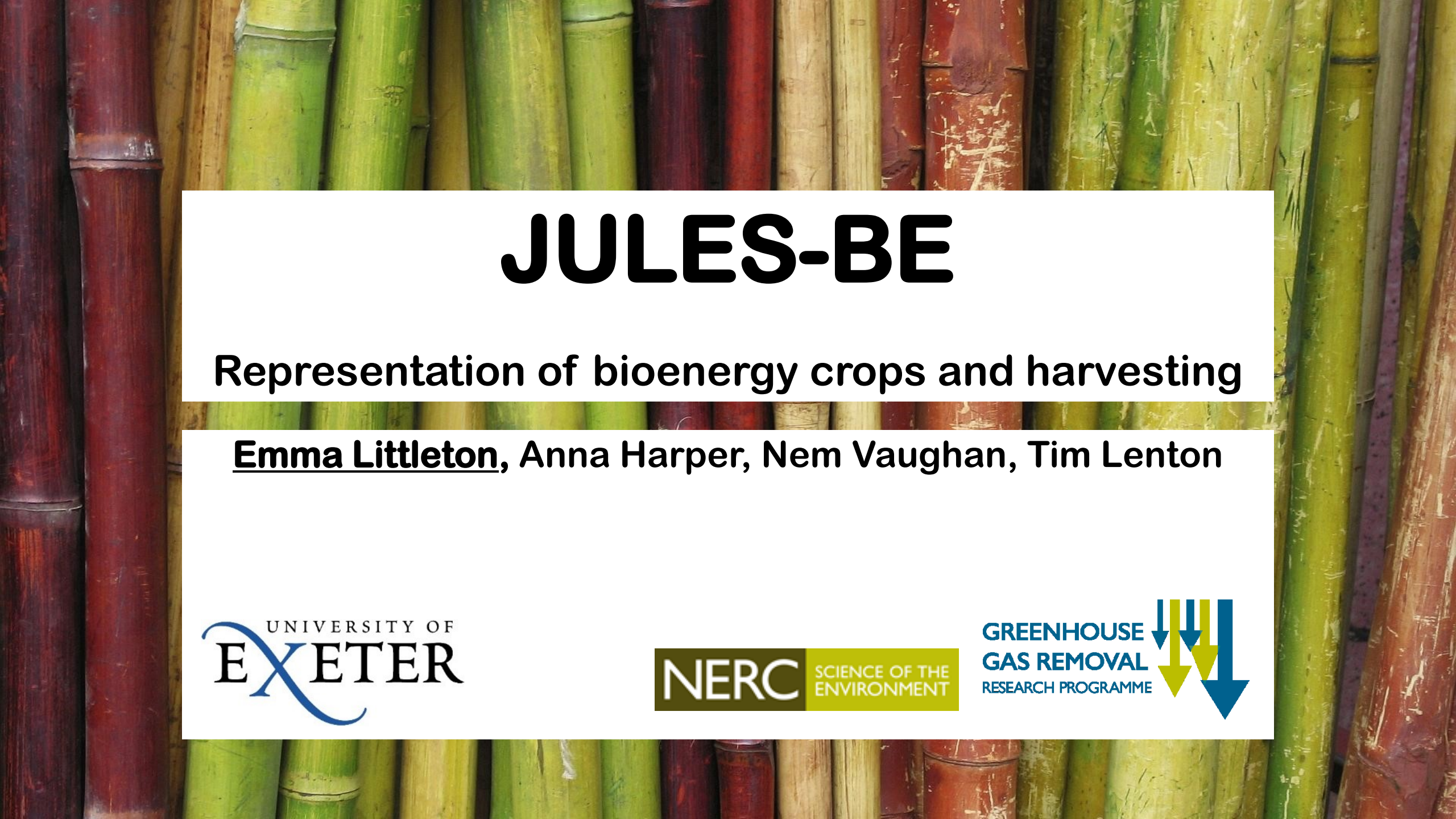

JULES-BE

Representation of bioenergy crops and harvesting

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NERC SCIENCE OF THE ENVIRONMENT

GREENHOUSE GAS REMOVAL RESEARCH PROGRAMME

outline

Intro
- Rationale
- Context
- Aims

New features
- Harvesting
- Assisted expansion
- *Miscanthus* PFT

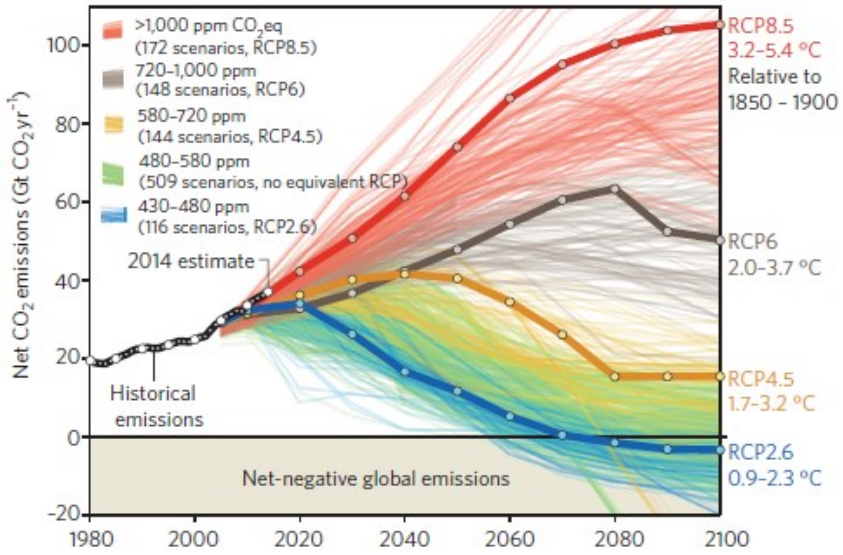
Evaluation
- PFT evaluation (site)
- *Miscanthus* yields
- SRC and forestry examples

Next steps
- Further developments
- Future work

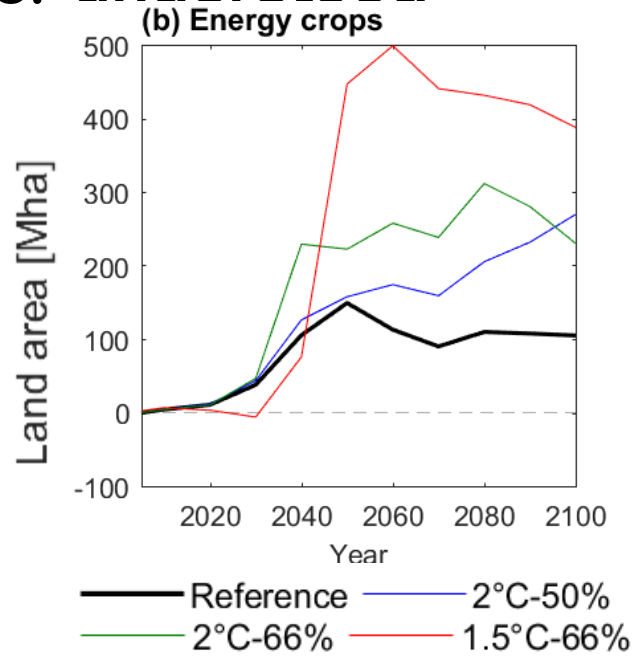
rationale

- **BECCS (bioenergy + carbon capture and storage) likely critical to limiting climate change**
- **Around 200–500 million hectares required for energy crops by 2050**
- **Impacts of such land use change must be better understood**

Future global CO_2 emissions



Fuss et al., 2014



Vaughan et al., 2018

context

- Consideration of BE growth and yields typically confined to crop models
- Bioenergy represented in ESMs in abstract (e.g. negative CO2 emissions)

- LPJml has included BE crops for several years (Beringer et al. 2011) and is used in the IMAGE integrated assessment model (RCP2.6 etc)
- Recent representation of BE in ORCHIDEE (Li et al. 2018)

aims

- Representation of bioenergy plant species in JULES
- Physical/mechanistic representation of harvests in JULES
- Develop new functionality in JULES for bioenergy yields
- Evaluate global GGR scenarios: RCP2.6-SSP2 (BECCS), RCP1.9-SSP1 (BECCS & afforestation)
- Model integration with UKESM
- Interrogation of large-scale bioenergy scenarios in UKESM, under climate change
- Explore effects on climate system (biophysical e.g. albedo, hydrology; biogeochemical e.g. reduced sinks, LUC emissions)

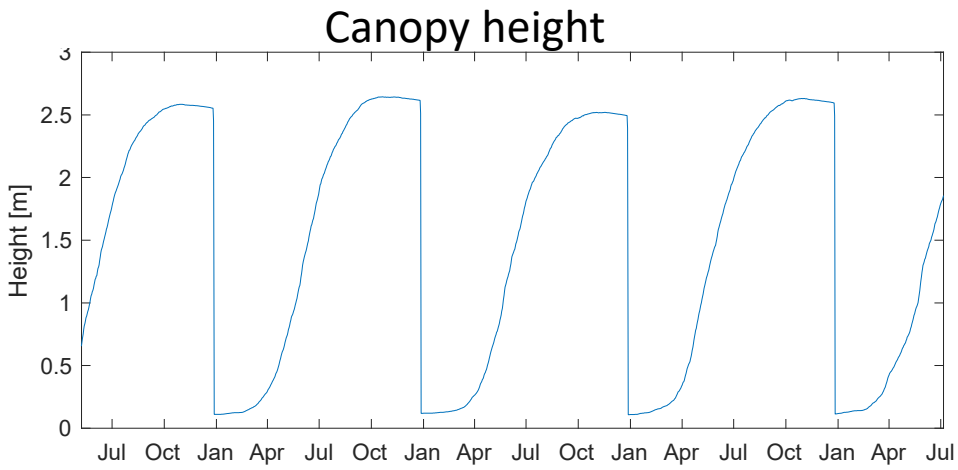
harvesting

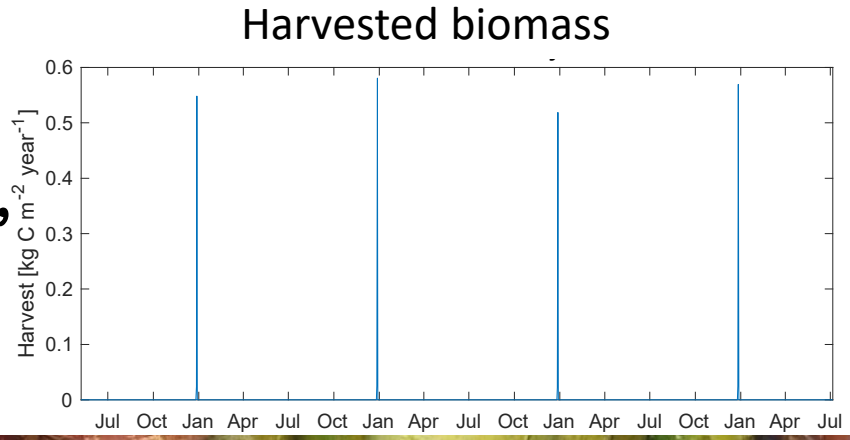
- Based on TRIFFID-crop (Defines multiple separate land classes and allows continuous harvesting from litter)
- Periodic harvesting (new): PFT cut to short height at regular intervals. Harvest height, frequency and day-of-year all user-prescribed per PFT

$$harvest = \frac{(leafC_{t-1} + woodC_{t-1}) - (leafC_t + woodC_t)}{\Delta t}$$

$$lit_c = lit_c + \frac{(rootC_{t-1} - rootC_t)}{\Delta t}$$

Suitable for perennial grasses (annual harvest), short rotation coppicing (3-8 years), rotation forestry (15-50 years)



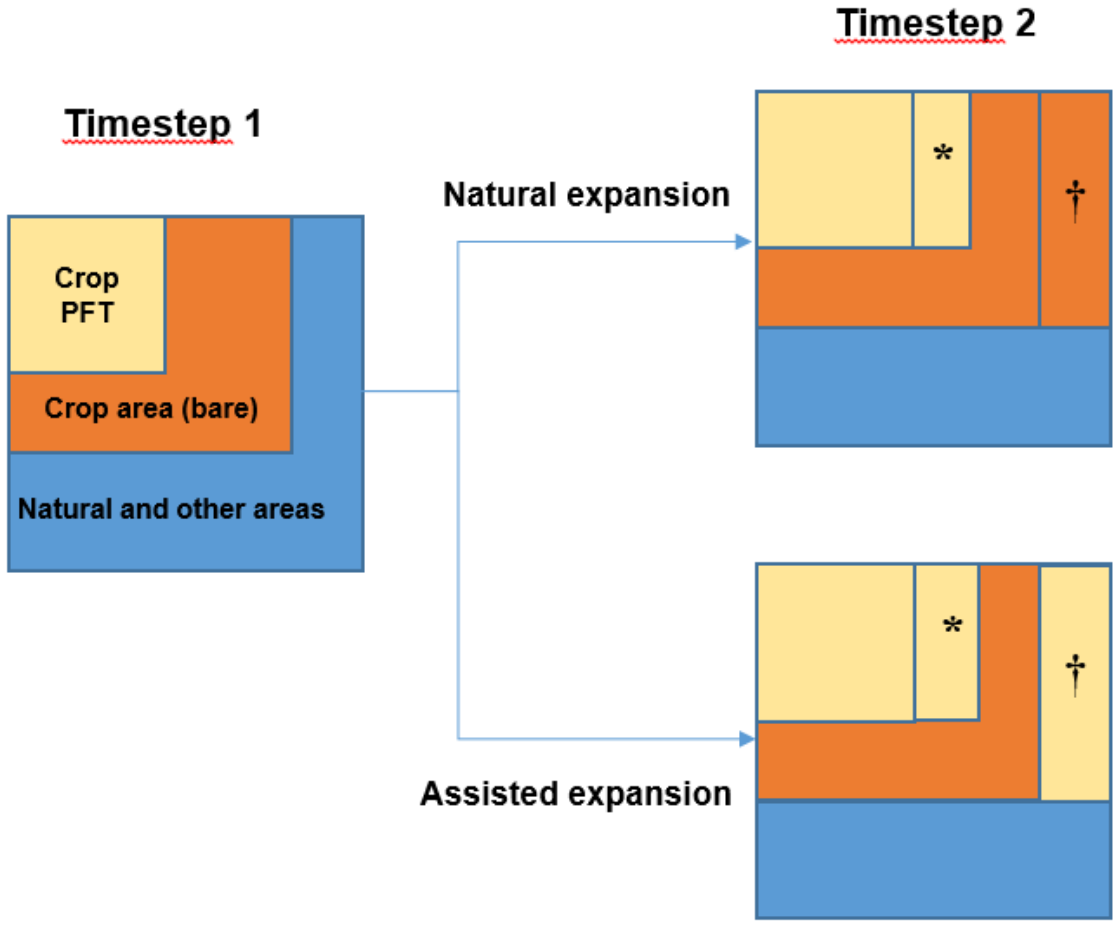


assisted expansion

$$C_v \frac{dv}{dt} = \lambda \Pi v_* \left(1 - \sum_j c_{ij} v_j\right) - \gamma_v v_* C_v$$

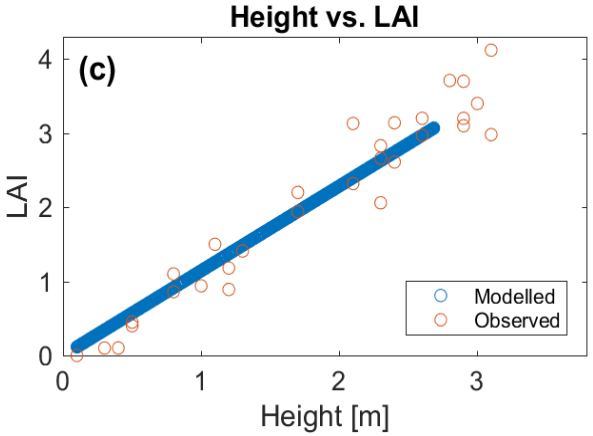
(Clark et al. 2011, Eq. 52)

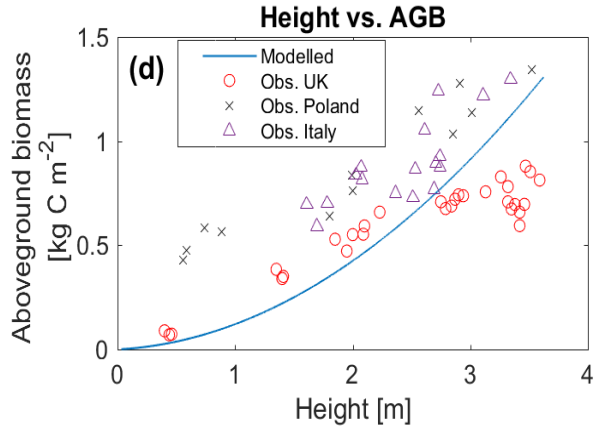
- BE crops have large C_v which restricts dv/dt
- Workaround: When crop area increases, crop PFTs fill new area (instead of bare soil)
- Simulates plantation of new crop areas



Miscanthus PFT

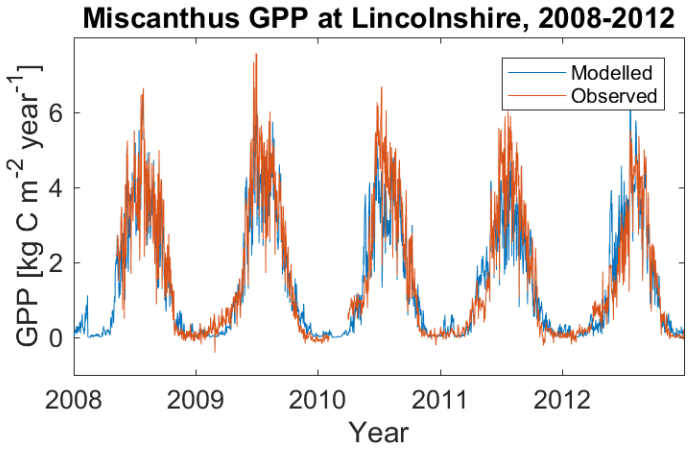
- Fast-growing perennial C4 grass with high lignin content
- Typically yields 10-20 tonnes DM ha^{-1} $year^{-1}$
- Yields up to 50 tonnes DM ha^{-1} $year^{-1}$ have been observed
- Cold-tolerant and suitable for poor soils
- PFT params tuned to optimise height:AGB relationship

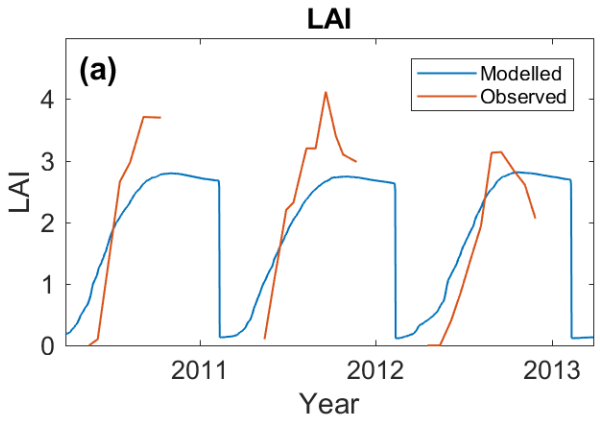


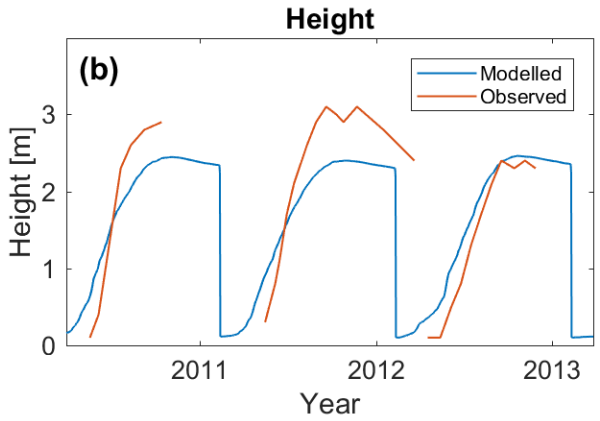


PFT evaluation (site)

- *Miscanthus* plantation in Lincolnshire
- Measurements of GPP, LAI and height



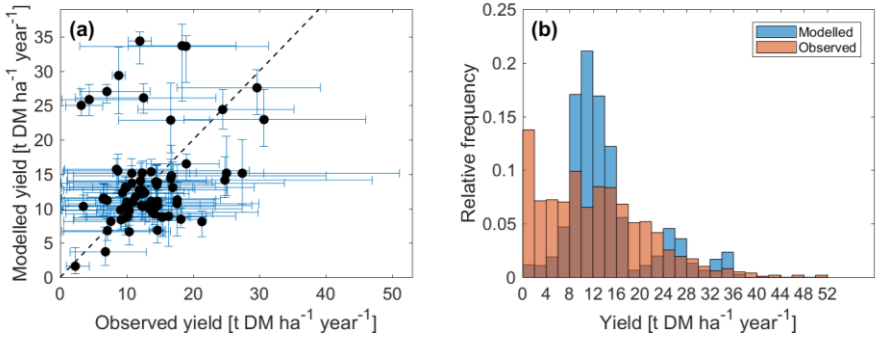




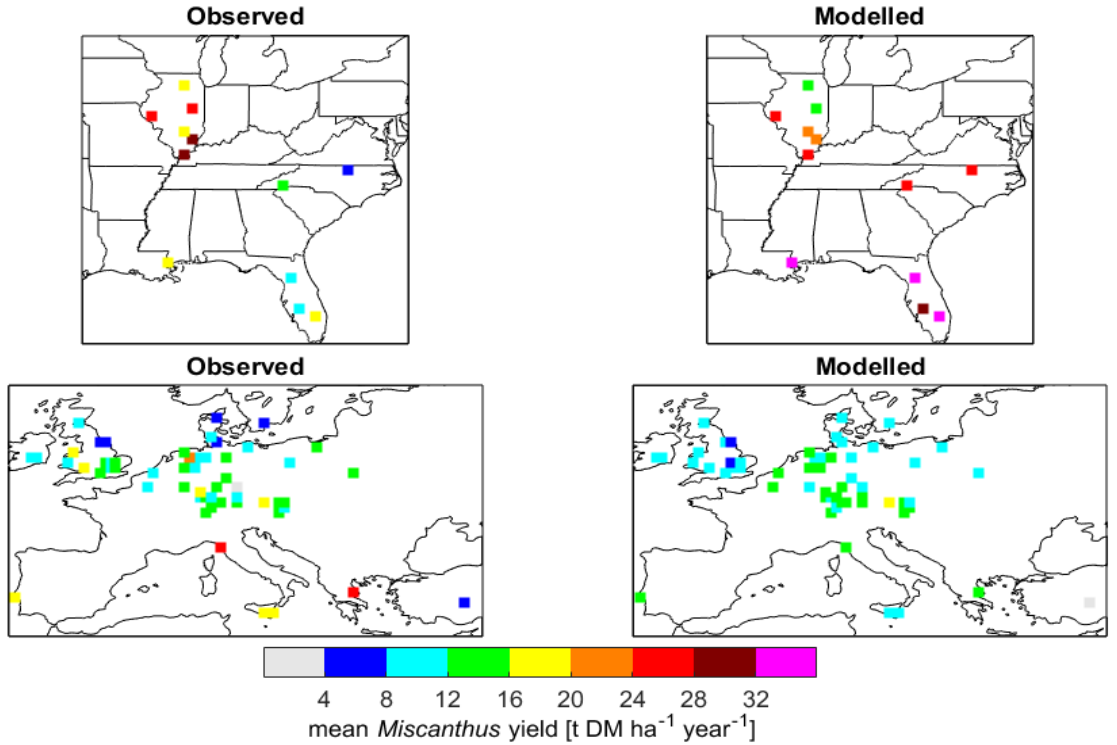
Miscanthus yields

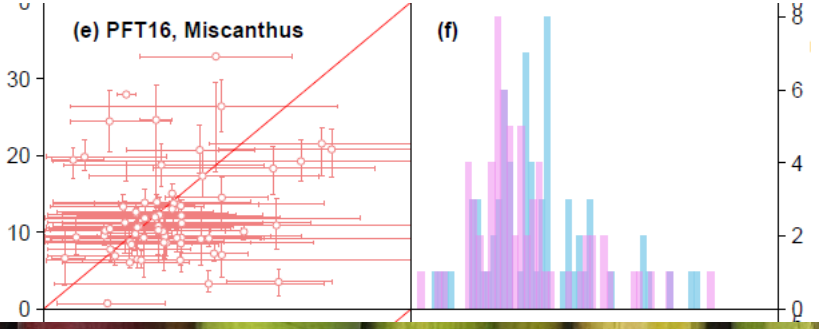
Modelled yields compared against Li et al. (2018; *Sci. Data*)

Good fit in Europe but over-estimates yields in southern USA



<- JULES

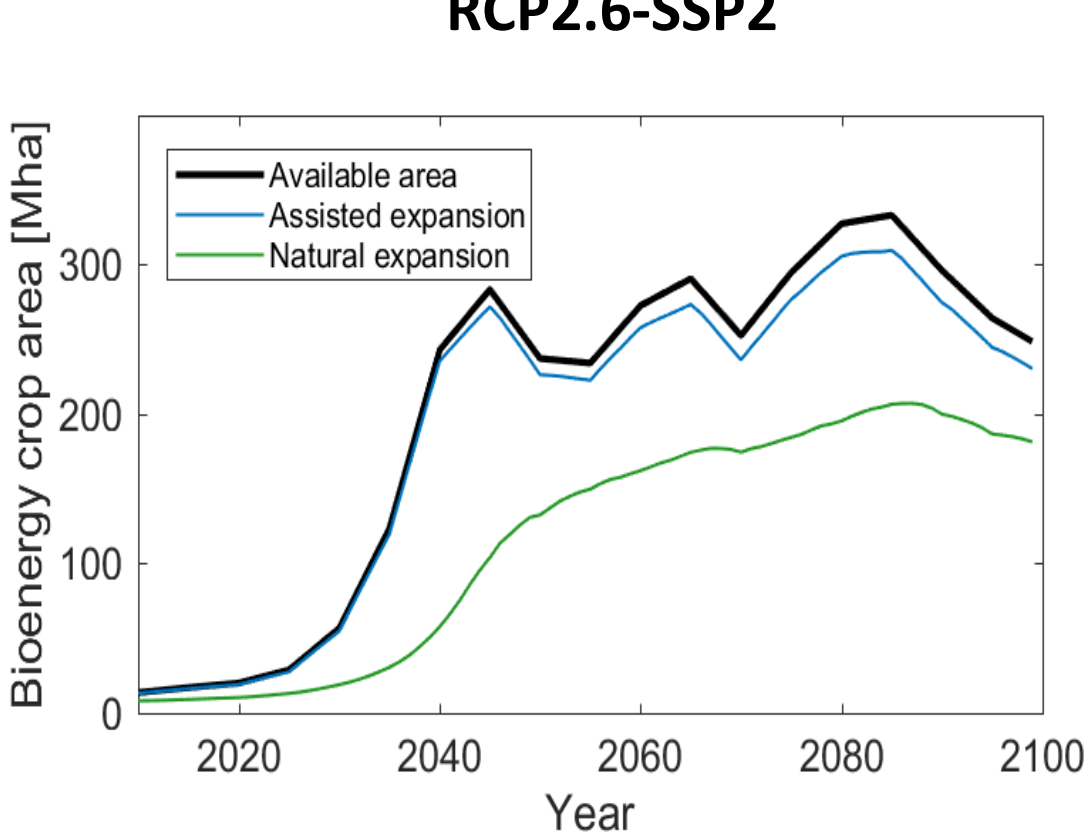




<- ORCHIDEE
(Li et al. 2018; *GMD*)

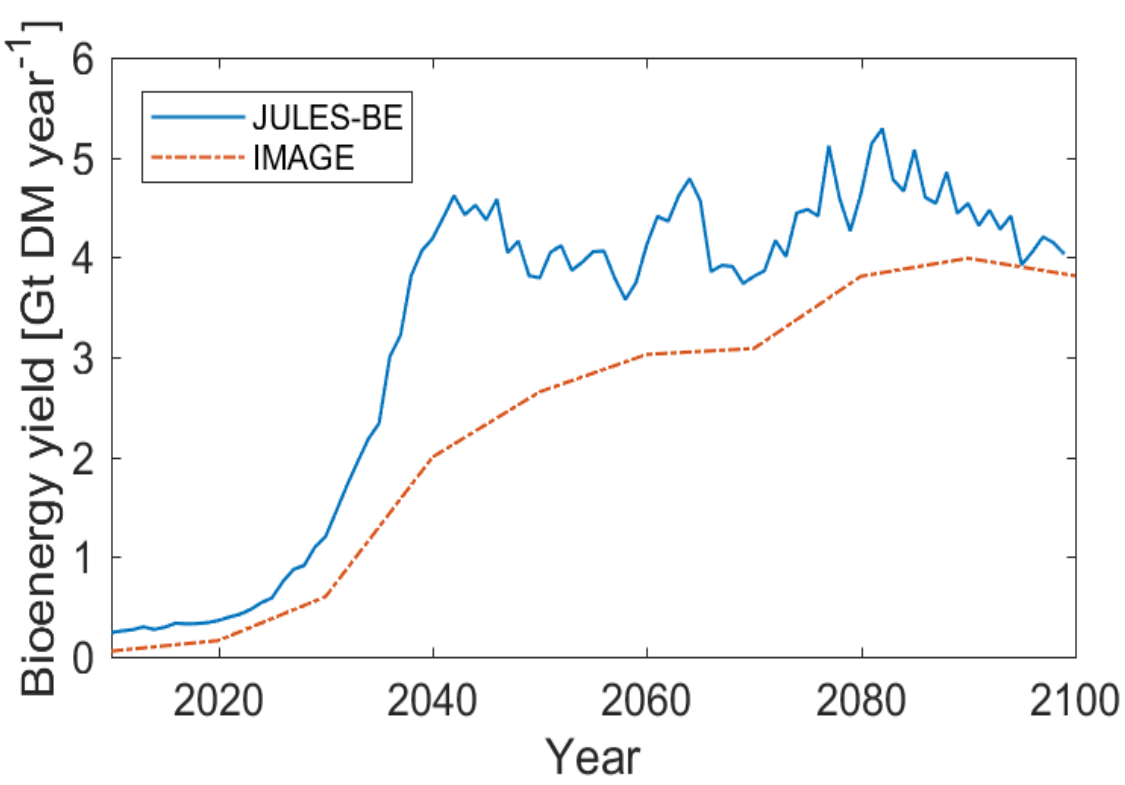
assisted expansion

- Assisted expansion option facilitates simulating rapid land-use transitions
- Here BE crop area increases ~250 Mha over 2025–2045
- Allows crop area to die back in unsuitable environments, preserving benefit of dynamic vegetation



future scenario

- Global BE yield is 4.3 Gt DM year^{-1} over 2040–2100
- Exceeds yields in IMAGE required by bioenergy system

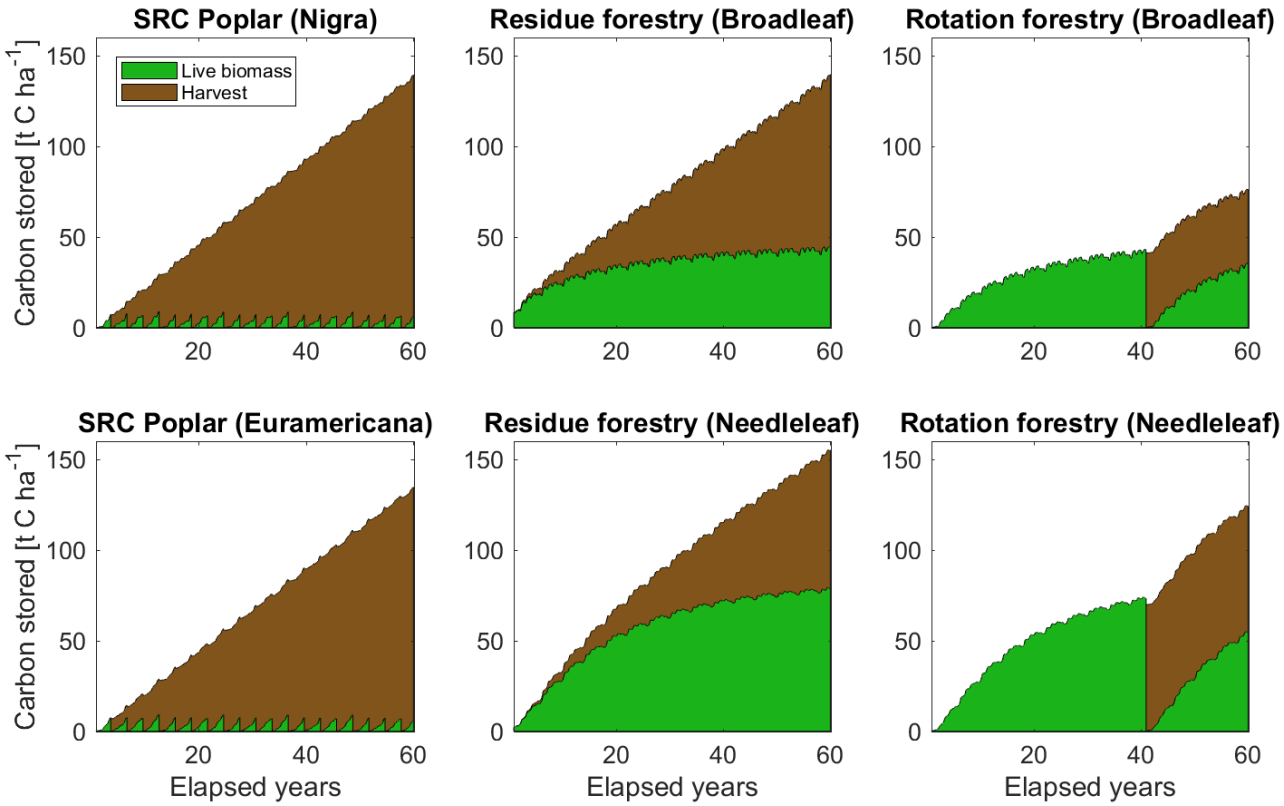


SRC and forestry

Illustrated examples of:

- Short-rotation coppice
- Residue forestry
- Rotation forestry

Further tuning required for these PFTs and harvest options



further development

Forestry representation on multiple cells:

- Staggered harvests across different grid cells
- Regionally appropriate rotation length and harvest date

Competition between BE PFTs:

- Height-based competition not useful for BE PFTs
- Based on aboveground biomass would be better, but not ideal

future work

- Cross-model evaluation against MiscanFor (a bioenergy crop model) and IMAGE (an integrated assessment model)
- Permanent afforestation
- Evaluation of BECCS and afforestation scenarios in UKESM

publication

JULES-BE: representation of bioenergy crops and harvesting in the Joint UK Land Environment Simulator vn5.1

Emma W. Littleton, Anna B. Harper, Naomi E. Vaughan, Rebecca J. Oliver, Maria Carolina Duran-Rojas, Timothy M. Lenton

Submitted to *Geoscientific Model Development*

Online for discussion soon with any luck!

summary

- New planting and harvesting mechanisms within TRIFFID for bioenergy crops
- *Miscanthus* PFT performs reasonably in temperate regions; further tuning required for tropical & arid zones
- Also suitable for short-rotation coppicing and forestry simulations
- Aiming for trunk of JULES 5.6
- Model development MS (submitted)
- Comparison of *Miscanthus* with crop model & IMAGE (in prep)
- Afforestation study (in prep)