Alfalfa Intercropped with Corn & Sunflower Provides Profitable Ecosystem Services in Alfalfa's Establishment Year

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Environmental benefits of perennial crop production and cropping systems:

BAU: Only single annual crop.

BAU-improved: More the one annual crop in a cropping system.

Perennial: Perennial crop production system(s).

Perennial Systems:

- ✓ Reduced terrestrial acidification, ecotoxicity, eutrophication potentials (Figure 1).
- ✓ More prominent reduction in ecosystem quality variables.

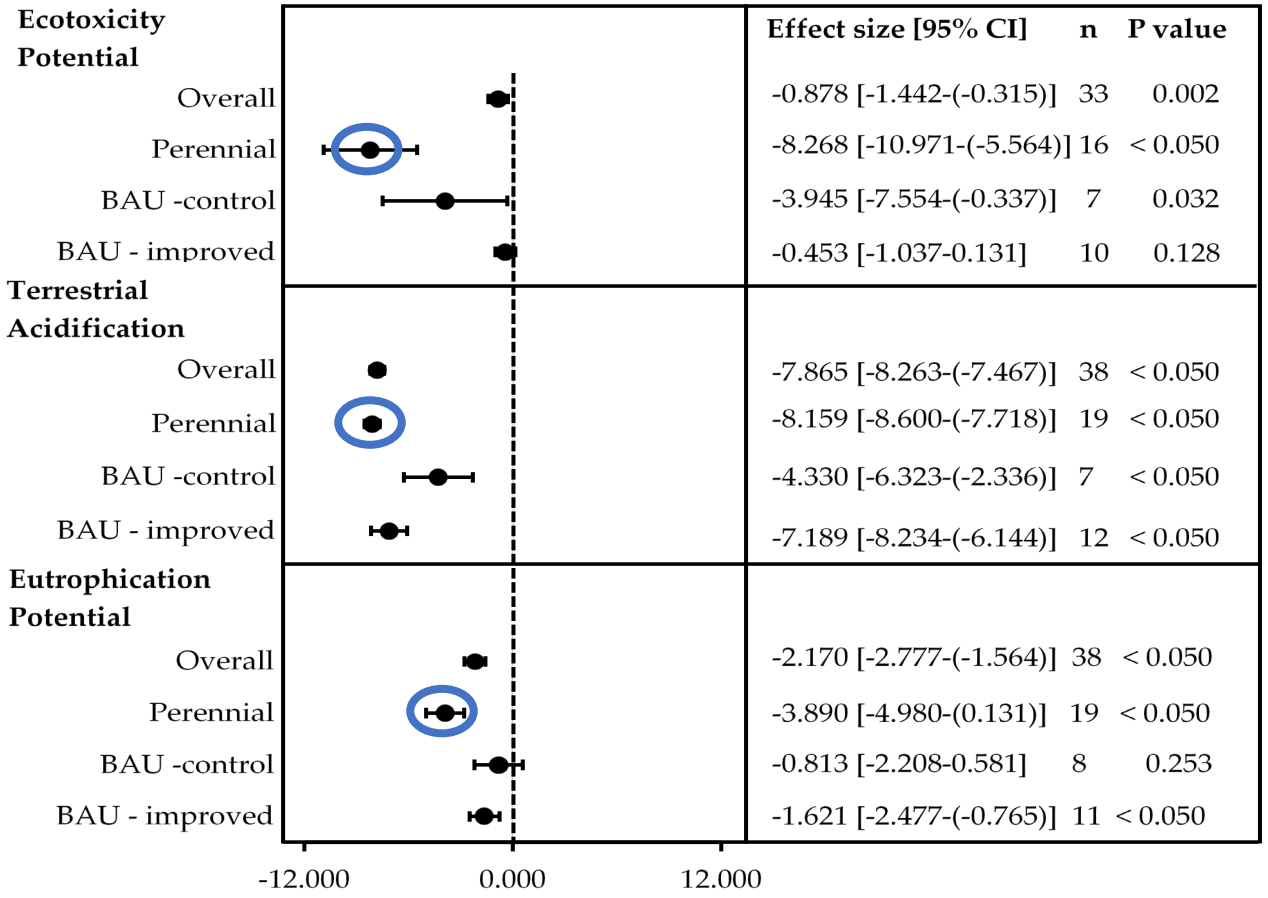

Figure 1. Effect size of cropping systems on impact categories of ecotoxicity potential, terrestrial acidification, and eutrophication potential.

(Igboke et al., 2024)

Main Objective: Compare alfalfa intercropped with corn or sunflowers at two row spacings, with spring-seeded alfalfa alone in a two-years system.

Specific Objectives are to determine:

- Corn and oilseed sunflower yield.
- Alfalfa forage yield and nutritive value.
- Effects of rainfall, soil NO_3-N, and soil gravimetric water.
- Profitability of establishing alfalfa with corn and oilseed sunflower.
- Environmental impact assessment using SimaPro software and DNDC model.

METHODOLOGY

- **Randomized complete block design for cropping systems**
- **Environmental impact assessment using SimaPro software and DNDC model:**
  - **Life cycle assessment (LCA): Cradle to Farm-gate**

LCA — Emissions to air, water, and soil — Functional unit (kg, MJ, and ha)

Carbon Intensity — Mostly emissions to the air (Global warming potential)

SimaPro Software — Eutrophication, terrestrial acidification, ecotoxicity, ozone layer depletion, fossil energy consumption, and abiotic depletion potential.

(Igboke *et al.*, 2024)

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Limitation of Excel calculation: It only estimates emission to air.

GREET Software: Same as Excel.

SimaPro

Estimates emission to:

- Air
- Water
- Soil

DNDC MODEL

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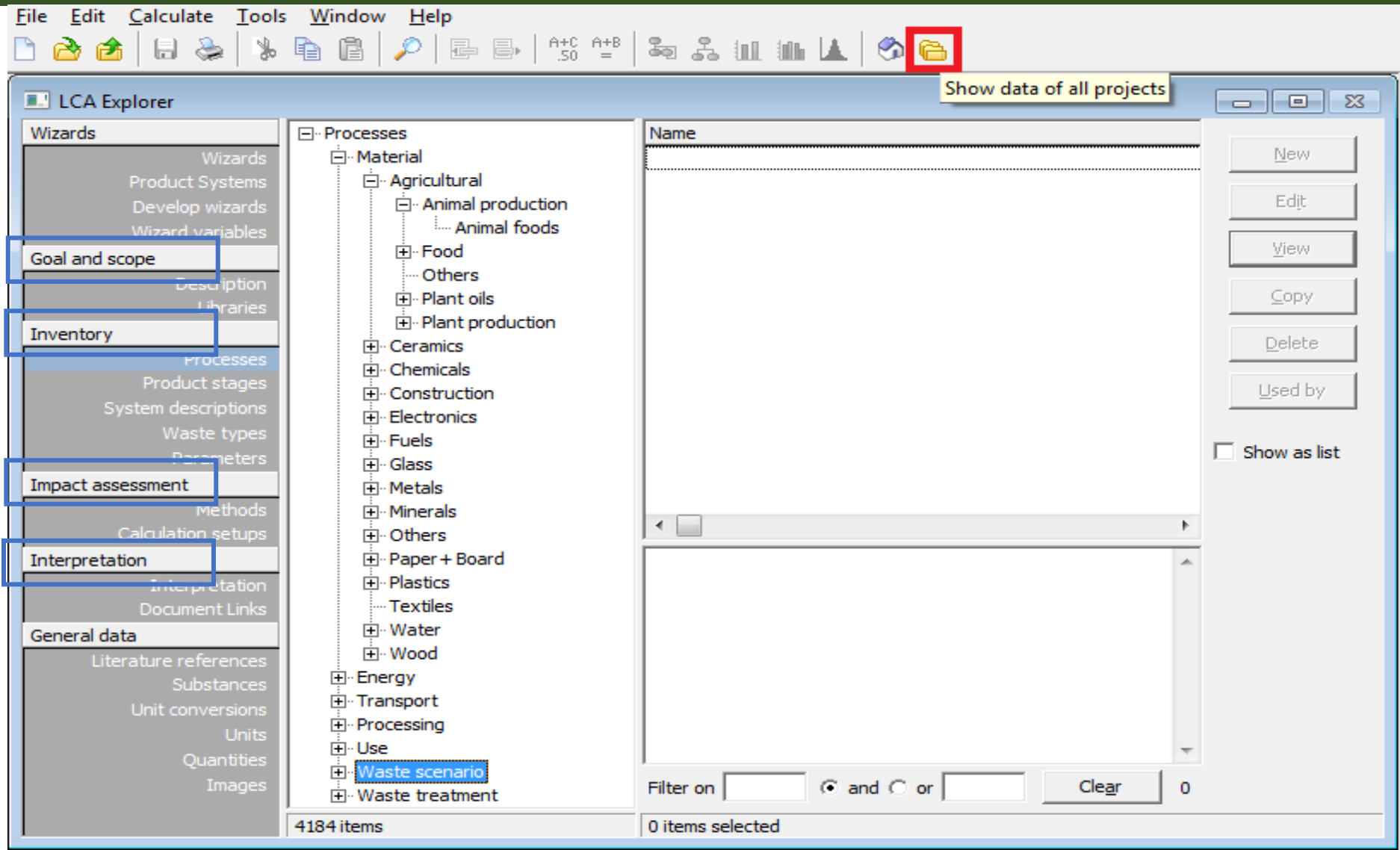
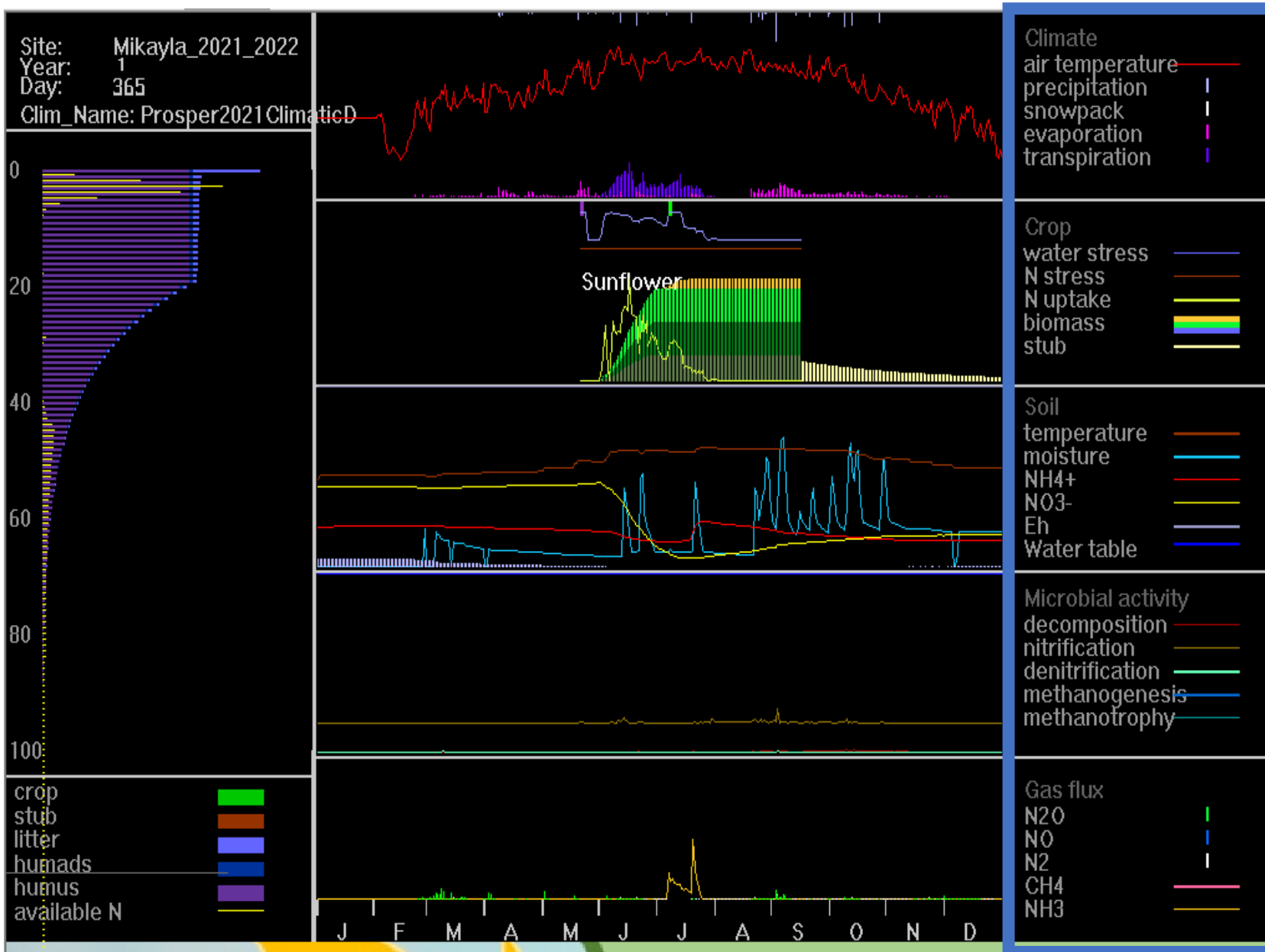


The Denitrification-Decomposition (DNDC) model

- A process-based computer simulation model.

Simulates:

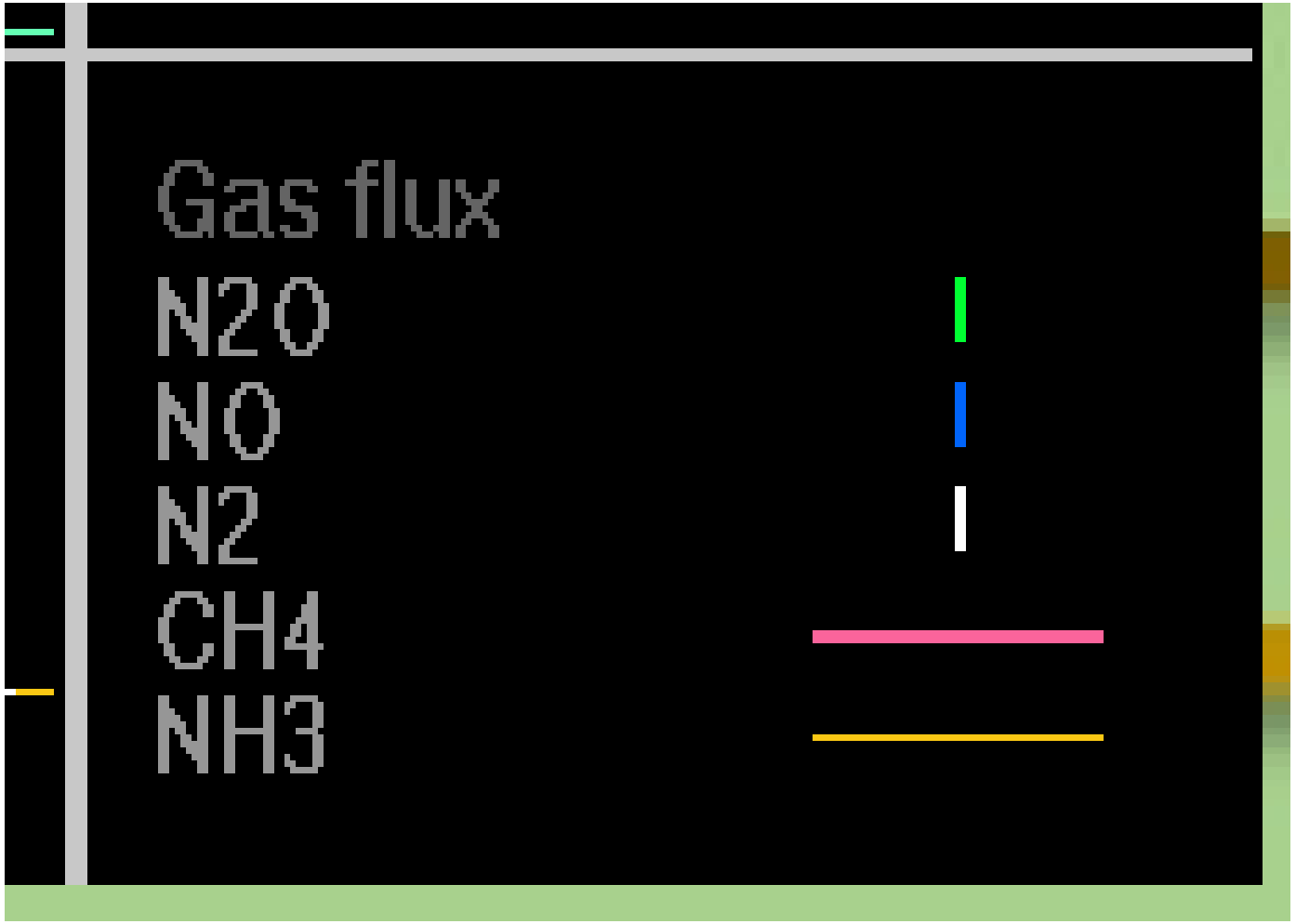
- Carbon and nitrogen biogeochemical cycles in agricultural ecosystems.
- Plant growth.
- Emission of gases.



The Denitrification-Decomposition (DNDC) model

Simulating:

- Emission of gases including CO_2 and sediment yield.



RESULTS

From the agronomic result:

- Alfalfa intercropped with corn at 76-cm row spacing followed by established alfalfa to save an estimated \$297 ha^{-1} compared with seeding alfalfa in the spring after corn.

- Alfalfa did not impact sunflower yield at 76-cm row spacing, yet it was the most profitable two-year cropping system evaluated.

- However, the 152SF+A treatment had a 32% reduction in sunflower achene yield compared to the 76SF treatment.

- Overall, it was determined that sowing alfalfa at the same time decreased the sunflower head diameter and number of achenes per head.

- Alfalfa system had a slightly lower yield the following year due to intercropping.

- Alfalfa take up soil NO3-N, agreeing with its scavenging abilities.

Parameterization, calibration, and validation of DNDC Model for sunflower-alfalfa intercropping.

- Excellent performance based on nRSME score.

Table 2. Crop parameters used to calibrate the DNDC model for grain yield in Sunflower alone grown at 76-cm row spacing with simulated and measured yield.

Cropping season/parameters	Grain	Leaf	Stem	Root	Simulated yield (KgC/ha)	Measured yield (KgC/ha)
76SF 2021						
Maximum biomass production (KgC/ha/yr)	3840	3200	3200	2560	787	787
Biomass fractions	0.3	0.25	0.25	0.2		
Biomass C/N ratio	10	45	45	50		
Thermal degree days	1727					
Water demand (g water/g DM)	495					
Optimum temperature (°C)	27.2					
Maximum root length (m)	2.5					

DNDC model performance on 76SF soil water data:

- Excellent and moderate performance based on nRSME and NSE scores, respectively.
- Adjustment still needed in the model.

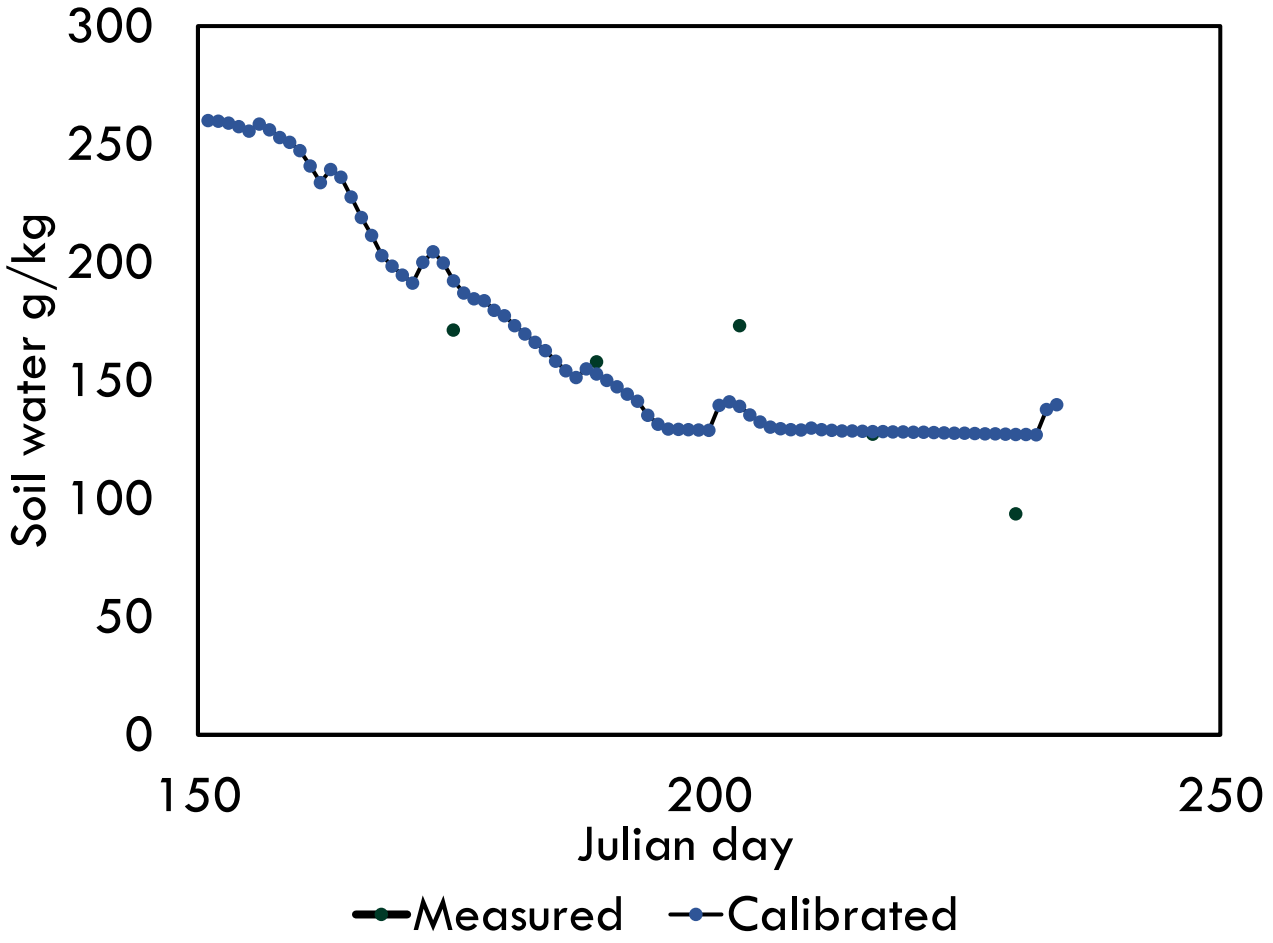


Fig. 1. Measured and Simulated 76SF Soil water

$$\text{nRSME} = \frac{\sqrt{\sum_{i=1}^{n}(S_i - M_i)^2/n}}{\bar{M}} \times 100 = 7.3\% \quad (1)$$

$$\text{NSE} = 1 - \frac{\sum_{i=1}^{n}(S_i - M_i)^2}{\sum_{i=1}^{n}(M_i - \bar{M}_i)^2} = 0.4 \quad (2)$$

$$\text{MBE} = \frac{\sum_{i=1}^{n}(S_i - M_i)}{n} = 3.4 \quad (3)$$

$$\text{RSME} = \sqrt{\sum_{i=1}^{n}(S_i - M_i)^2/n} = 10.5 \quad (4)$$

$$d = 1 - \frac{\sum_{i=1}^{n}(S_i - M_i)^2}{\sum_{i=1}^{n}(|S_i - \bar{M}| + |M_i - \bar{M}|)^2} = 0.2 \quad (5)$$

CONCLUSIONS

- Overall, intercropping corn and sunflower has the potential to enhance ecosystem services to improve future farm sustainability.
- Alfalfa take up soil NO_3-N, agreeing with its scavenging abilities.
- Excellent and moderate performance based on nRSME and NSE scores, respectively.
- Adjustment still needed in the model for better predictions of emissions.

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Thank you for listening!

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