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Theme 2.2: Modelling the productivity of short rotation coppice (SRC)

M.J. Aylott, G. Taylor

University of Southampton, UK

E. Casella

Forest Research, UK

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Mature Poplar plantation from UK National Field Trials (2006)

1. Introduction

First modelling phase (Finished July 07)

- Develop an empirical model to measure current productivity and spatial capacity of SRC in the UK

Second phase (Aug 07-Mar 09)

- Parameterise the ForestGrowth process model for SRC and model yield changes in future climates by incorporation of the UKCIP02/08 future climate scenarios

1. Introduction

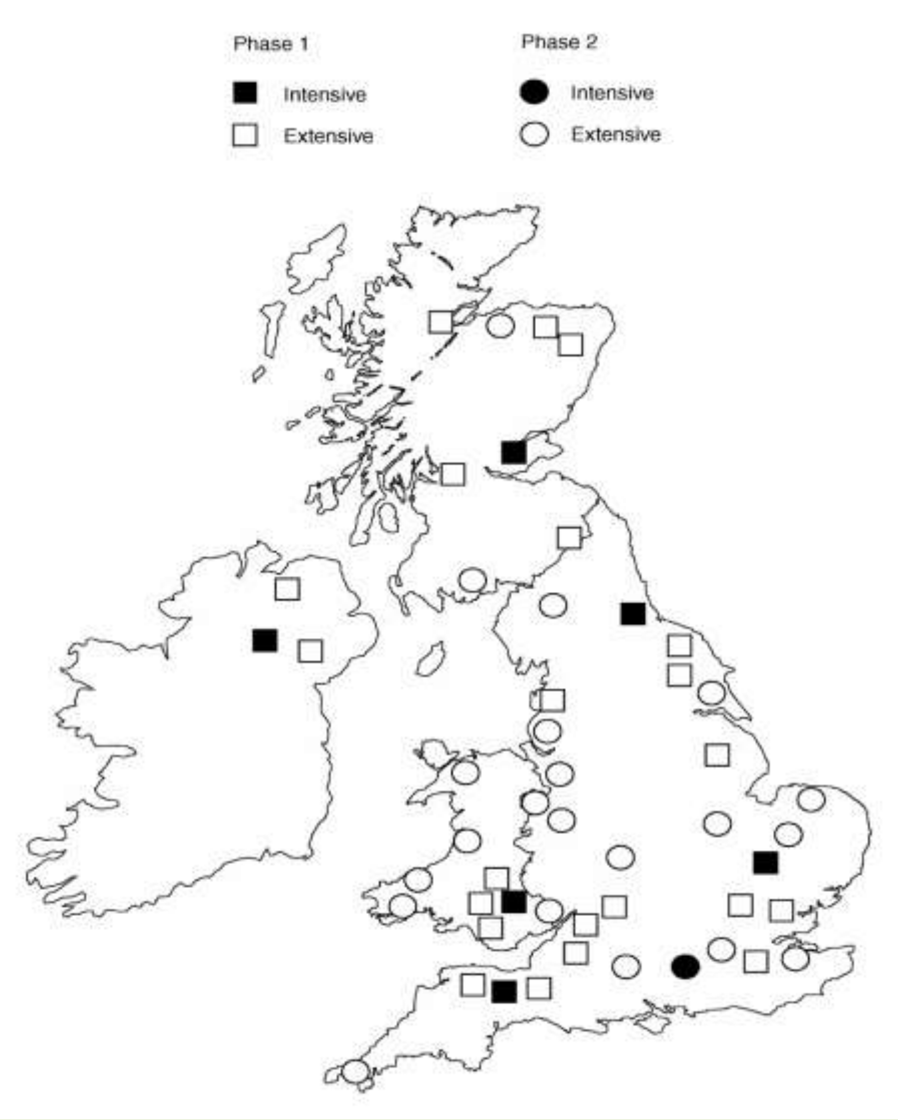
My original PhD objectives:

- Utilise forest models developed by Forest Research
- Critically assess the existing parameterisation of the ForestGrowth model
- Prepare maps of potential yields and spatial supply of bioenergy SRC
- Use a GIS-based approach to study future potential biomass production based on socio-economic (UKCIP02) and land-use scenarios

2. Empirical model

Method

- An empirical model was constructed using selected measurements from almost 150 plots from the national SRC field trials network.
- *Soil, topographical and climatic* variables were used to construct the model.
- Plot data for each genotype was modelled using Partial Least Squares regression (Simca-P 11.5, Umetrics).



2. Empirical model

Conclusions

- Recorded yields varied between 1.97 and 13.34 odt ha^{-1} y^{-1}.
- Using the best genotypes the UK could realistically grow >1.3 Mha (12.6 Modt yr^{-1}) of biomass, exceeding both short & long term planting targets of 125,000 ha[1] & 1Mha[2].
- Low precipitation was identified as the principal limiting factor to crop yield.
- In the future temperate landscape, it is likely we will see an increase in the value and production of these crops, therefore a robust process based model is required.

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1. (Britt *et al.*, 2002), *2.* (Gill *et al.*, 2005)

3. Process model

Introduction

- Process-based models allow linkages between climate change scenarios and productivity to be investigated
- The forest productivity model, ForestGrowth[1,2], has been parameterised for SRC using literature and field measurements[3,4] and outputs have been validated against site/species-specific data[5]

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1. (Evans et al., 2004), 2. (Deckmyn et al., 2004)

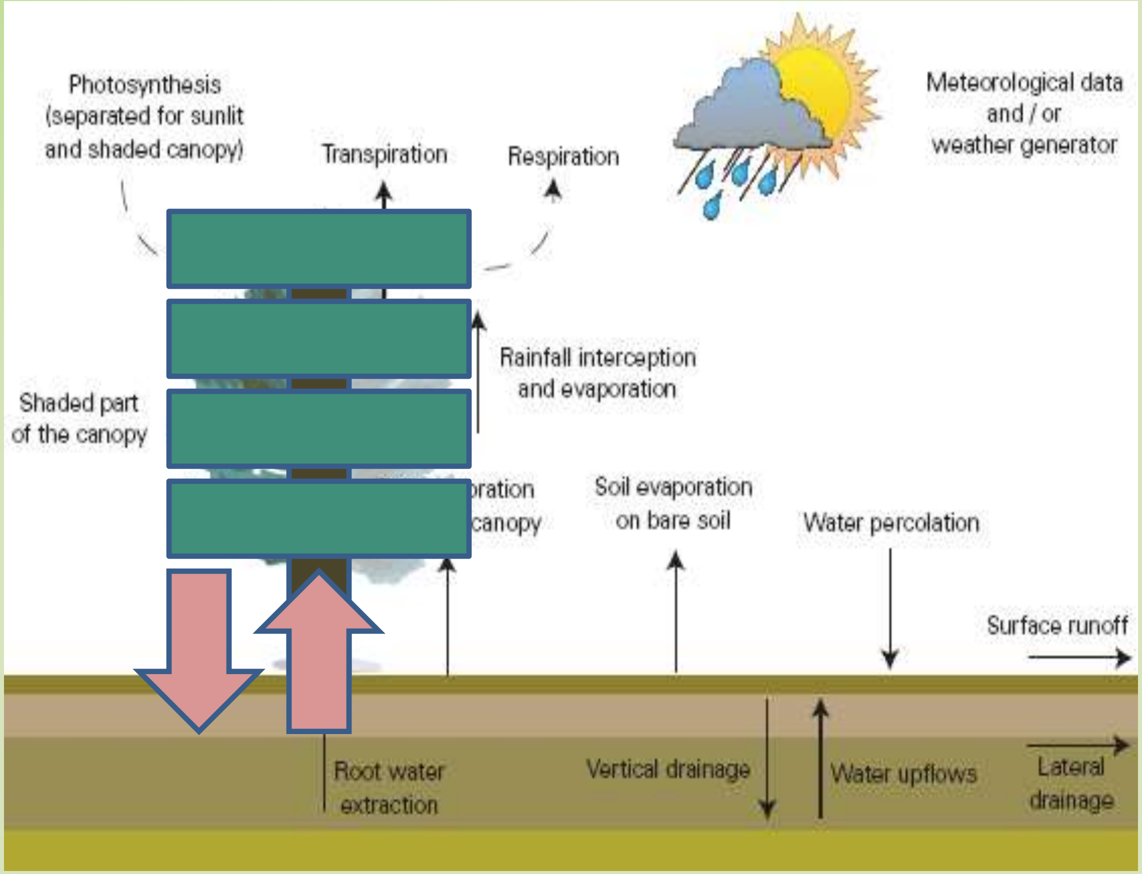
3. (Casella & Sinoquet, 2003), 4. (Gielen et al., 2003)

5. (Aylott et al., unpublished data)

3. Process model

ForestGrowth

- ***Phase 1:*** Storage carbon replenishes the existing canopy for 20 days
- ***Phase 2:*** Leaves are then added and if there is insufficient light, stem growth will occur
- ***Phase 3:*** Carbon will be added to the pool of stored carbon – in preparation for the following years growth
- ***Phase 4:*** Leaf fall occurs
- ***Phase 5:*** Dormancy



3. Process model

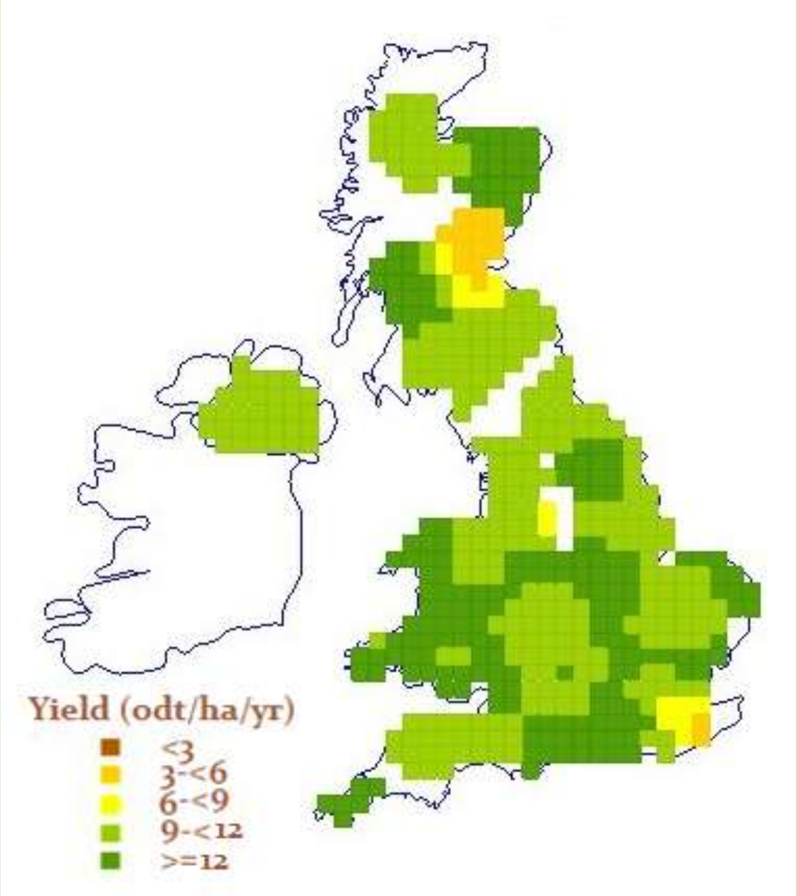
ForestGrowth Inputs

- Incorporated work by Casella and Aylott to improve the V_{cmax}, J_{max} & R_d relationships with seasonal temperature (see *Casella et al., 2008*).
- Improved light interception module and removed the different shoot classes (therefore removing competition between shoots but simplifying the model) – height now driven by height area growth relationship.
- DePury photosynthesis model replaced with more complex Ball/Berry model.
- Canopy profile of the tree improved by using a max LAD for each 25 cm canopy profile, rather than a maximum leaf area and number of leaves per layer.
- Carbon allocation now differs through time, particularly done for the initial year of growth to take into account the juvenile development of root infrastructure.
- Fine roots now kept over rotations, as some may survive between rotations as they do between years.
- Leaf removal function incorporated – whereby leaf layers are removed when they don't have enough light rather than x percentage of total leaves per day.
- Developed a different allocation of nitrogen to the tree layers, to take into account within canopy variability.

3. Process model

ForestGrowth Outputs

- ForestGrowth has been parameterised for two poplar species & two willow
- Validated against existing data from the 49 national SRC field trial sites (ongoing – currently only validated for two sites, Alice Holt (clay loam soil) & Hayburn Wyke (sand/silt soil))



Productivity map of *Populus trichocarpa* genotype ‘trichobel’, second rotation

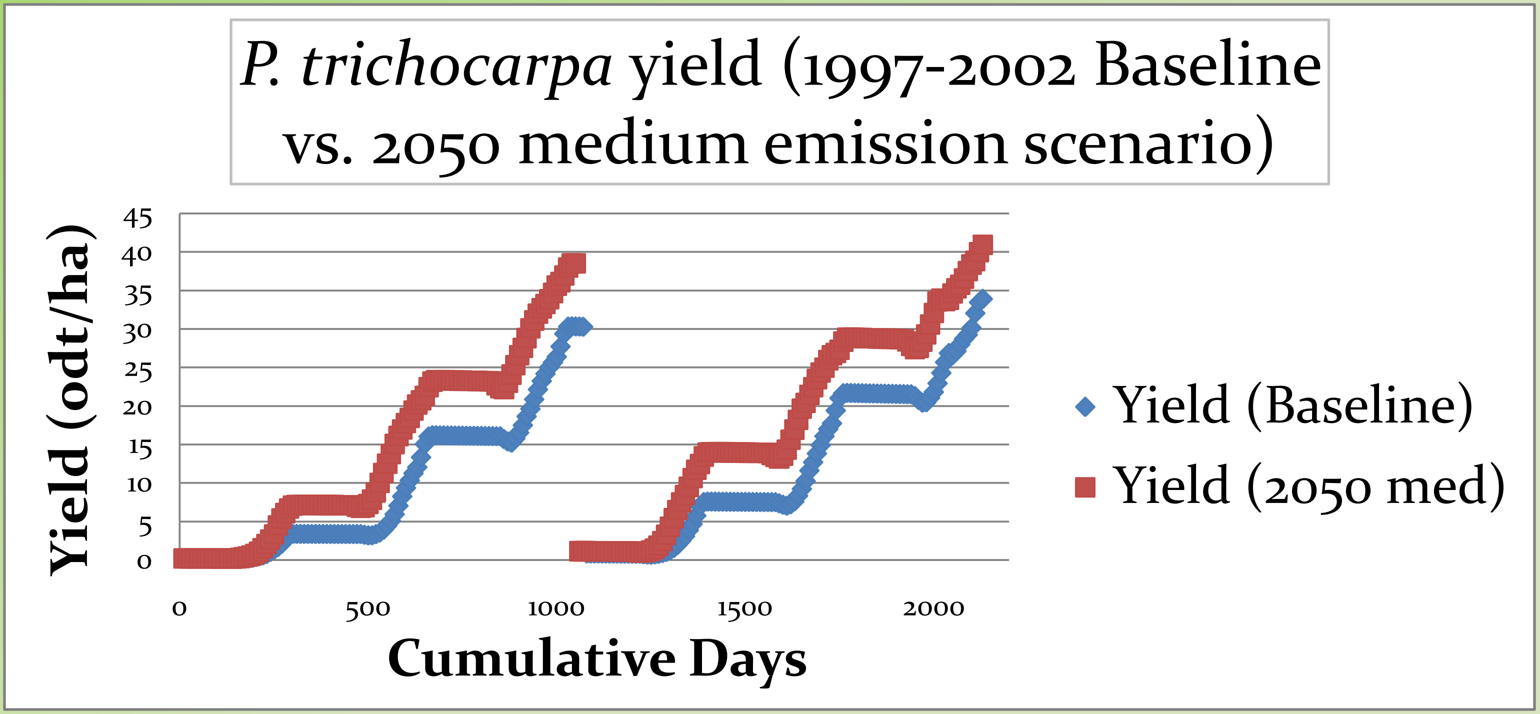
3. Process model

Future Climate Scenarios

- ForestGrowth is currently being tested using arbitrary increases in CO_2, temperature and precipitation (based on UKCIP02 2050 medium emission scenario), without irrigation or fertiliser.
- In the future, ForestGrowth will be run using weather data generated by the UKCIP02 climate change scenarios (developed by the Tyndall and Hadley Centres)
  - Allows us to account for a wider range of climatic variables, including radiation and seasonal temperature/precipitation
  - And different emission scenarios for the 2020's, 2050's & 2080's

3. Process model

Results: 2050 Climate Scenario



- **CO2** (550ppm) x **Temp.** (increased by 2.5°C in summer + 0.5°C for rest of year) x **Precipitation** (decreased by 10%)
  - Yield **increased by 2.1 odt/ha/yr (+19%)** by the third year of the second rotation(at Alice Holt), driven by CO2 fertilisation

3. Process model

Conclusions

- C3 bioenergy crop yields could increase by up to 20% in a future temperate UK landscape – however, as plants acclimate to new climates so too will pests and disease, potentially counteracting these effects.
- These results should be linked to future plant breeding, even GM to ensure bioenergy crops for the future.
- Extend to hotter drier climates across Europe.

4. Theme interaction

- There is ongoing collaboration within Theme 2:
  - GHG balance of energy crops with Aberdeen – paper under construction
  - Modelling supply chain scenarios with Imperial College – paper under construction
- Future interaction with Theme 4:
  - Providing clear and concise yield information

5. Publications

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- AYLOTT M.J., CASELLA E. & TAYLOR G. Current trends in global bioenergy crop yields. *In prep*.
- AYLOTT M.J., CASELLA E., TUBBY I., STREET N. R., SMITH P. & TAYLOR G. (2008) Yield and spatial supply of bioenergy poplar and willow short-rotation coppice in the UK. *New Phytologist,* 178, 358-370.
- BAUEN A.W., RICHTER G.M., DUNNETT A.J., RICHE A.B., DAILEY A.G., AYLOTT M., CASELLA E. & TAYLOR G. Modelling demand and supply of bioenergy from short rotation coppice and Miscanthus in the UK. *In prep*.
- CASELLA E., DREYER E., VANDAME M., CEULEMANS R., AYLOTT M.J., TAYLOR G. & SINOQUET H. (2008) Seasonal changes in temperature response of photosynthetic model parameters in relation to leaf nitrogen content for poplar. *In submission with Tree Physiology*.
- FARRELL K., AYLOTT M.J., CASELLA E. & TAYLOR G. Limits to the possible production and distribution to short rotation coppice in the UK? *In prep.*
- HILLIER J., SMITH P., RICHTER G.M., AYLOTT M., CASELLA E. & TAYLOR G. *GHG balance of soils planted with bioenergy crops. In prep.*

Non TSEC

- CASELLA E. & SINOQUET H. (2003) A method for describing the canopy architecture of coppice poplar with allometric relationships. *Tree Physiology*, 23:1153-1169.
- DECKMYN G., EVANS S.P. & RANDLE T.J. (2004) . Refined pipe theory for mechanistic modelling of wood development. *Tree Physiology,* 26:703–717.
- EVANS S.P., RANDLE T., HENSHALL P., ARCANGELI C., PELLENQ J., LAFONT S. & VIALS C. (2004). Recent advances in mechanistic modelling of forest stands and catchments, Forest Research Annual Report 2003-2004.

6. Acknowledgements

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