# Modelling exchanges between surface water reservoirs and groundwater in basement areas: Case of Kierma (Burkina Faso)

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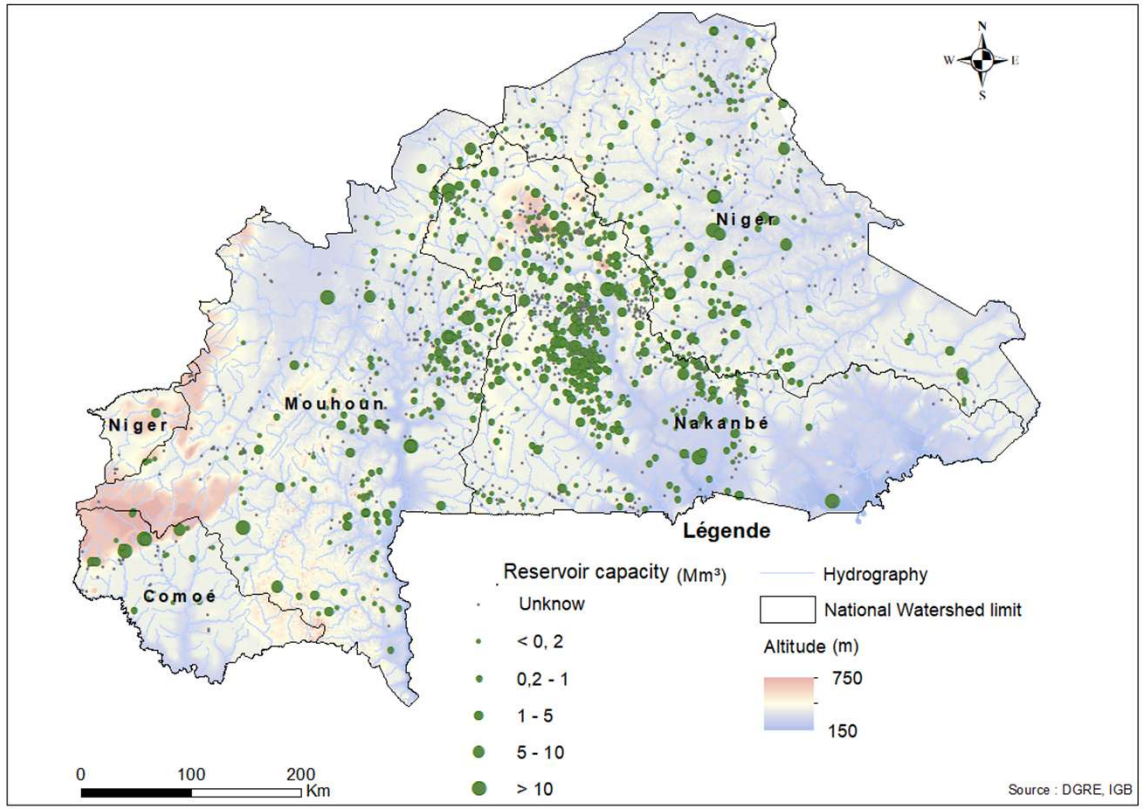
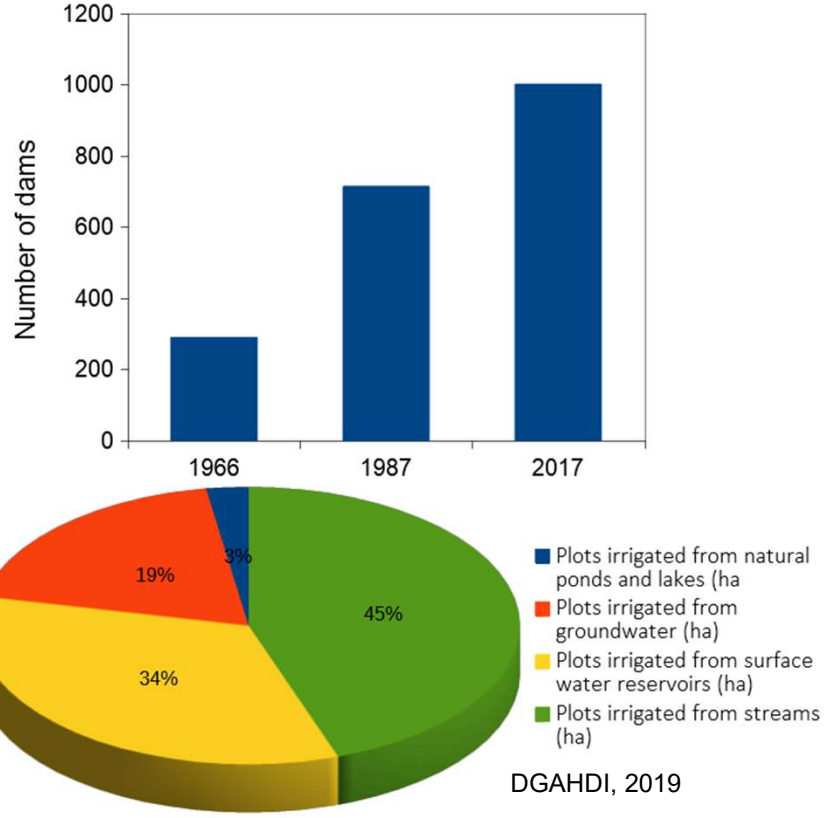
# General Context

Small-scale surface water reservoirs are essential for water storage in arid and semi-arid areas, particularly in Burkina Faso (subsistence farming = 80% of the population and 30% of GDP)




DGAHDI, 2019

# General Context


Financial losses for producers

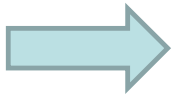
Increased exploitation of groundwater

# Questions

What solutions can be found to reduce the vulnerability of irrigators to the early drying up of surface water reservoirs?

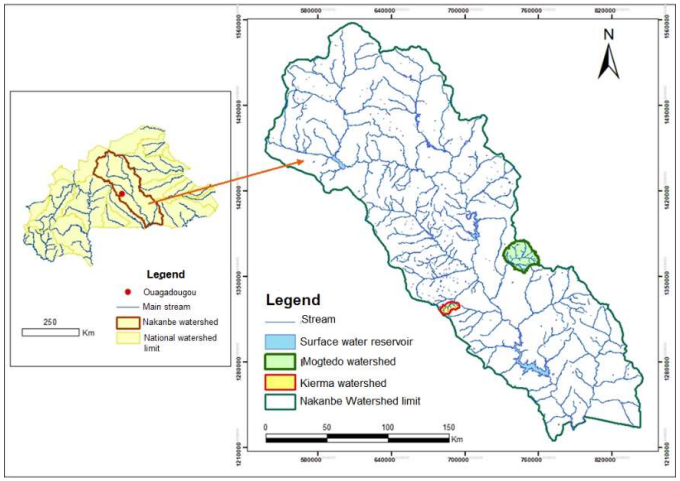
- ✓ More rational management of water in reservoirs?
- ✓ **What are the links between surface water reservoirs and groundwater?**
- ✓ **Can groundwater resources be used for supplementary irrigation?**
- ✓ How can reservoirs and groundwater resources be used together in an optimal way?

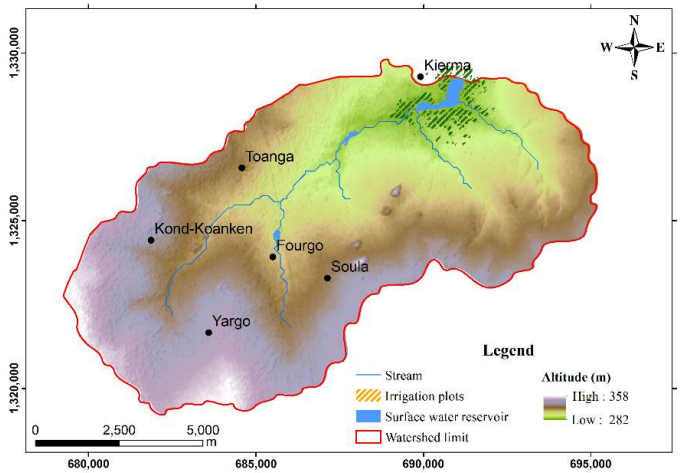
Applied research project financed by the Wallonie – Bruxelles International (Belgium regional cooperation) : PADI II, Commission Mixte Permanente WBI – Burkina Faso 2015 – 2017 : **Sustainable water management for irrigated agriculture**

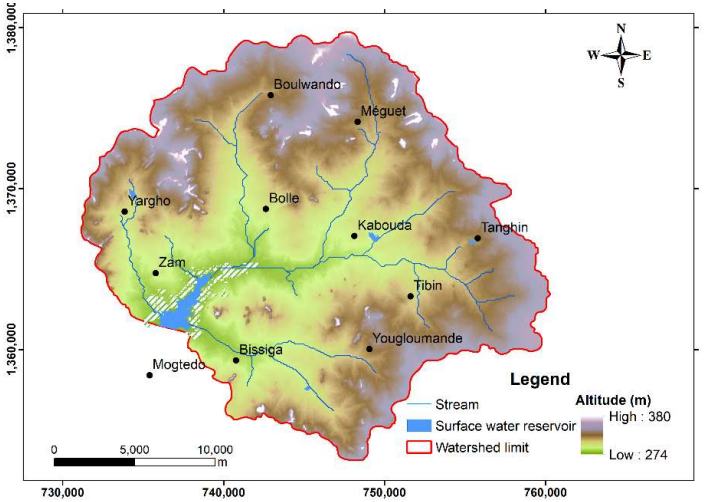


Characterisation and modelling of groundwater in the vicinity of small surface water irrigation reservoirs in crystalline basement areas

# Investigated catchments



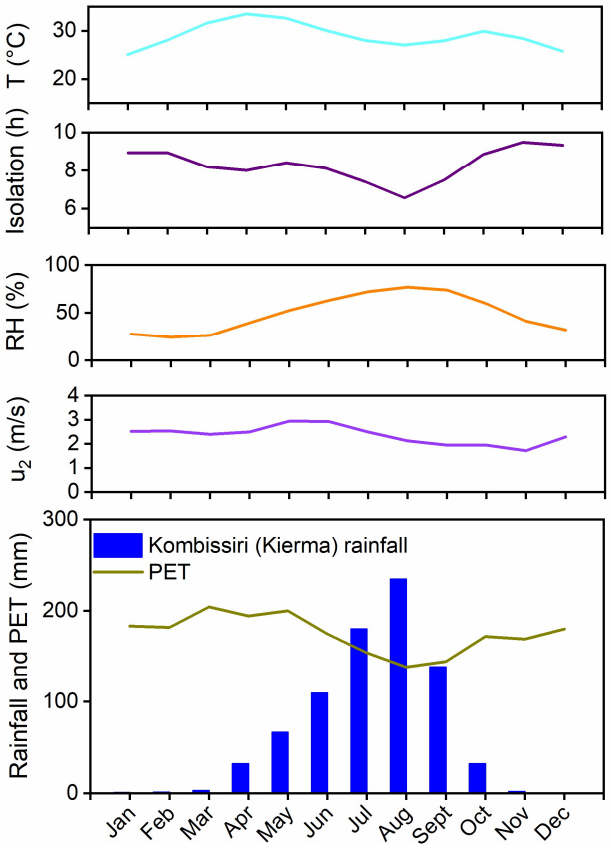



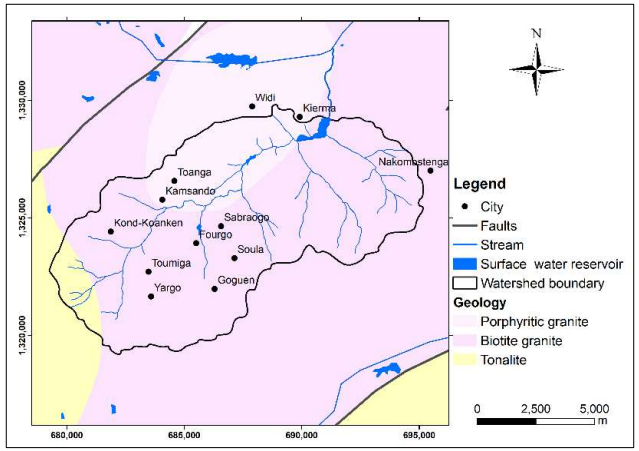




| | Kierma (1998) | Mogtédo (1963) |
|---|---|---|
| Storage capacity (m³) | 916 000 | 7 194 000 |
| Length of the dam (m) | 268 | 2 600 |
| Watershed surface (km²) | 100 | 500 |
| Irrigated plots (ha) | 80 | 430 |

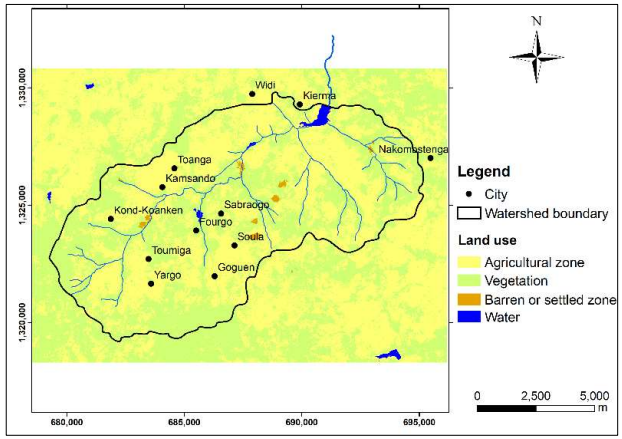
# General context of the Kierma catchment

## Climate

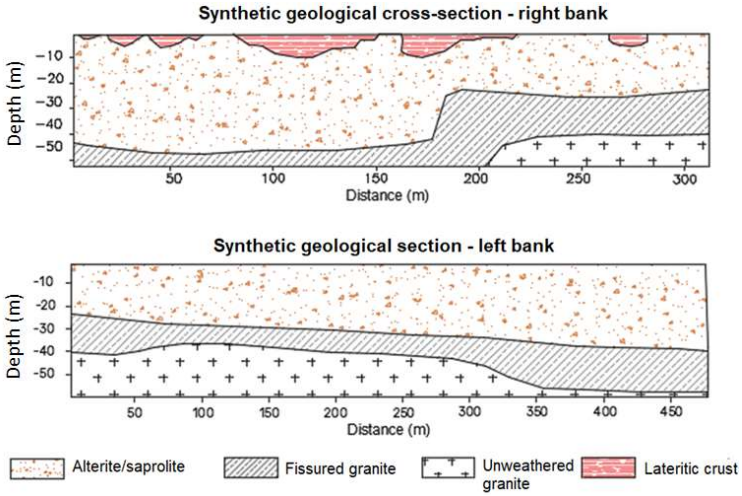



## Landuse




## Geology

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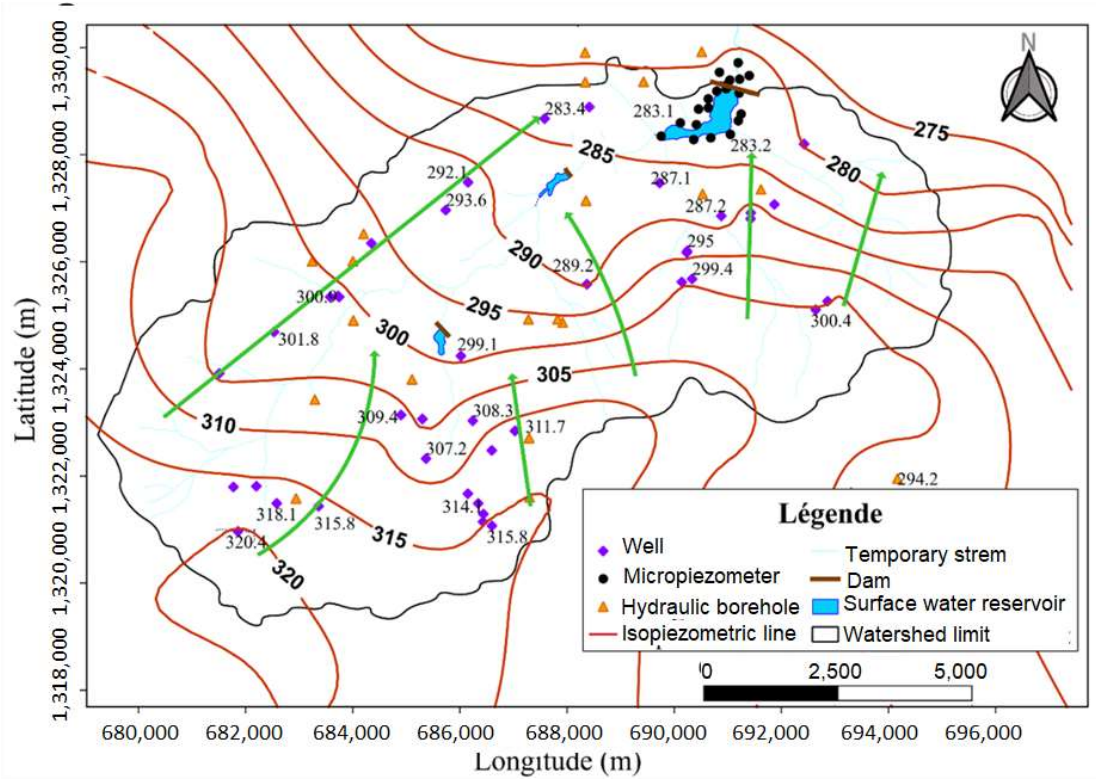
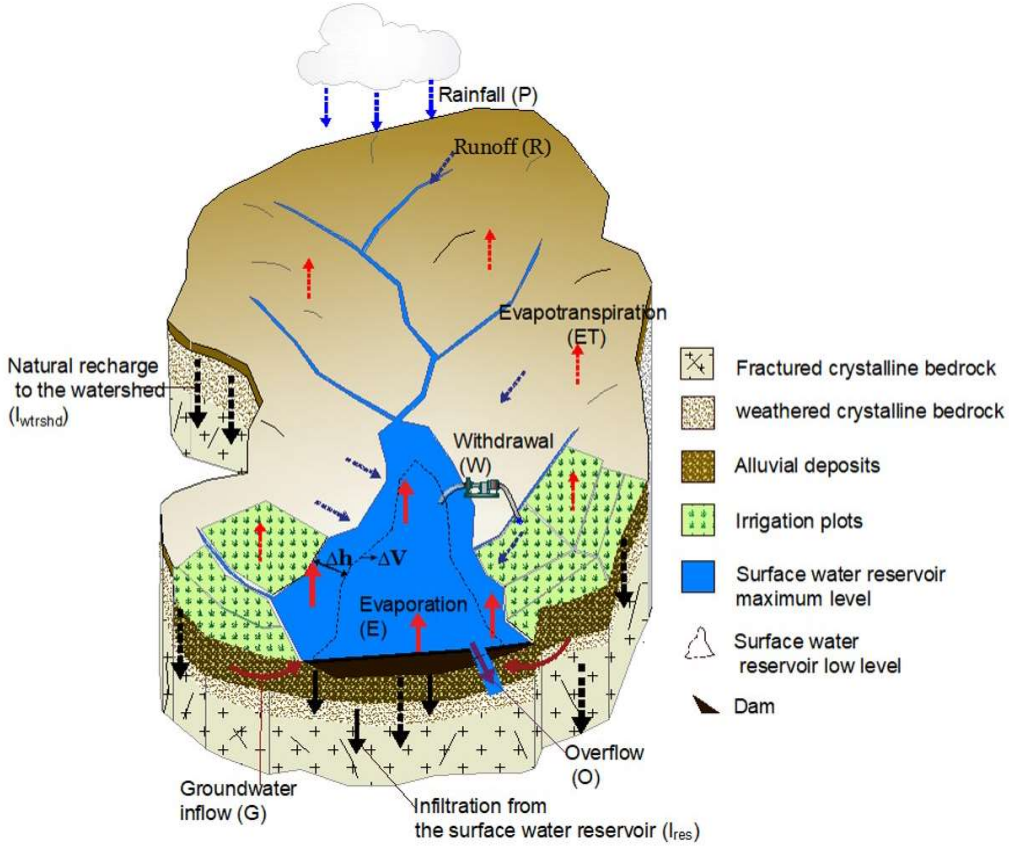
# General context of the Kierma catchment

## Watershed hydrogeology




## Conceptual model

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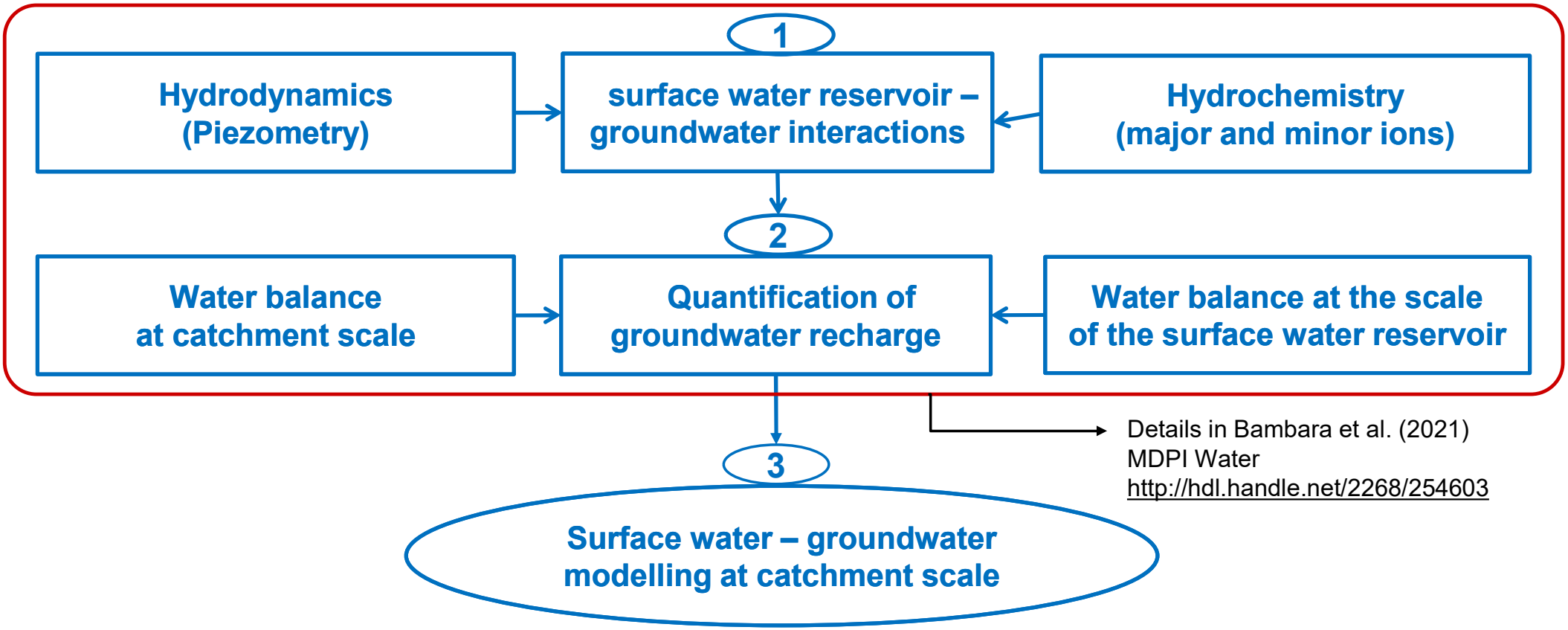
# Methodology



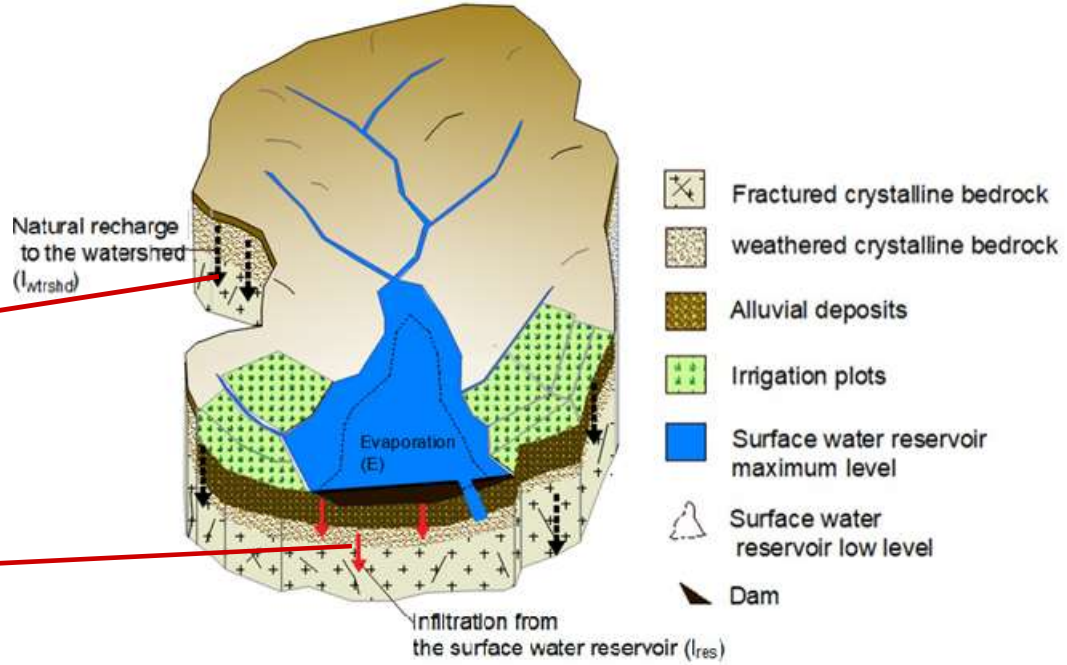

Details in Bambara et al. (2021)
MDPI Water
http://hdl.handle.net/2268/254603

# Objectives of surface water – groundwater modelling

**Water balances resulting from field investigations**

Catchment scale mean groundwater recharge:
**82 mm/year**

Local scale infiltration from Kierma surface water reservoir:
**1350 ± 540 mm/year**

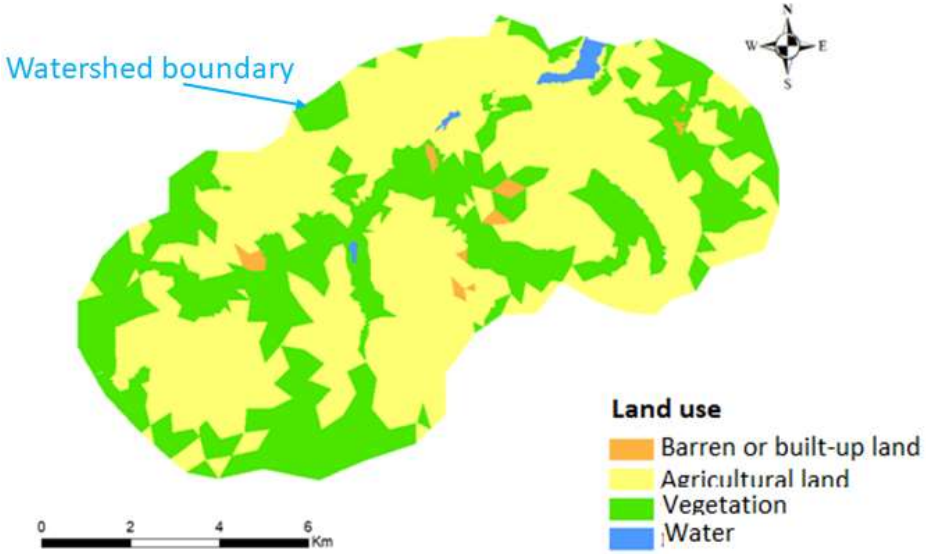


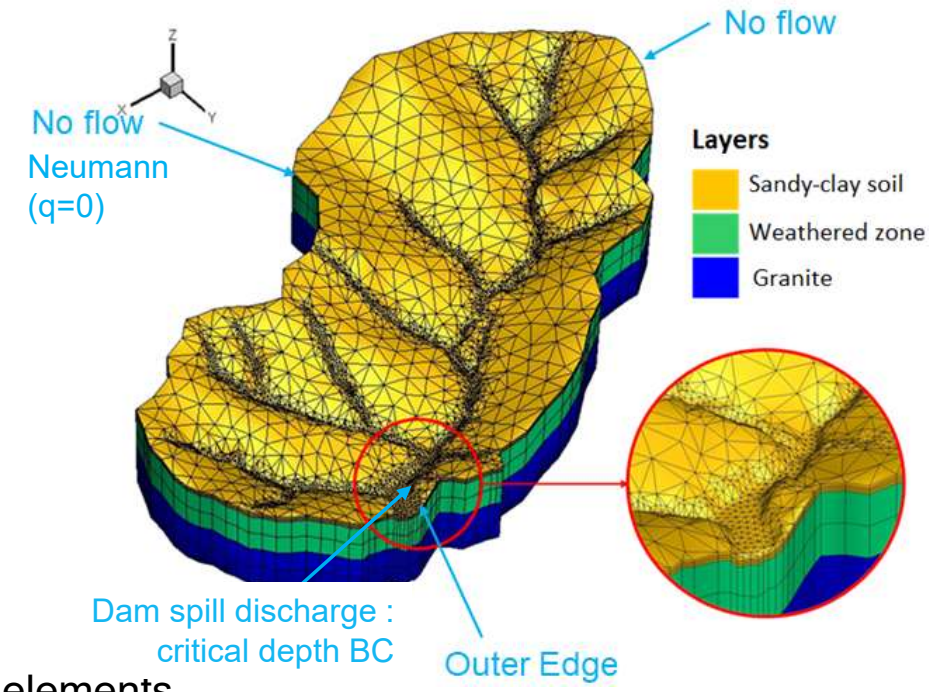

➔ Significant local groundwater recharge but interesting to develop an integrated surface water – groundwater modelling in order to integrate all the information available, improve the understanding of the groundwater catchment and validate the results of the investigations

# Surface water – groundwater modelling using HydroGeoSphere

**HydroGeoSphere Hydrological Model – HGS (Therrien et al. 2010)**

- 3D solution of groundwater flow with variable saturation coupled 2D solution of surface water flow
- Recharge and evapotranspiration calculations integrated with the simulation of groundwater and surface water flows, flows exchanged between rivers and reservoirs and groundwater




**2D surface model :** 3392 nodes and 6664 éléments

**3D subsurface model :** 7 layers, 27136 nodes and 46648 elements

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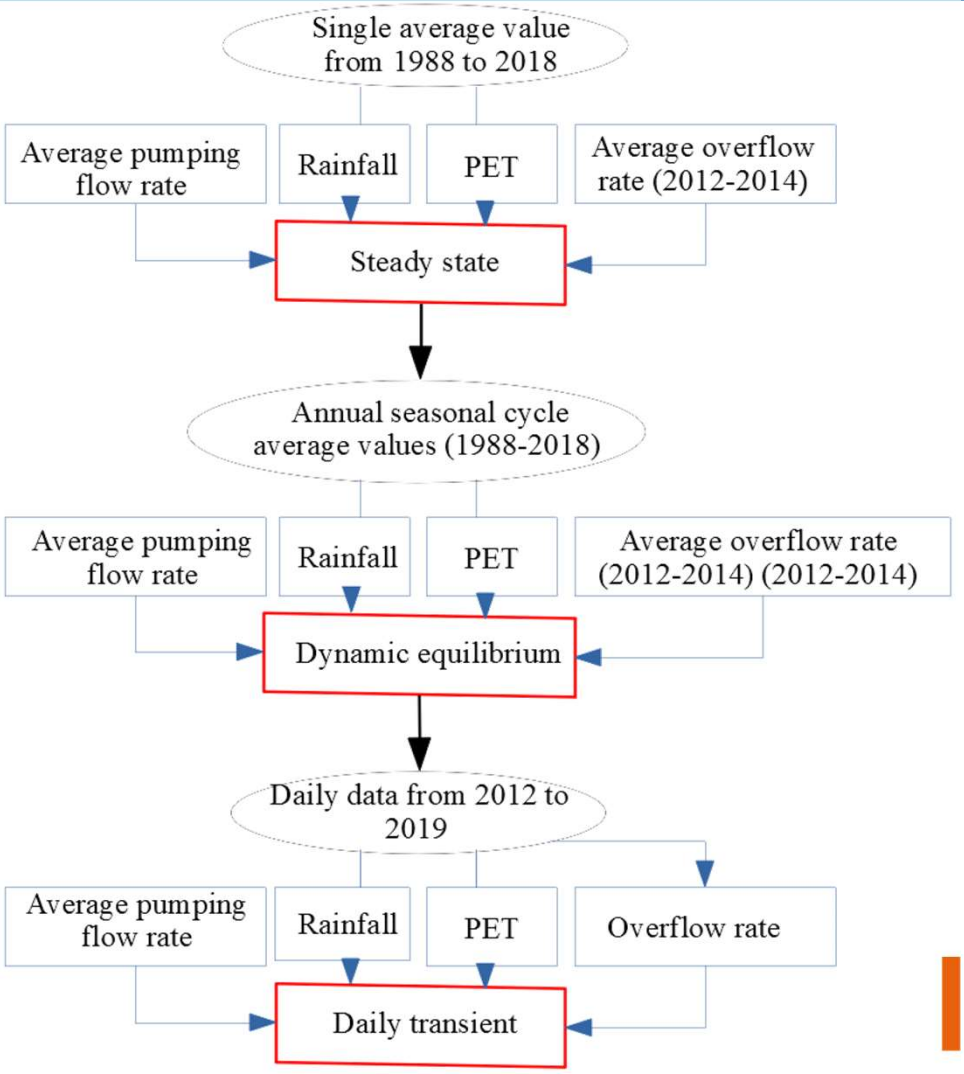
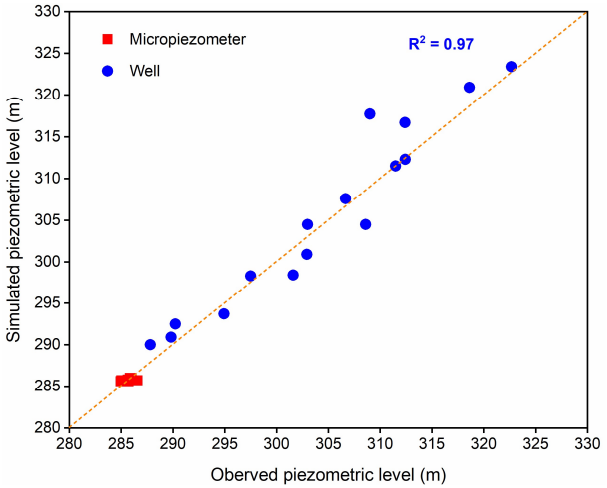
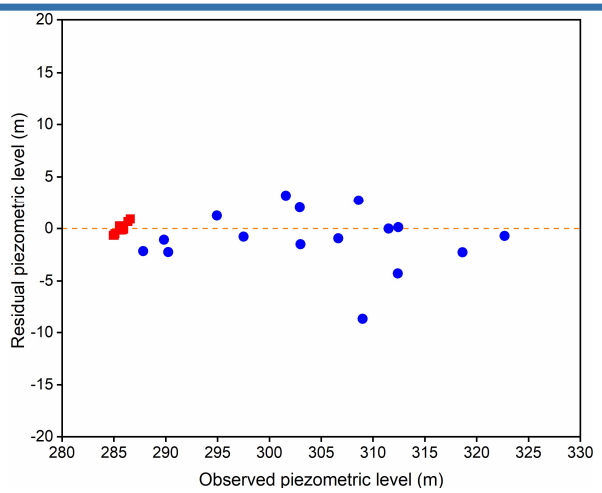
# Calibration procedure



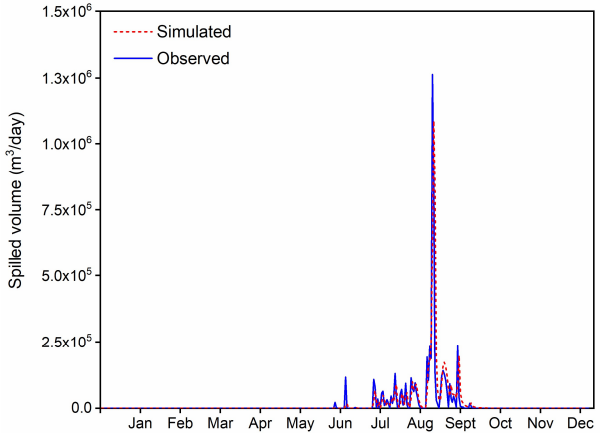
# Calibration : steady state vs dynamic equilibrium

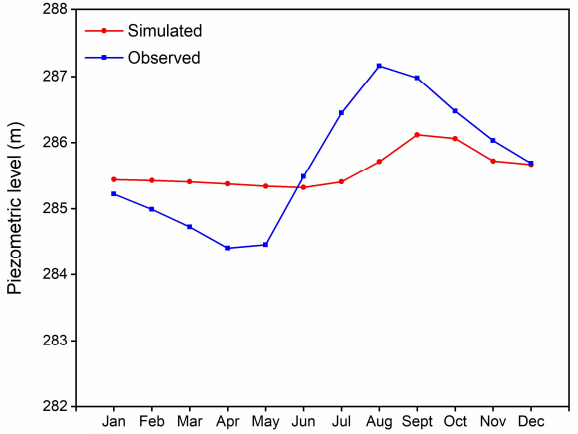



**Steady state model**

**Dynamic equilibrium model**

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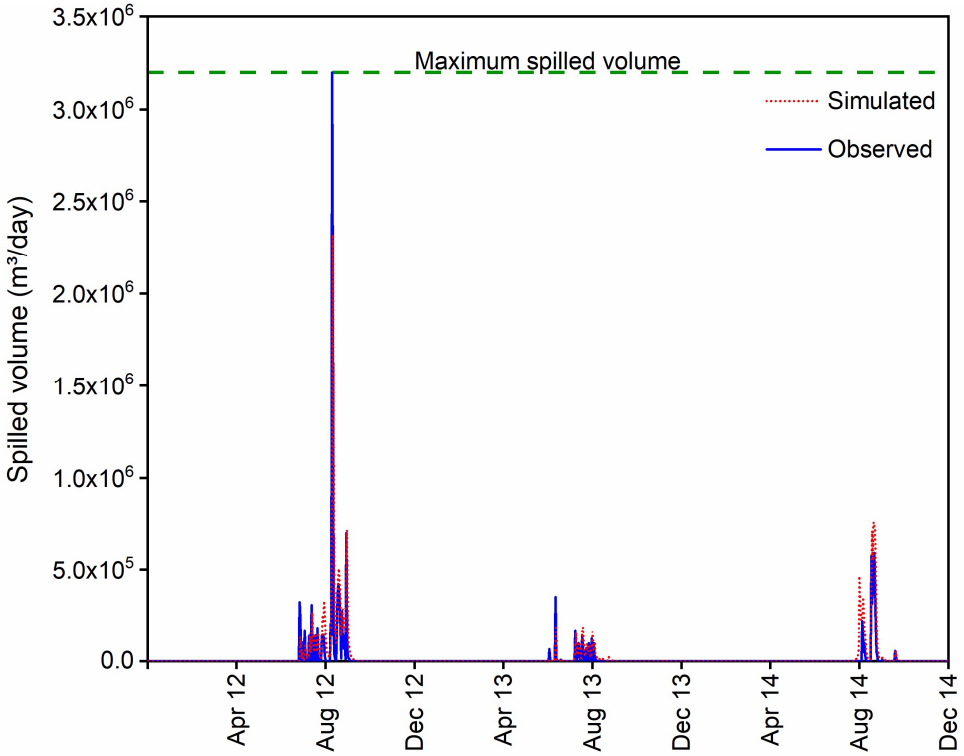
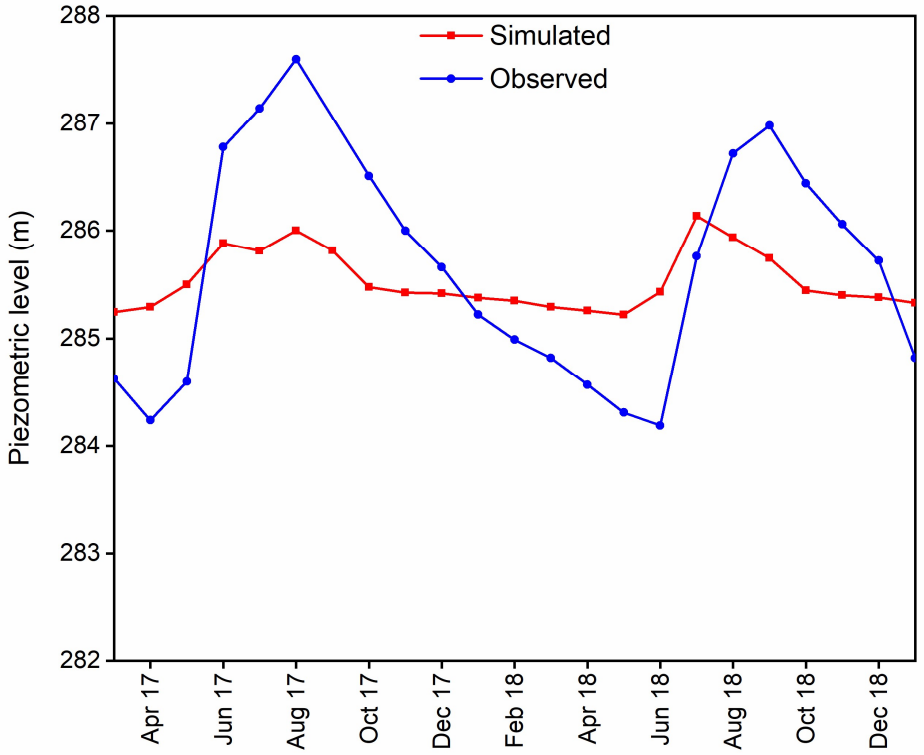
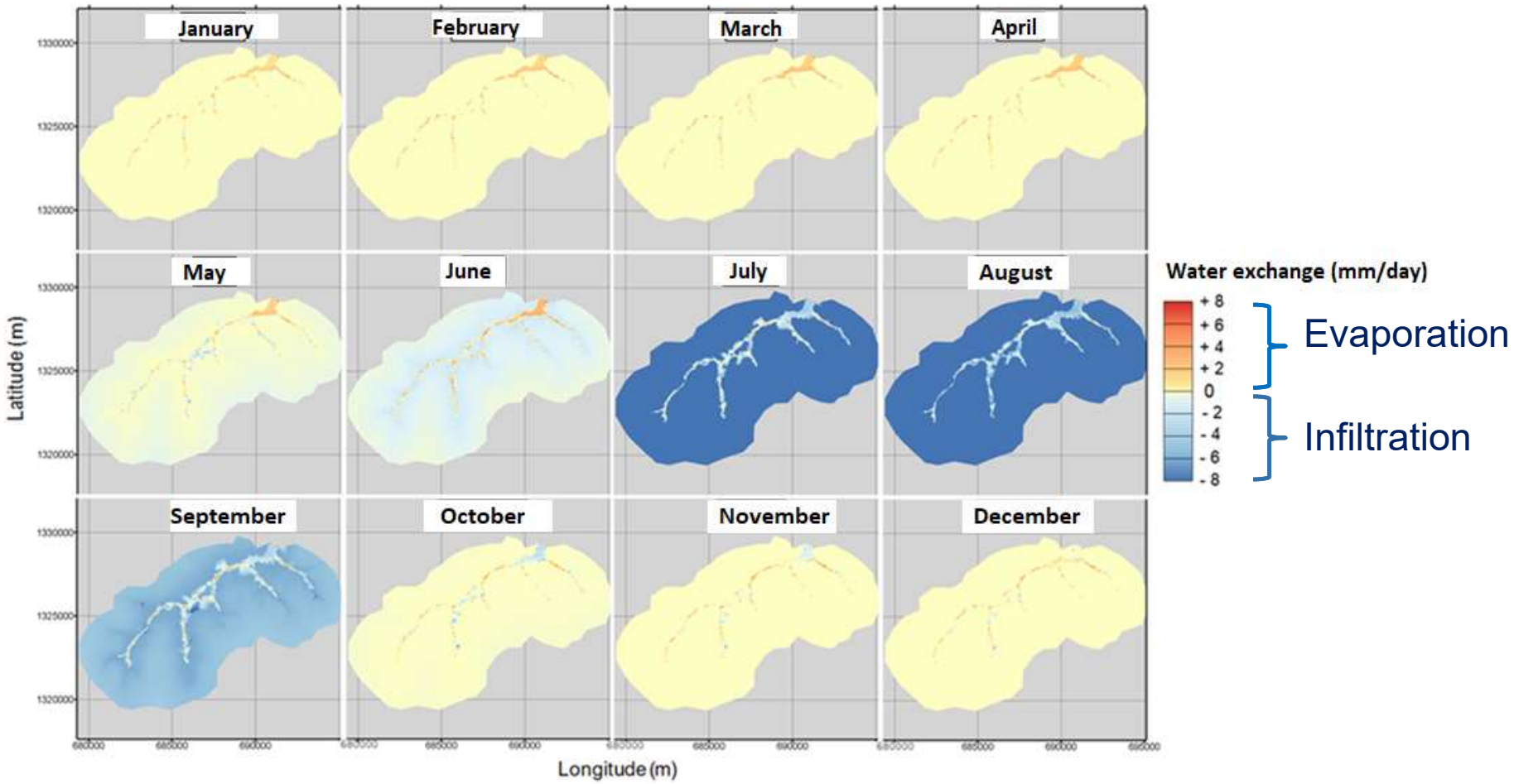
# Calibration : transient state

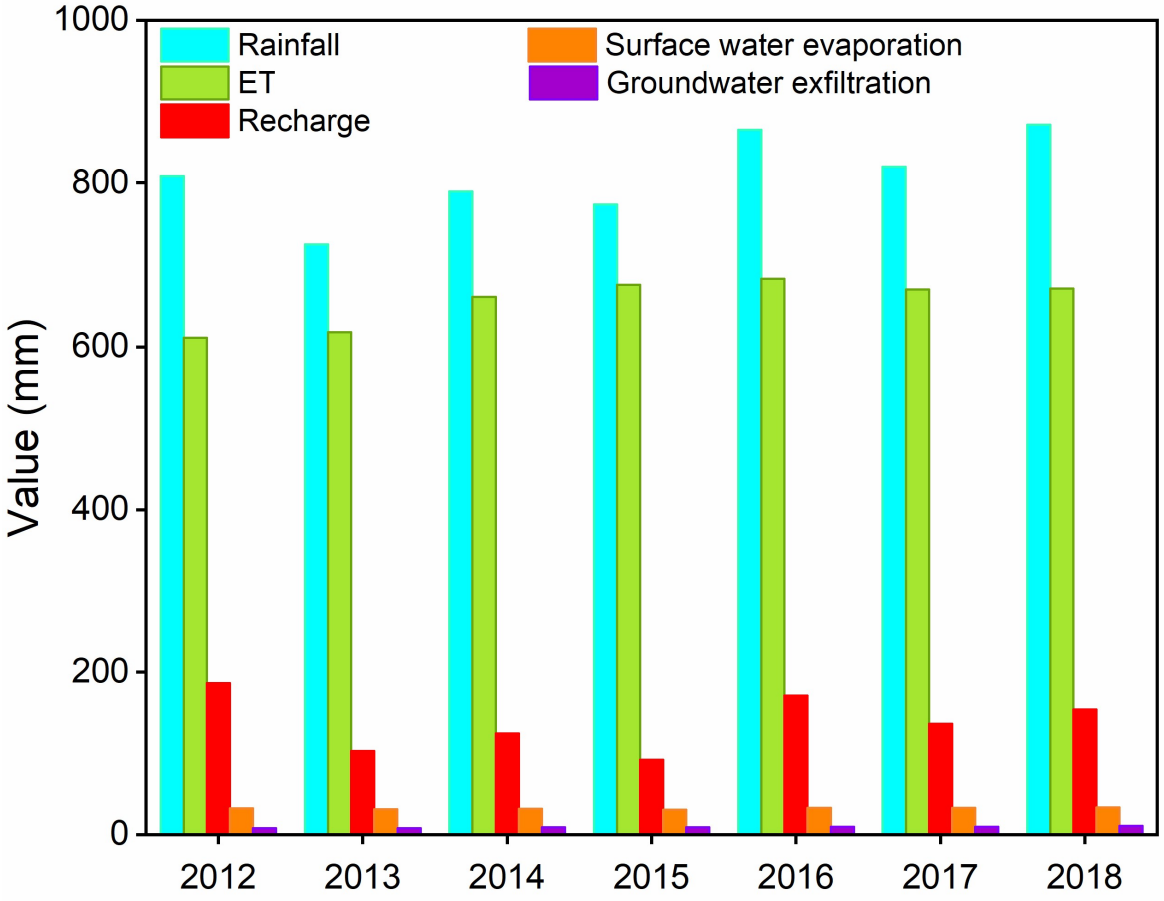


# Modelling results : groundwater surface water exchanges



# Water balance : modelling results vs field investigations




**Mean catchment scale recharge:**

- HGS model : 144 mm/year
- Water budget : 82 mm/year

**Mean focused recharge:**

- HGS model : 504 mm/year
- Water budget : 1530±540 mm/year

# Conclusions & Perspectives

Modelling results with HGS able to reproduce satisfactorily field observations, particularly in terms of global discharge rates at the dam level, a bit less in terms of amplitudes of piezometric variations

Recharge estimates from HGS slightly differ from calculated based on on field investigations, but results are on the same order of magnitude, at both scales of the catchment and surface water reservoir

From an operational point of view, groundwater in the vicinity of the surface water reservoir is significantly recharged and it is expected the use of groundwater for supplemental irrigation can reduce the vulnerability of irrigators to the early drying up of water reservoirs

HGS model could be used in the future to run scenarios of groundwater exploitation through pumping wells and sumps

# Thank you for listening! Any questions?

Acknoweldgement:
Wallonie – Bruxelles International for financing the project and PhD thesis of Apolline Bambara
DGADI Burkina Faso for continuous support during field investigations

# Further reading


- Bambara, A. (2021), Caractérisation et modélisation des nappes d'eau souterraine au voisinage de petites retenues d'eau d'irrigation en zone de socle : cas de Kierma et de Mogtédo, Burkina Faso (*Characterisation and modelling of groundwater in the vicinity of small irrigation reservoirs in the basement zone: the cases of Kierma and Mogtédo, Burkina Faso),* PhD thesis, University of Liège, Faculty of Engineering, Urban and Environment Engineering, 291p (http://hdl.handle.net/2268/255500)

- Bambara, A., Orban, P., Ouedraogo, I., Hallot, E., Guyon, F., Zangré, A., Brouyère, S. (2020), Quantifying focused groundwater recharge induced by irrigation surface water reservoirs in crystalline basement areas for complementary irrigation, Water 2020, 12, 2880; doi:10.3390/w12102880 (http://hdl.handle.net/2268/254603

# Slides for any questions

**Tableau VII-6.** Estimation des débits du puits, des besoins en eau des cultures et de la surface irrigable

| | Paramètres | Minimum | Q1 | Médiane | Q3 | Moyenne | Maximum |
|---|---|---|---|---|---|---|---|
| **Kierma** | K (m/jour) | 0.01 | 0.02 | 0.1 | 0.2 | 0.2 | 2 |
| | Q ($m^3$/jour) | 0.6 | 1 | 6 | 12 | 12 | 120 |
| | Besoins en eau des cultures ($m^3$/ha/jour) | 54 | | | | | |
| | Surface irrigable ($m^2$/jour) | 100 | 200 | 1000 | 2200 | 2200 | 22300 |
| **Mogtédo** | K (m/jour) | $1\times10^{-4}$ | $9\times10^{-4}$ | $1\times10^{-3}$ | $3\times10^{-3}$ | 0.01 | 0.2 |
| | Q ($m^3$/jour) | 0 | 0.1 | 0.1 | 0.2 | 1 | 10 |
| | Besoins en eau des cultures ($m^3$/ha/jour) | 56 | | | | | |
| | Surface irrigable ($m^2$/jour) | 0 | 15 | 15 | 25 | 120 | 1800 |

Q1 : premier quartile et Q3 : troisième quartile