

Rethinking Water Use Impact Assessment: A Novel Multimedia Fate Model Covering the Full Water Balance

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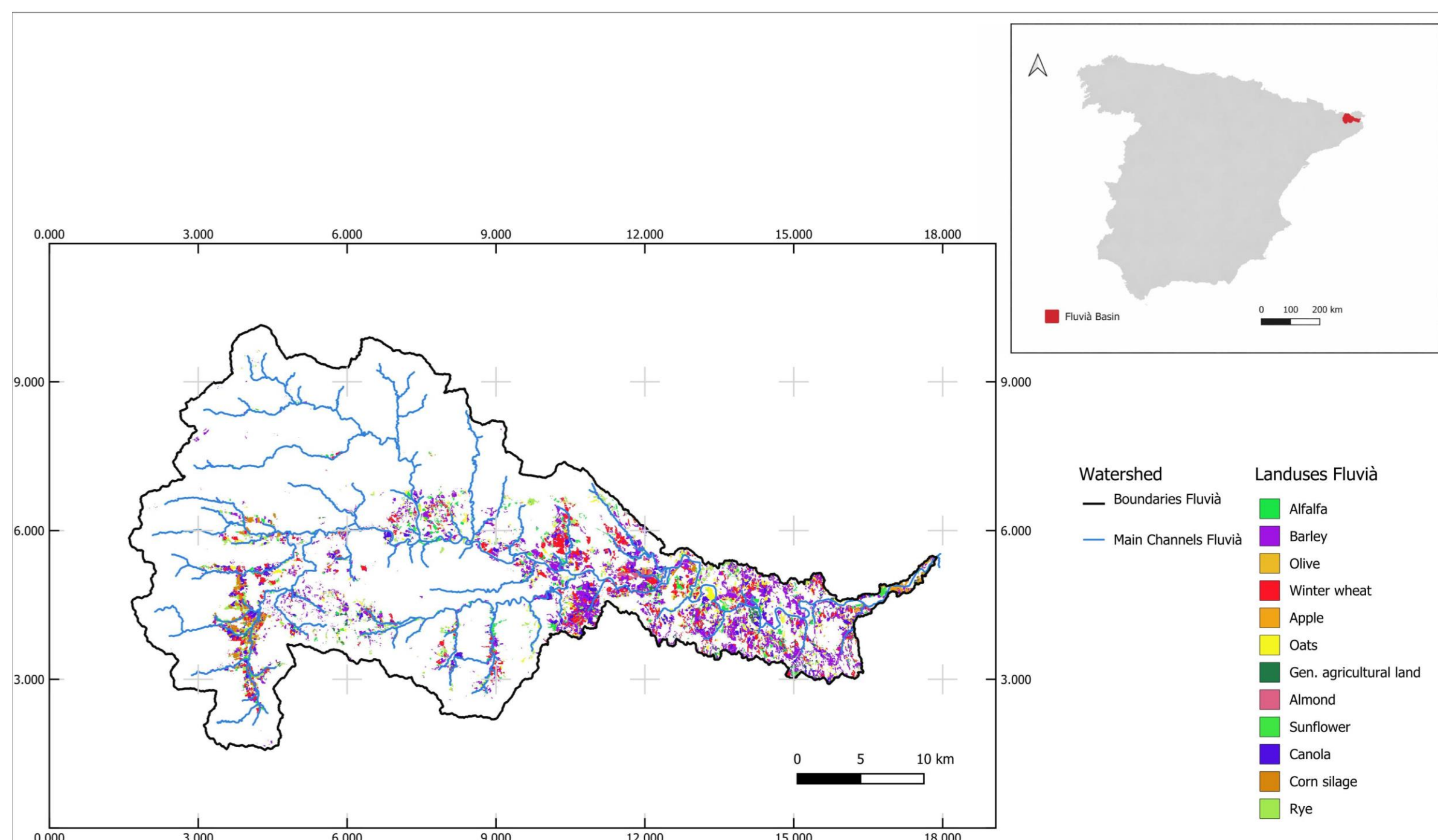
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INTRODUCTION

- Green water (rainwater stored in soil) supplies ~75% of agricultural water use.
- LCA and water footprint (WF) methods only address blue water (surface and groundwater).
- **Excluding green water reduces assessment accuracy and completeness**, particularly in agriculture and in the quantification of ecosystem quality damages.

OBJECTIVE

- (1) Include soil water consumption (LCI) and its associated impacts (LCIA) in LCA
- (2) Integrate all water sources (surface, ground, and soil water) within a single LCA methodology
- (3) Set up pilot watershed to develop LCI data and FFs
- (4) Distinguish impacts from different farming practices in the pilot watershed



1. Proof-of-concept watershed Fluvià in the NE of Spain. Coloured areas represent agricultural land uses in the watershed while white areas represent non-agricultural land uses.

MATERIALS AND METHODS

Study Area:

- Fluvià watershed (Catalonia, Spain), Figure 1

Modeling Details:

- SWAT+ (Soil and Water Assessment Tool Plus)
- Simulation period: 2013-2023
- Spatial resolution: Hydrological Response Units (HRU), based on land uses

Outputs:

- Water balance, crop yield, aquifer and channel variables at different time steps

Fate Factor (FF) Concept:

- FFs: Inverse of rate constants (k^{-1}); represent steady-state hydrology. k mainly from SWAT+ outputs
- FF matrix: for a given column i , values represent the water volume in each compartment j (m^3) resulting from a unit extraction or release in compartment i ($m^3/month$), Table 2
- Temporal resolution (FFs): average monthly and average annual

RESULTS AND DISCUSSION

Results for total crop water consumption (blue + green water), average annual (2013-2023) in $m^3 t^{-1}$

	Default*	No irrigation	No fertilizer	Full irrigation
Alfalfa	166.6	159.77	163.46	164.09
Almond	12895.7	12890.35	13335.85	12899.46
Apple	175.89	177.70	177.70	181.26
Barley	1146.73	1236.36	1300.51	1242.29
Agricultural area, gen.	3100.49	3821.81	3821.89	3783.42
Corn silage	347.33	326.16	334.58	325.1
Oats	2030.09	2306.67	2383.34	2317.56
Olive	4709.1	4747.03	4857.35	4860.22
Rapeseed	2659.6	2534.12	2568.13	2523.18
Rye	1631.7	1592.2	2158.33	1629.05
Sunflower	1531.53	3170.66	3283.46	3063.3
Wheat	1870	2058.20	2185.01	2059.35

Table 1. Total crop water consumption (m^3 water t^{-1} crop yr^{-1}) for selected crops in the Fluvià watershed * Current conventional agricultural practices

LCI level:

- No fertilizer generally leads to the highest water consumption.
- No irrigation and full irrigation show similar patterns, with moderate increases for cereals (barley, oats, wheat).
- Sunflower shows the strongest sensitivity to scenarios ($\approx 1,532$ default vs. $>3,000$ in alternative scenarios).

FF matrix (months)

	Air	Soil	GW	SW	Veg
Air	0.19	0.19	0.19	0.19	0.19
Soil	0.62	15.64	15.6	14.74	0.62
GW	4.1	77.48	202.6	191.1	4.1
SW	0.01	0.21	0.23	0.72	0.01
Veg	0.006	0.05	0.05	0.047	0.12

Table 2. Fate factors (FFs) for April (avg results for the study period 2013-2023). Similar tables were developed for the remaining months and for the annual average. GW: groundwater; SW: surface water; veg: vegetation

LCIA level:

- Groundwater: Longest residence (~ 203 months); dominant storage. Strong $GW \rightarrow Soil$ and $GW \rightarrow SW$ coupling shows depletion affects other compartments over multi-year timescales.
- Vegetation & Air: Very short residence (< 0.2 months), rapid cycling. Soil (~ 16 months) provides intermediate buffering between fast and slow pools.

CONCLUSIONS

- SWAT+ provides both vertical water balance data for LCI (crop water consumption at HRU scale) and horizontal water balance data for LCIA (FFs at watershed scale).
- Combining LCI data and FFs enables the integrated assessment of all water sources for the first time