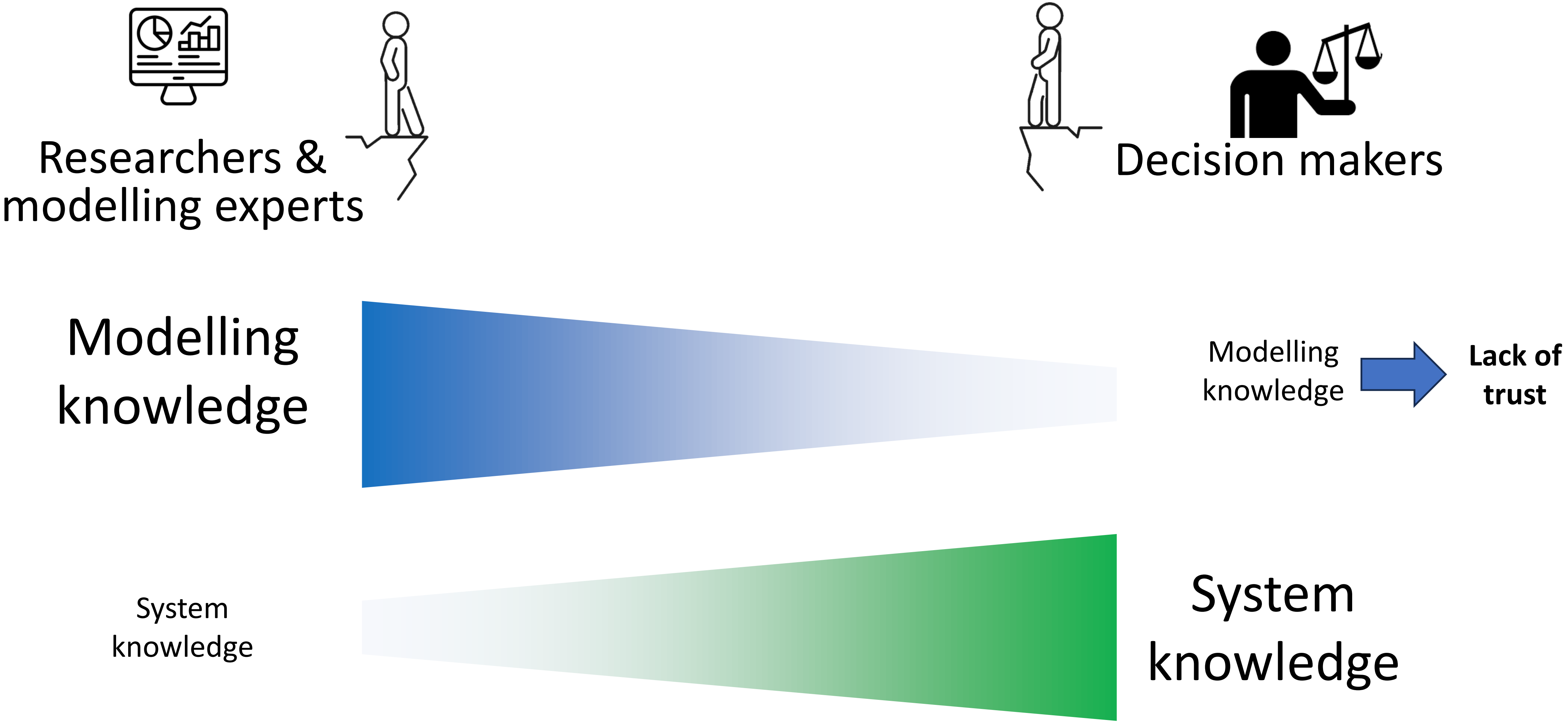
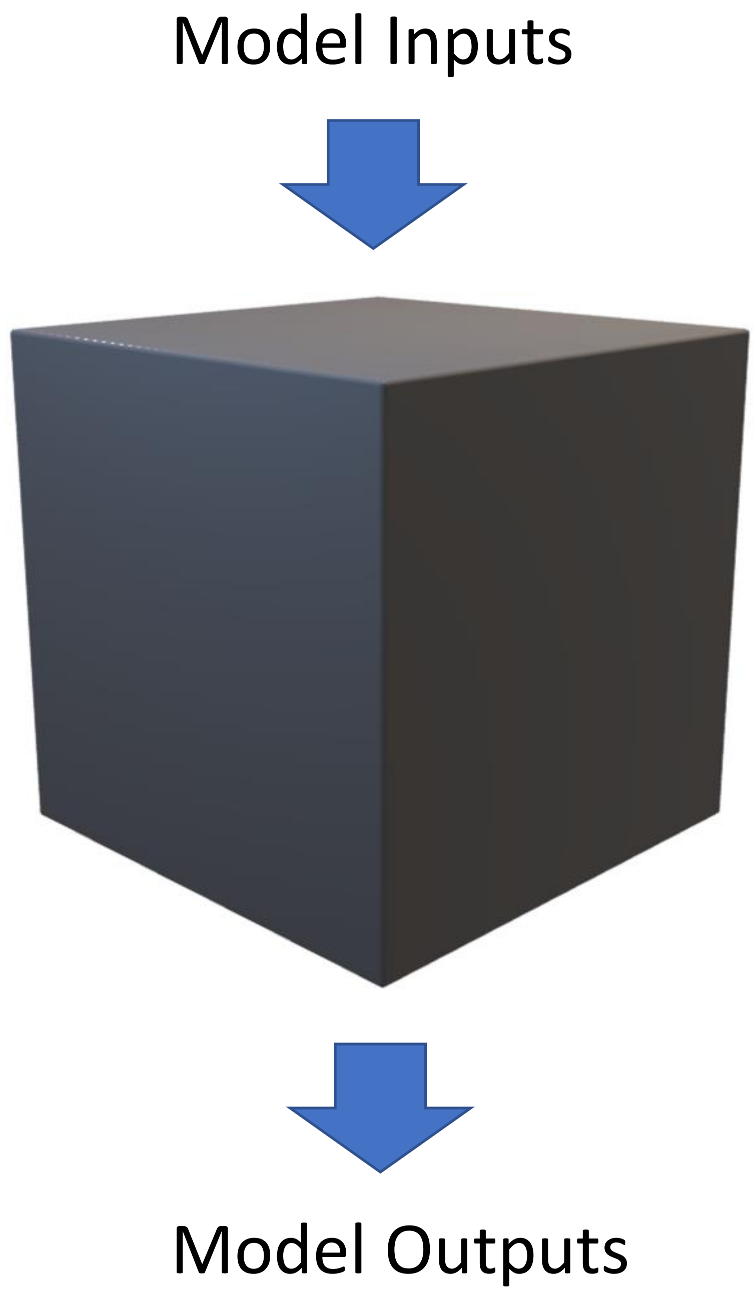





Researchers &
modelling experts
Decision makers
Modelling
knowledge
Modelling
knowledge
Lack of
trust
System
knowledge
System
knowledge

How can we understand models if we do not have the necessary technical knowledge?



6 The algorithms

We will give insight in the various factors needed for calculations, and how they are implemented in the program.

6.1 Water erosion

The WATEM / SEDEM model was created at the Laboratory for Experimental Geomorphology (K.U. Leuven, Belgium). Within the WaTEM / SEDEM model, soil loss is based on the RUSLE-model (Revised Universal Soil Loss Equation; Renard et al., 1997):

$$A = R * K * LS * C * P \quad \textbf{(1)}$$

Where:

- A: average amount of soil loss caused by gully erosion (tons / ha.year)
- R: rain erosivity factor (MJ.mm / ha.year)
- K: soil erodibility factor (tons h / MJ.mm)
- LS: topographical slope and length factor
- C: crop erosivity factor
- P: erosion control factor

These parameters will be discussed in the following paragraphs.

6.1.1 R-factor or rain erosivity factor

The R-factor represents the long term value of rain erosivity on a yearly basis. For small area's (a few km²) we assume that R is uniform for the whole study area so you can use only one value for R. For larger areas, spatial variability in rainfall erosivity may be more important, however. If this is the case, this can be compensated by multiplying a rainfall erosivity map with the soil erodibility map (K-factor) and use this map as input for the K-factor. The value of R then needs to be 1.

6.1.2 K-factor or soil erodibility factor

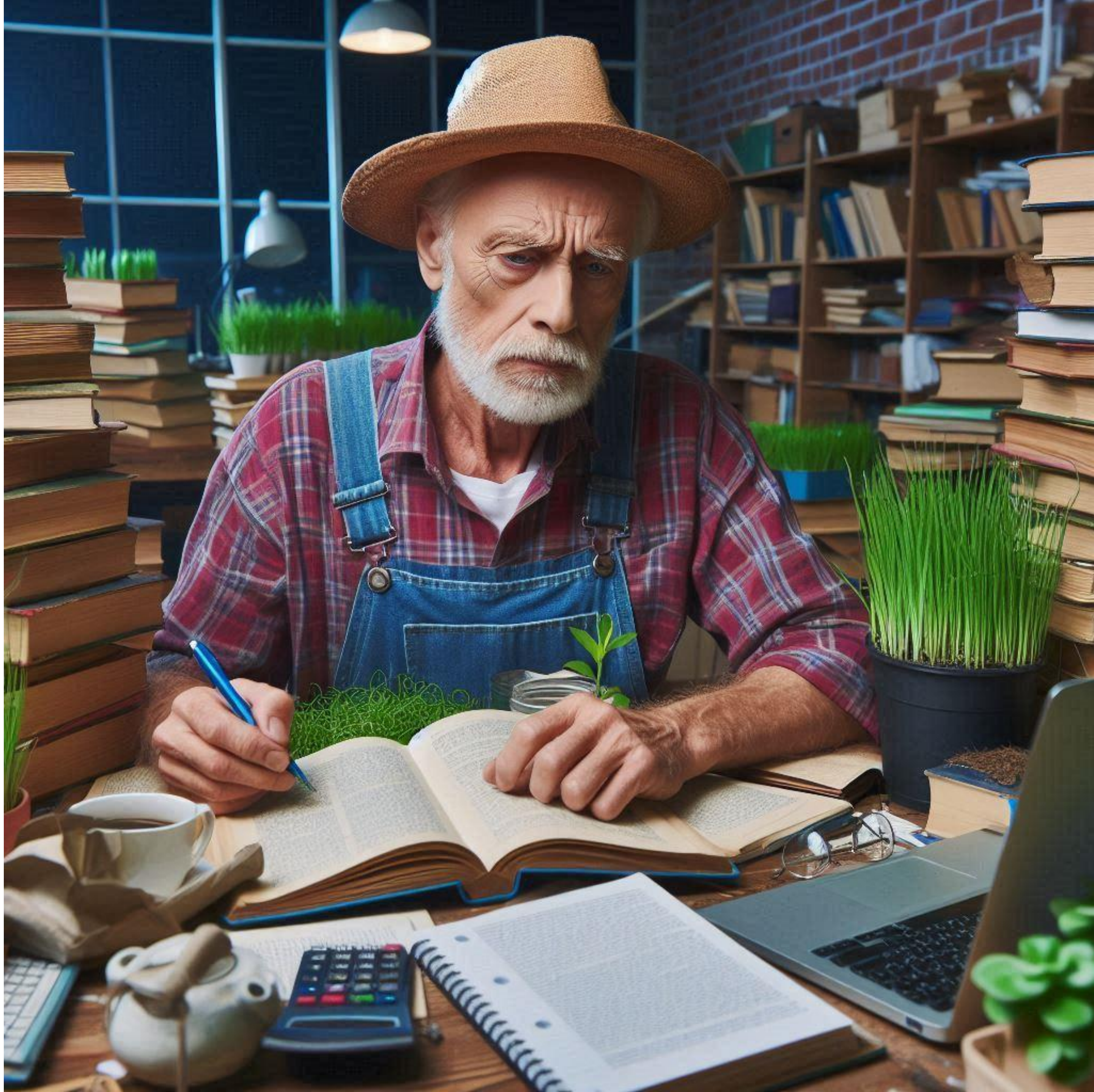
The K-factor is dependant on several factors like texture, organic matter content and moistness. Mostly, only the texture is used for K-factor calculations because of the lack of data. Van Rompay et al. (2000) calculated the K-factor for Flanders by means of texture classes of soil erosion maps using the formula (Declercq en Poesen 1992):

$$K = 0.0035 + 0.0388 \exp[-0.5 ((\log Dg + 1,519) / 0.7584)^2] \quad \textbf{(2)}$$

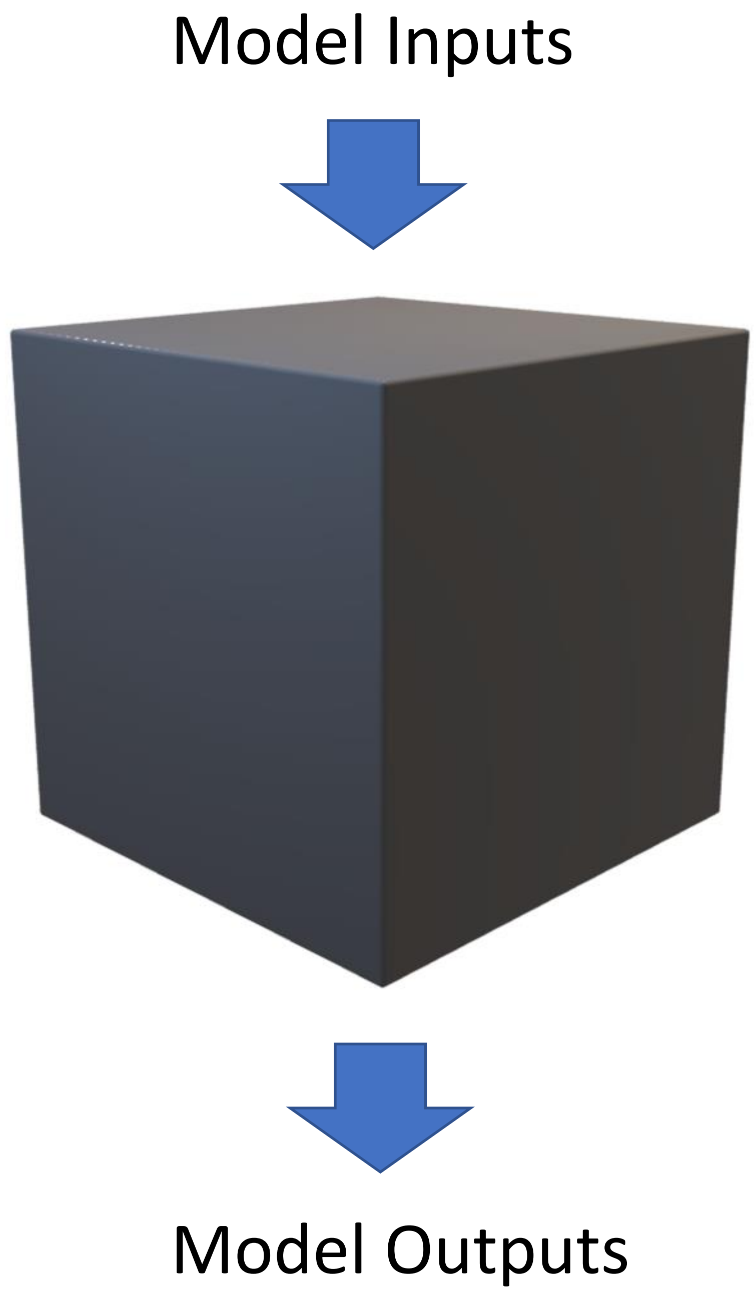
Where Dg = geometrical mean particle diameter (mm) (Shirazi en Boersma 1984):

$$Dg(mm) = e^{\sum f_i * \ln[(d_i + d_{i-1}) * 0.5]} \quad \textbf{(3)}$$

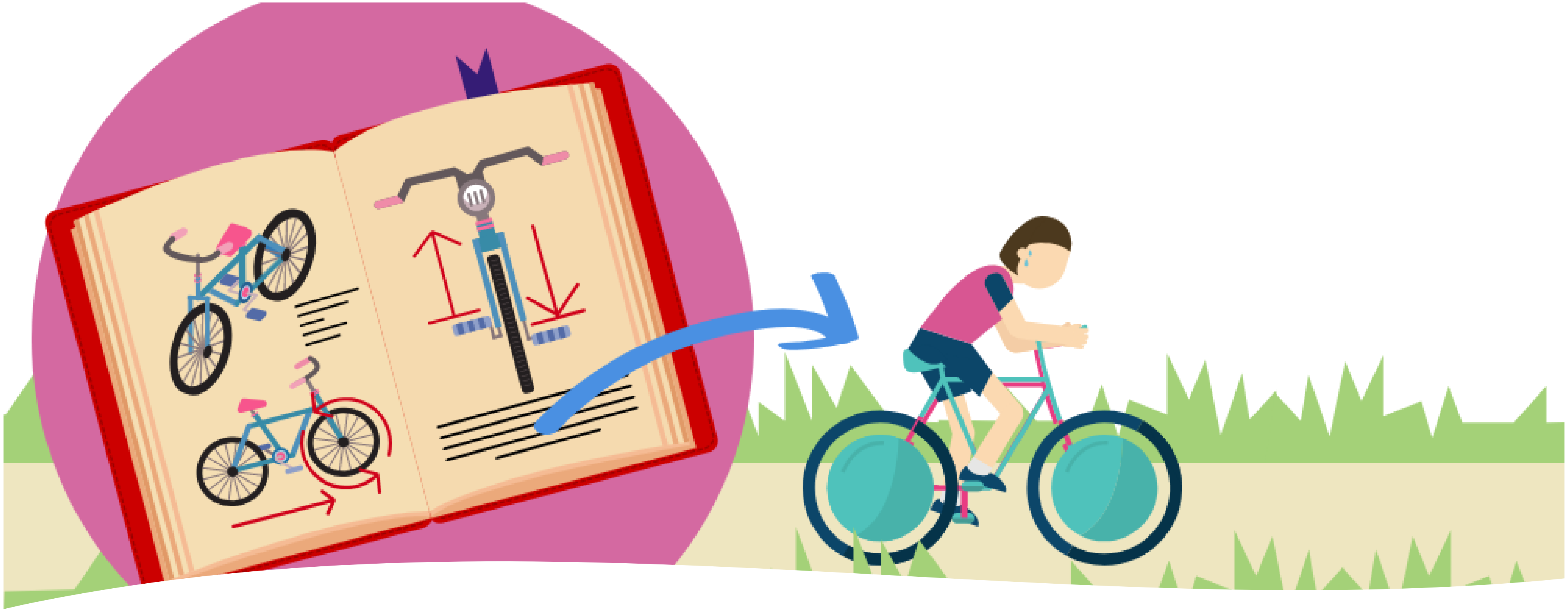
Other formulas for the K-factor are available in literature (e.g. Wischmeier et al. 1971, Declercq en Poesen 1992, Foster 2005).



Let’s rephrase the question…
How can we understand models that look like a black box to us?



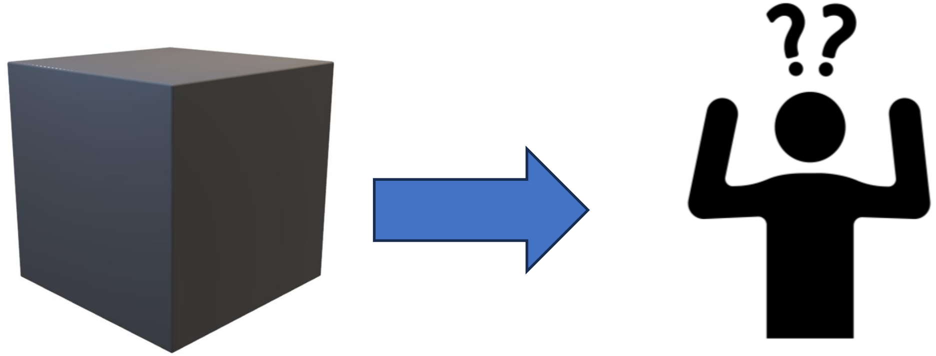
Did you learn to ride a bike by reading a manual?





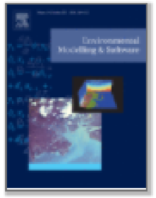
How can we understand models that look like a black box to us?

Learning through **interaction** or **learning by doing**



Note: This is not new… in machine learning (black-box models) they call it **interactive** machine learning (IML)

ELSEVIER



Environmental Modelling & Software
Volume 145, November 2021, 105188

An open-source package with interactive Jupyter Notebooks to enhance the accessibility of reservoir operations simulation and optimisation

Andres Peñuela [a, b], Christopher Hutton [c], Francesca Pianosi [a, d]

“the characteristics of the Notebooks (literate programming and step-by-step structure) combined with visual **interactivity do enhance learning**” (Peñuela et al. 2021)

Interactive

Modular

Playful

AcCessible

Transparent

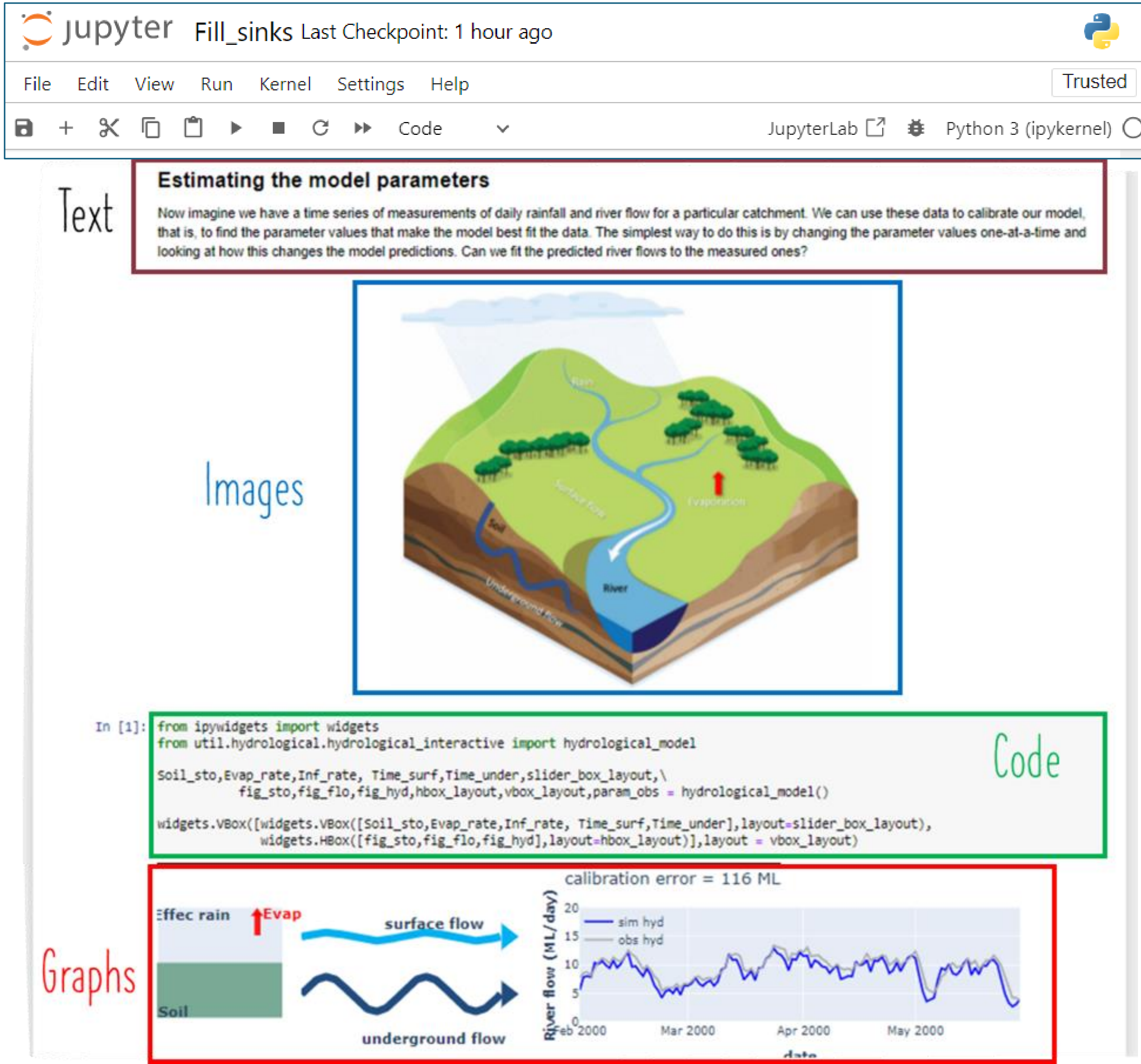
IMPAcT
erosion

soil
erosion
modelling

jupyter

What is Jupyter Notebooks?

- Single document that combines:
  - Text with explanations, pictures, diagrams, videos
  - Executable Python code
  - Figures



MPAcT erosion Notebooks

- Single document that combines:
  - Text with explanations, pictures, diagrams, videos… in a **non-technical language and with analogies**
  - Executable Python code that **is easy to read by users with limited coding skills**
  - **Interactive figures**

jupyter Fill_sinks Last Checkpoint: 1 hour ago

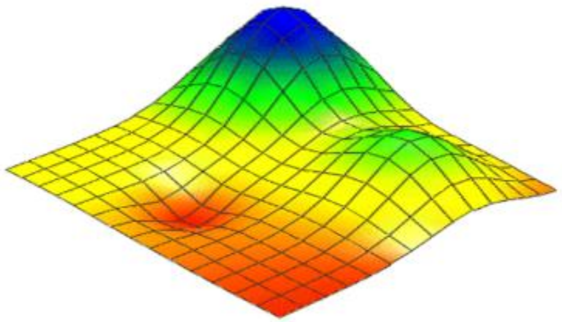
File Edit View Run Kernel Settings Help Trusted

Code JupyterLab Python 3 (ipykernel)

Fill sinks in a digital elevation model (DEM)

Filling sinks in a DEM is an important preprocessing step in hydrological and soil erosion modelling.

But what is a DEM? Imagine you have a map of a hilly area, like a model of a miniature landscape made out of LEGO pieces. Each lego piece represents a point on the terrain (i.e. a cell of the DEM), and its height corresponds to the elevation at that point. Some blocks are stacked higher, representing hills or mountains, while others are lower, representing valleys or plains. Now, imagine pouring water onto this LEGO terrain. Just like in real life, some spots might act like little bowls, where water collects because they're surrounded by higher LEGO blocks on all sides. These are our "sinks" - the places where water would naturally accumulate.



Why filling sinks is important? Sinks in a DEM represent areas where water can accumulate but not flow out. Filling sinks ensures a continuous and realistic representation of surface water flow, which is essential for hydrological modeling.

MPAcT erosion Notebooks

- Single document that combines:
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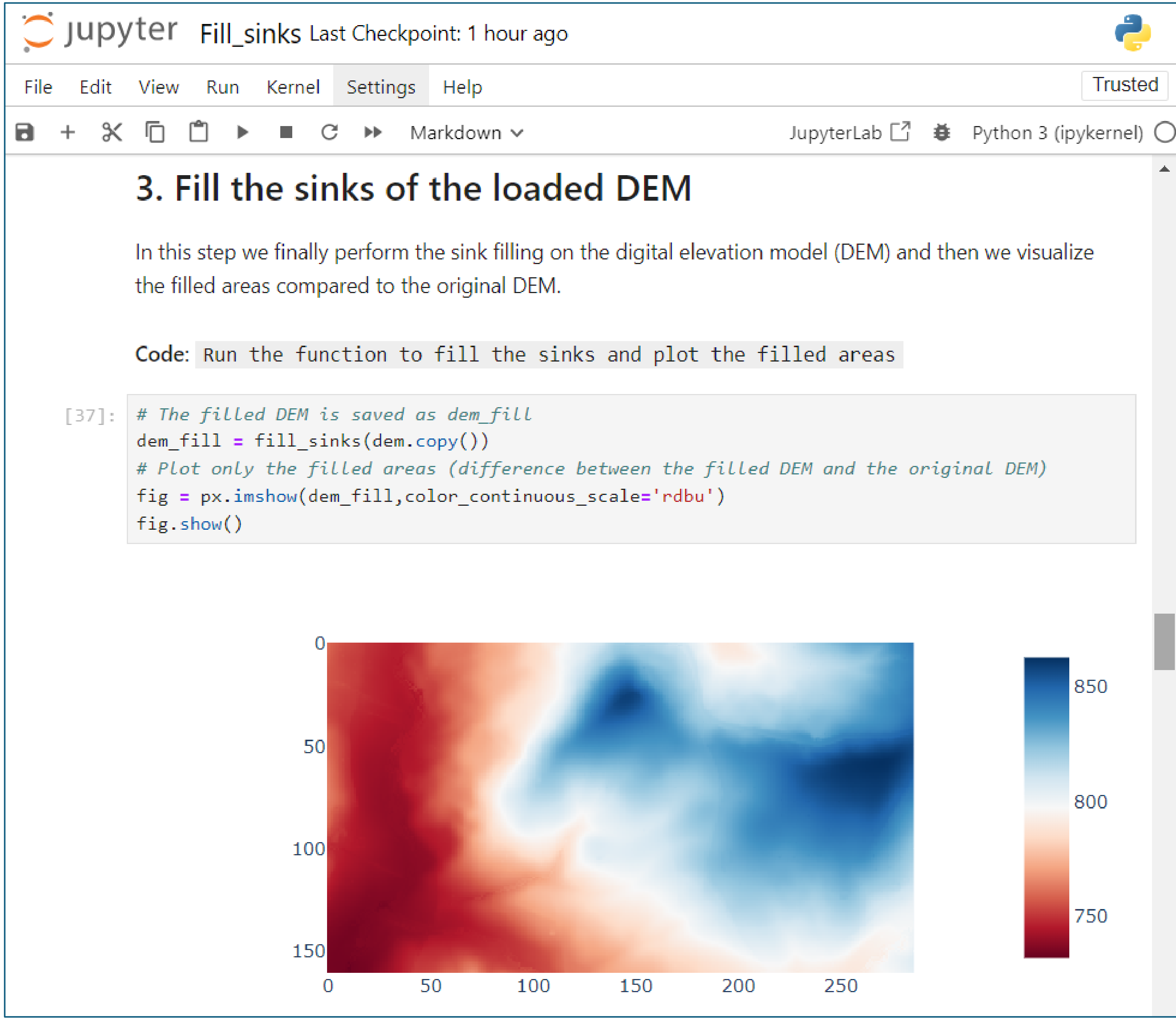
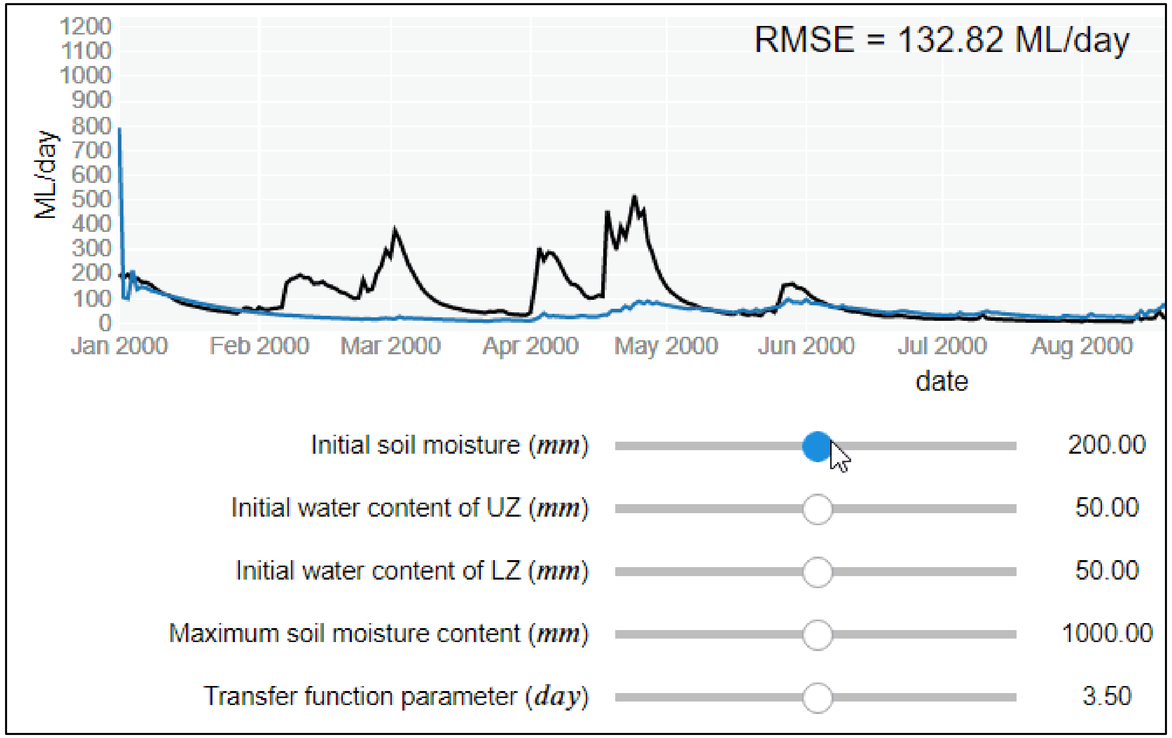
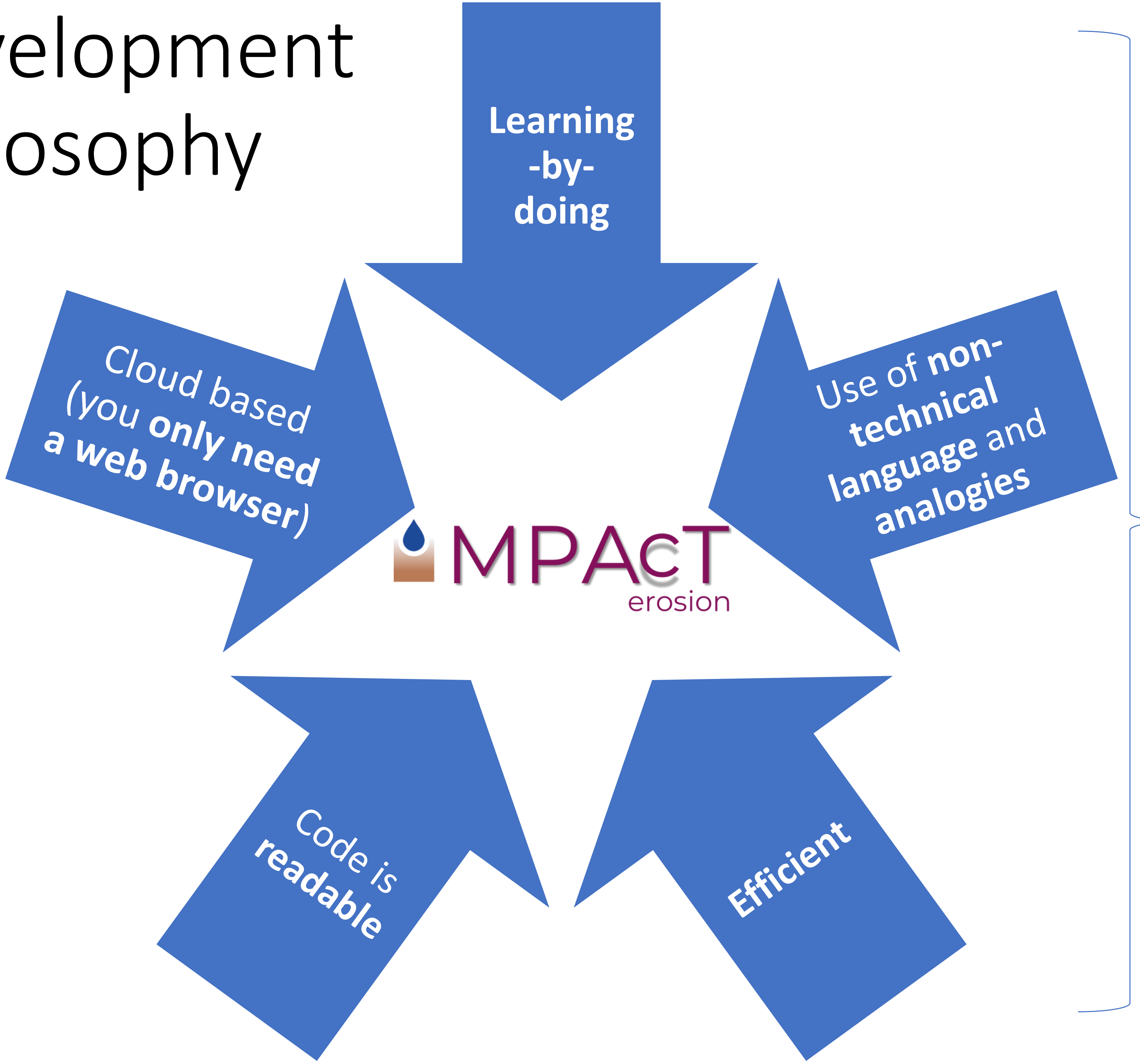


MPAcT erosion integrates interactive visualization

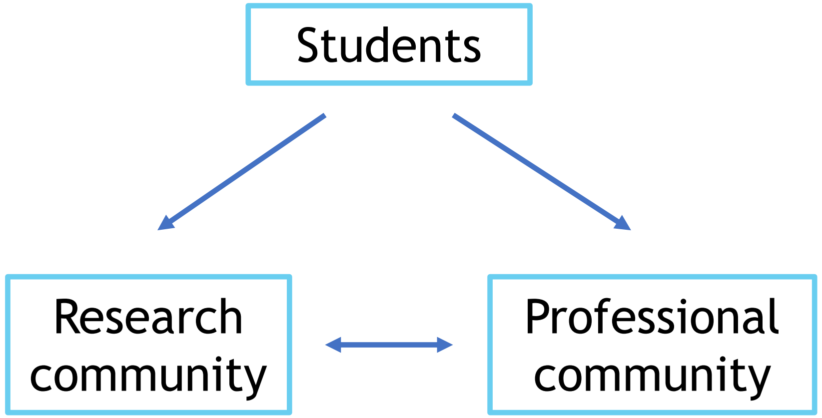
- **Reactive** figures + **intuitive** elements
- To make the Notebooks more **user-friendly**
- **No need to deal with code**
- To facilitate the **exploration** of model behaviour and results
- To facilitate the **communication** of technical concepts



Development philosophy



Accessible and useful to a wide range of users




Researchers &
modelling experts
MPAcT
erosion
Decision makers
Modelling
knowledge
Modelling
knowledge
System
knowledge
System
knowledge

A more **educational** and exploratory modelling approach to fill this gap

Researchers & modelling experts

Decision makers

Modelling knowledge

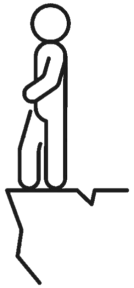
Modelling knowledge

System knowledge

System knowledge

A more **educational and exploratory** modelling approach to fill this gap

Researchers & modelling experts



Decision makers

Researchers & modelling experts		Decision makers
Modelling knowledge		Modelling knowledge
System knowledge		System knowledge

iMPACT-erosion.github.io

- Modelling terminology
- Model assumptions, limitations, uncertainties...
- First steps: fill sinks, flow accumulation, watershed delineation...

- Calibration and validation procedures
- Soil sampling optimization
- Reconstruction of soil erosion history
- Interpolation of spatial data
- Sensitivity analysis
- Uncertainty analysis...

- Future scenarios (climate, land use)
- Bias correction procedures
- Impacts
- Effectiveness of mitigation strategies
- Dynamic sensitivity analysis...

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This study is funded by the European Research Executive Agency (REA) under the HORIZON-MSCA2021-PF-01 grant agreement 101062258

Trusting-by-modelling