
# Progress on new soil C and N parameterisations for JULES (ECOSSE and FUN)

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Including work by J. Smith, K. Coleman, H. Wong, P. Smith, J. Fisher, Spencer Liddicoat and others.

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# History

A long time ago....

QUEST (QESM, QUERCC)
Aimed to couple JULES with (amongst others!):
- the ECOSSE model of soil C and N turnover
- the FUN model of plant N uptake

ECOSSE: Estimation of Carbon in organic Soils – Sequestration and Emissions

Smith, J. et al., 2010, Climate Research, 45: 179-192.
Bell et al., 2012, Nutr. Cycl. Agroecosyst., 92: 161-181
ECOSSE (and its predecessors, RothC and Sundial) have been widely used.

FUN: Fixation and Uptake of Nitrogen
Fisher et al., 2010, Glob. Biogeochem. Cycles, 24, GB1014.
A new model!

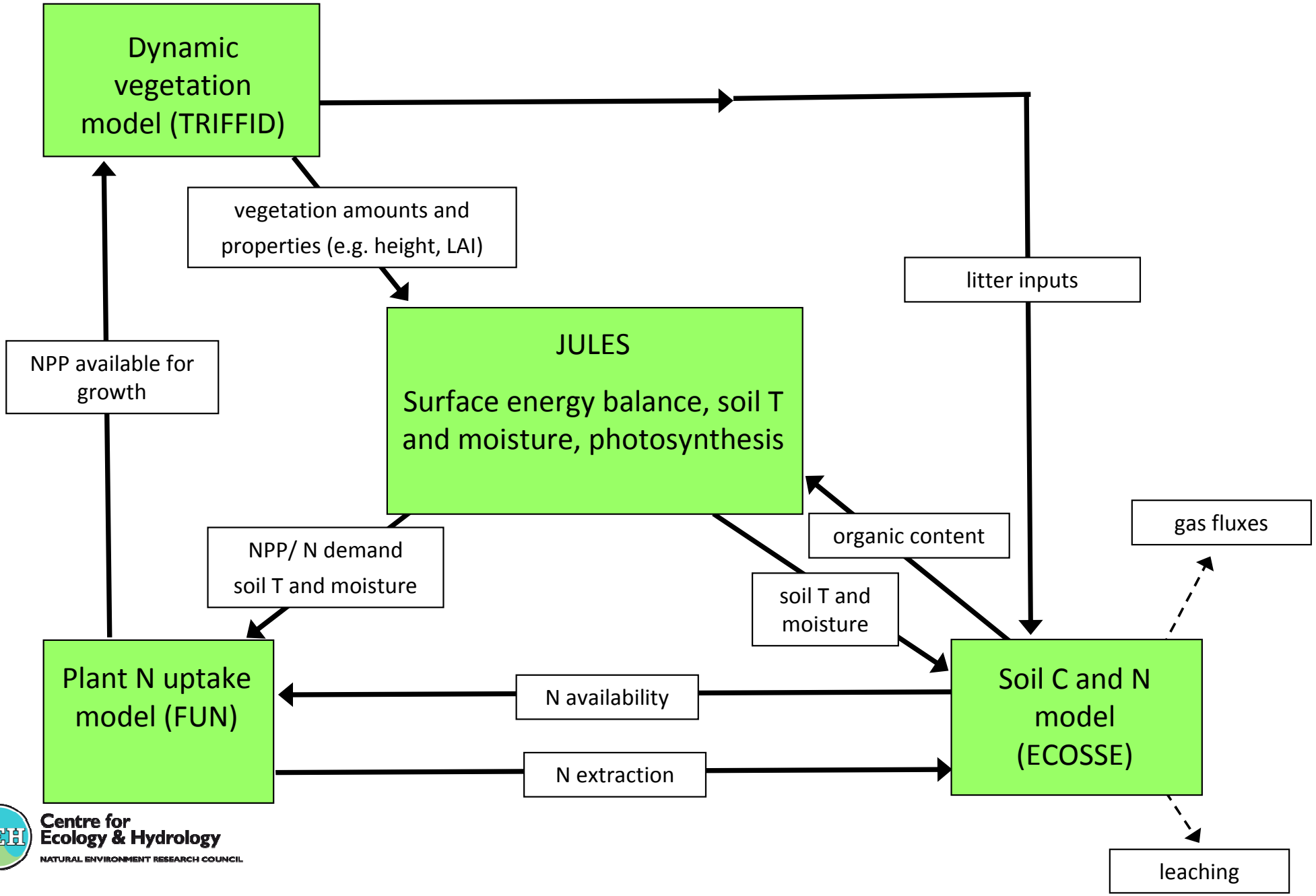
# History of the JULES-ECOSSE-FUN code

- JULES1.0 + ECOSSE (to ~2007/8).
  Rothamsted/U. of Aberdeen/Met.Office – mainly Jo Smith and Kevin Coleman.

- JULES2.0-ECOSSE-FUN (~2008-10)
  Better integrated with JULES, FUN added.

- JULES3.1-ECOSSE-FUN (2012)
  The best so far!
  Revised coupling between components.

# Schematic of the main connections between components of JULES-ECOSSE-FUN

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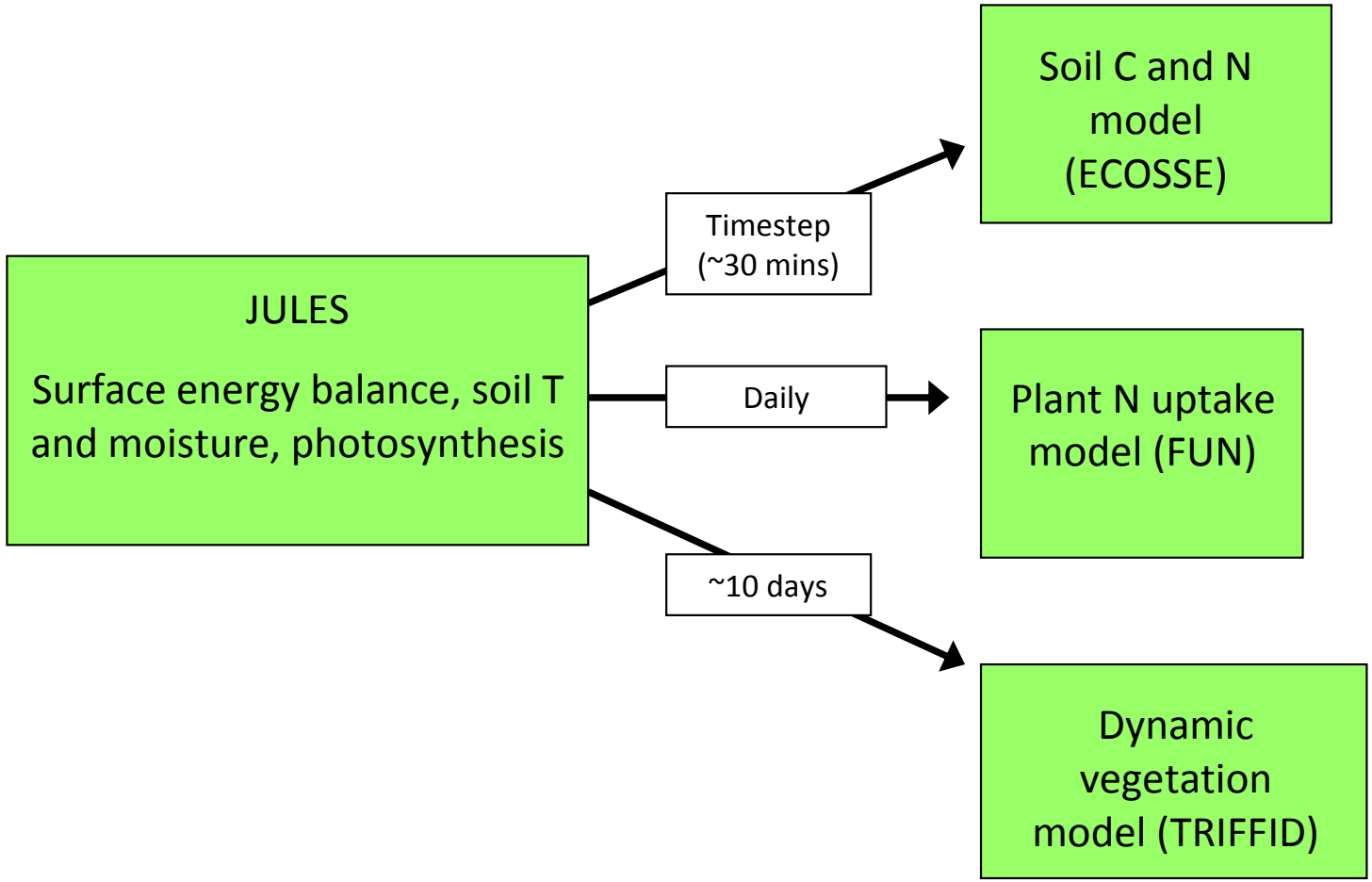
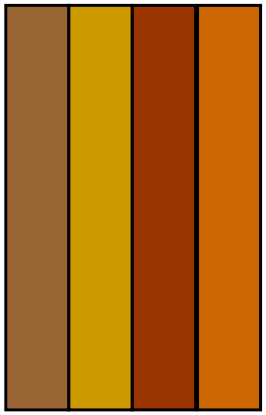
# Coupling frequencies between components of JULES-ECOSSE-FUN



# JULES with and without ECOSSE and FUN

## In JULES v3.2 (and before)

RothC



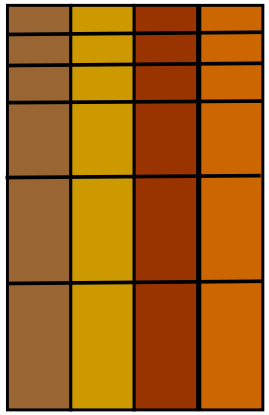
4 soil carbon pools
Decomposable plant material
Resistant plant material
Biomass
Humus

No structure with depth.

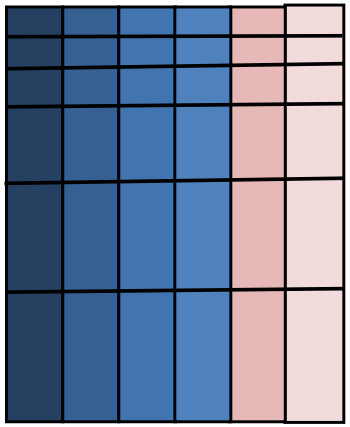
## ECOSSE and FUN additions

ECOSSE

ECOSSE is (essentially) a layered combination of RothC and a soil N model. (RothC → SUNDIAL → ECOSSE)



4 soil carbon pools - layered
Decomposable plant material
Resistant plant material
Biomass
Humus



6 soil nitrogen pools
Nitrate, ammonium + 4 pools as for C

## Plant N uptake

Plant growth assumes no restriction by soil N.

## Plant N uptake: FUN

Plants acquire N via passive and active mechanisms.
Active uptake reduces NPP => reduced plant growth.

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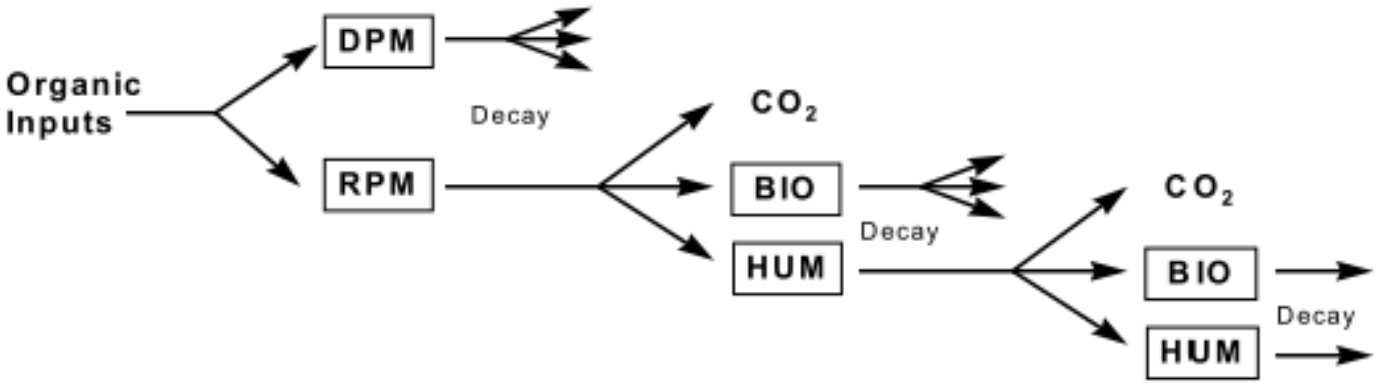
# Overview of ECOSSE (1)

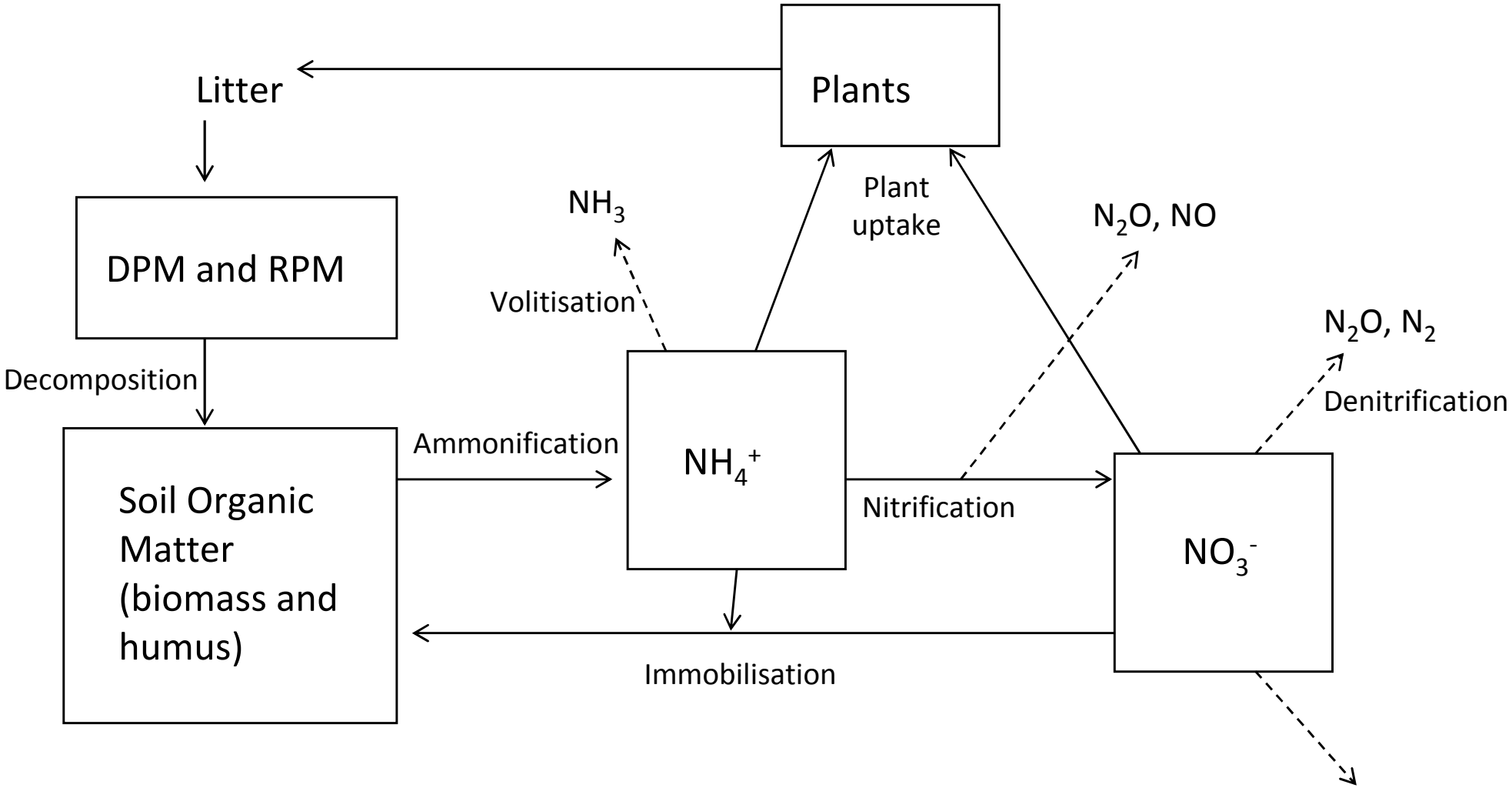



1st order reactions

Rates modified by soil T and moisture, and pH.

Also anaerobic decomposition ($CH_4$).

# Overview of ECOSSE (2) – soil and plant N processes




Decomposition of SOM results in mobilization or immobilization of inorganic N ($NO_3^-$ and $NH_4^+$) to maintain C:N.

If insufficient N, decomposition is slowed and produces more $CO_2$.

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# Inputs and outputs: JULES-ECOSSE

Inputs from JULES to ECOSSE:

- Litterfall C and N amounts
- Soil temperature and moisture
- Soil water flux (for leaching)
- Root distribution (for distribution of plant inputs)
- N deposition

Outputs from ECOSSE:

- soil C and N stores
- $CO_2$, $CH_4$, $N_2O$, NO, $N_2$, $NH_3$
- leaching DOC, $NO^-_3$, DON

# Overview of FUN

FUN considers mechanisms through which plants can take up N:

- passive uptake (via water for transpiration)
- active uptake (extract N from soil)
- retranslocation (N removed from leaves before they are dropped)
- fixing by nodules

These 3 all have a C cost.

At each timestep the cheapest source is used (unrealistic?).
If soil N is plentiful, C uptake can be matched by N with little or no cost.
Otherwise NPP available for growth is reduced.

# Inputs and outputs: JULES(-ECOSSE)-FUN

Inputs from JULES (-ECOSSE) to FUN:

- soil N stores (for costs)
- NPP
- transpiration rate (for passive uptake)
- root distribution
- leaf turnover (for amount of N in falling leaves; retranslocation)
- vegetation C and N amounts (for calculation of veg C:N)

Outputs from FUN:

- updated NPP (available for growth) and plant respiration – to JULES/TRIFFID
- N uptake amounts (to update soil N) – to ECOSSE

# Configurations available (JULES3.1-ECOSSE-FUN)

- ECOSSE + FUN

- ECOSSE only

  Calculates plant N demand to match NPP.

  No C cost of N uptake.

- FUN only

  Uses a fixed map(ancillary) of soil N.

# Timings

Based on tests with JULES2.0-ECOSSE at a single site with ECOSSE called every JULES timestep:

| Number of ECOSSE layers | Relative CPU (wall clock) time | |
|---|---|---|
| 0 | 1.0 | |
| 4 | 1.44 | JULES default |
| 10 | 1.67 | |
| 20 | 2.00 | |
| 60 | 2.89 | Standalone ECOSSE |

Notes

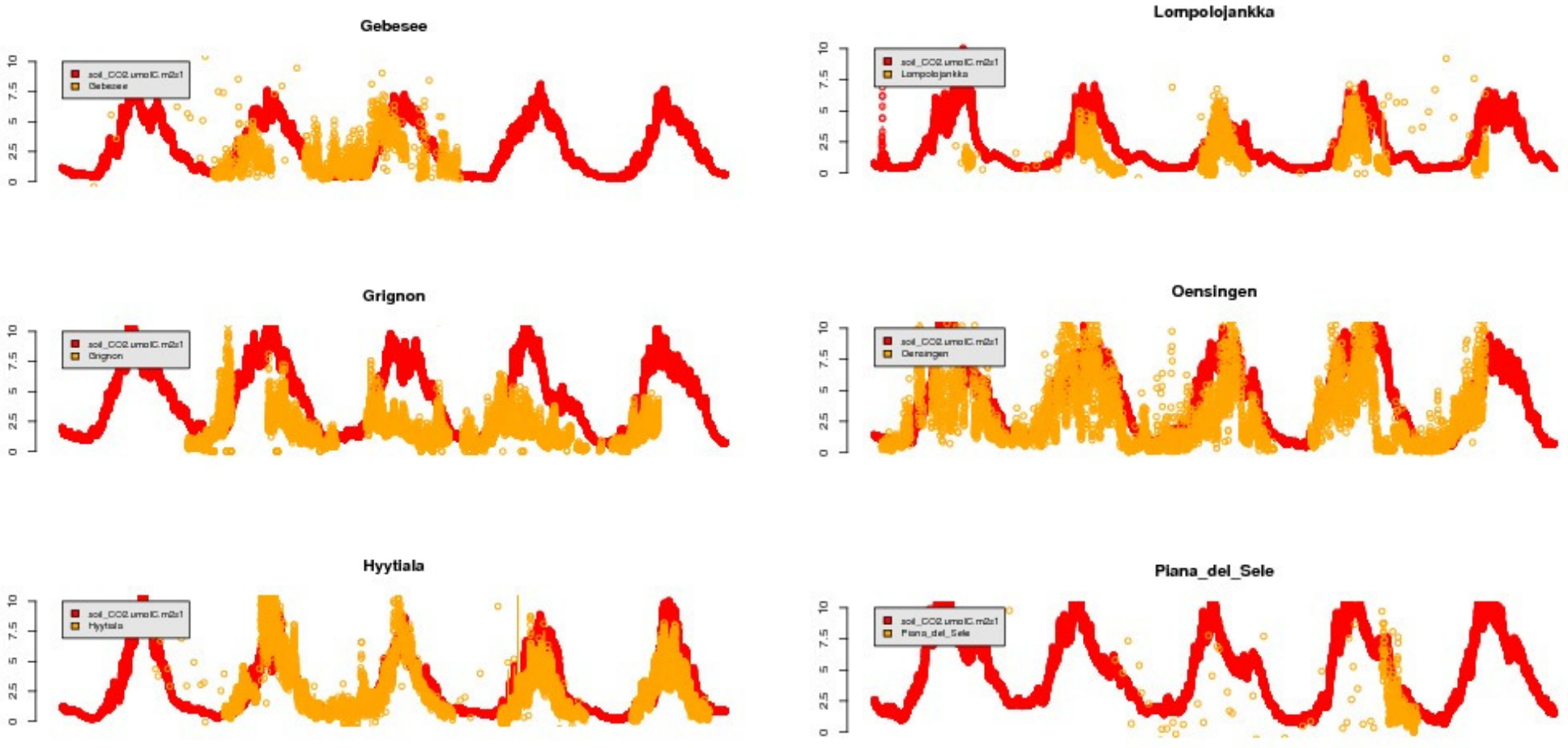
These were tests of run time; the results were clearly different.

Simple tests, with moderate optimisation by compiler.

Coupling less often (e.g. once every 1-2 hours) would be important in reducing CPU requirements.

# Evaluation of JULES-ECOSSE using $CO_2$ flux data

Homan Wong




Multi-year times series of soil $CO_2$ fluxes. Orange=observations, Red=JULES.

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# Ongoing and upcoming activities (and aspirations)

Coding

- Fertilisers (currently hardwired to zero).
- N15 – on a switch or remove?
- In the distant future - relax the restriction to one soil column per gridbox (e.g. fertilised and non-fertilised areas, wetland and non-wetland).

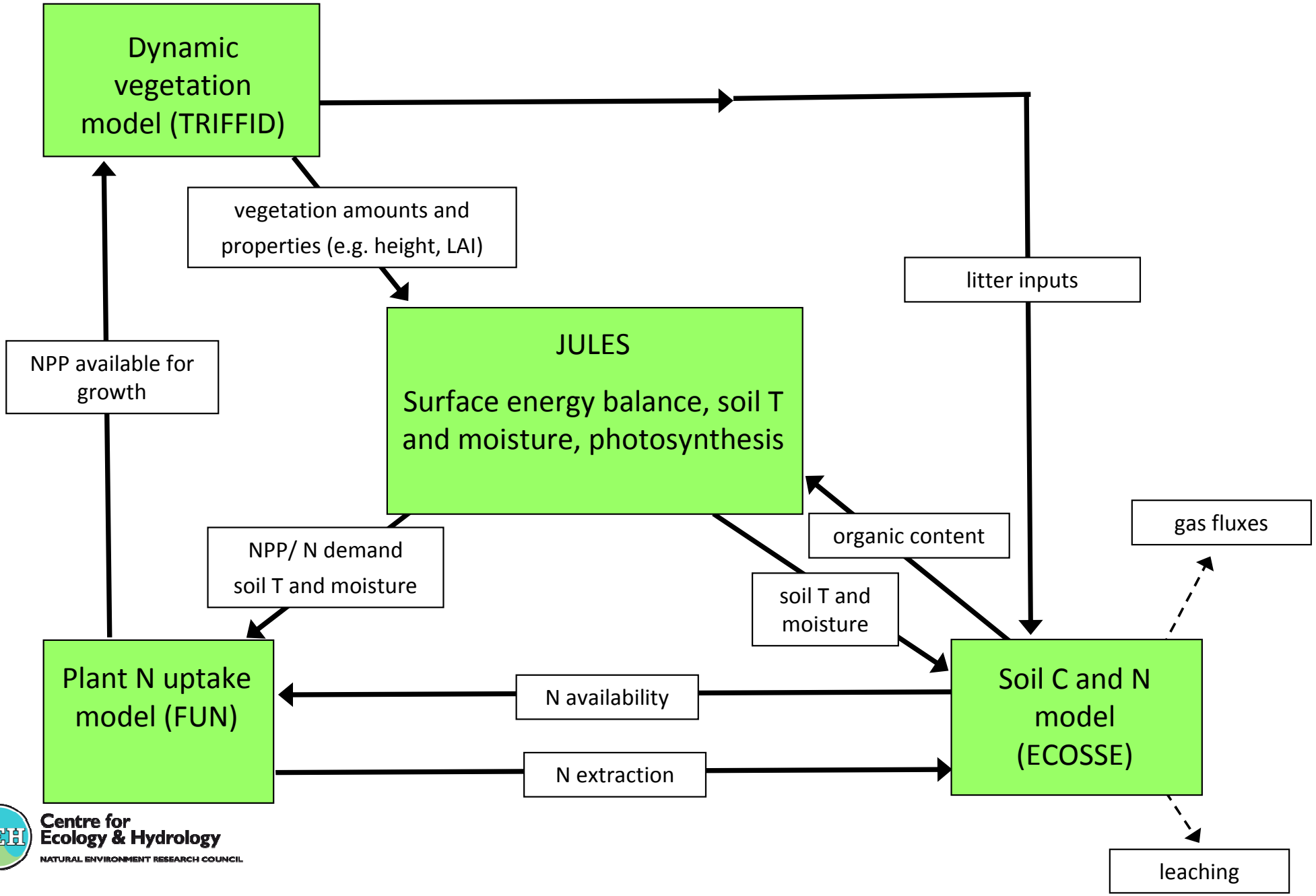
Spin up methods

Testing

- Against short-term gas fluxes (e.g. NitroEurope)
- Against long term SOM accumulations

The code is available on PUMA.

# Schematic of the main connections between components of JULES-ECOSSE-FUN

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