Testing steady states carbon stocks of Yasso07 and ROMUL models against soil inventory data in Finland

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Background

- **Why carbon stocks ?**
  - In Rantakari et al. (2012) and Ortiz et al. (2013) we found out that Yasso07 agreed with measured **soil carbon stock change**, but with high uncertainty
  - Todd-Brown et al. (2014): boreal forests may lose 28 Pg of carbon or accumulate 62 Pg of carbon during this century depending on the ESM (earth system model). *Differences between models mainly due to initial SOC content*
  - For emission estimation **due to land-use change and for future predictions** – we need to have precise and accurate estimate of **initial SOC stocks** and here we test if model match with data

- Rantakari, Miitta, et al. "The Yasso07 soil carbon model–Testing against repeated soil carbon inventory." *Forest Ecology and Management* 286 (2012): 137-147.
- Ortiz, Carina A., et al. "Soil organic carbon stock changes in Swedish forest soils—A comparison of uncertainties and their sources through a national inventory and two simulation models." *Ecological Modelling* 251 (2013): 221-231.
- Todd-Brown, K. E. O., et al. "Changes in soil organic carbon storage predicted by Earth system models during the 21st century." *Biogeosciences* 11.8 (2014): 2341-2356.

Objectives

Testing Yasso07 and ROMUL model steady-states against soil carbon stock measurements, we ask:

1. Are litter quantity, -quality and weather data enough to estimate spatial trends with soil carbon stocks in Finland ?

2. Does soil texture have impact on carbon stocks through drought limitation on decomposition?
   - We hypothesize that increased fraction of coarser soil textures increases soil carbon stocks by reduced deconposition due to drought.

Material and methods – model inputs

We need litter input for soil models and that is obtained here from forest inventory

- NFI9 (national forest inventory) stem volume maps based on kriging methods (Tomppo et al. 2011), biomass models and litter turnoverrates

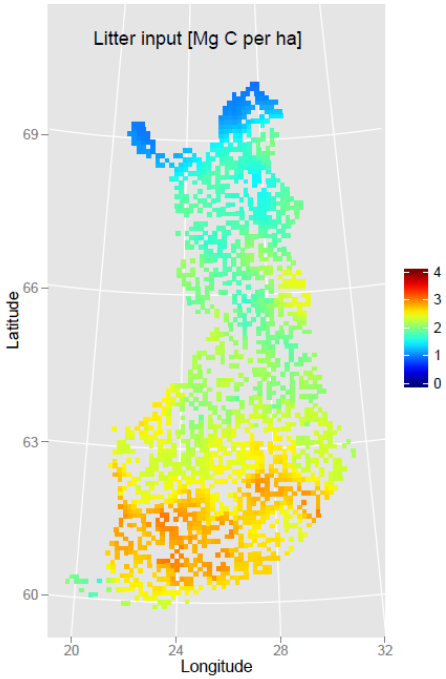
- Updated understorey models (coverage ~ biomass) for litter input estimation, and application with 1995 data (permanent sample plots)

- Regional input from natural mortality and harvesting residues

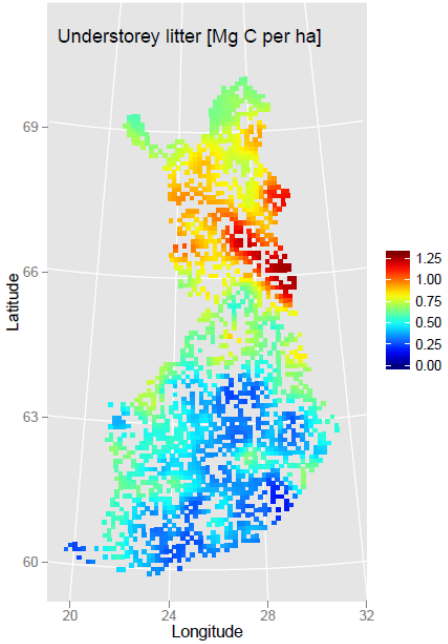
- 10*10km^2 FMI grid for weather data

- Tomppo, E., Heikkinen, J., Henttonen, H.M., Ihalainen, A., Katila, M., Mäkelä, H., Tuomainen, T. & Vainikainen, N. 2011. Designing and conducting a forest inventory - case: 9th National Forest Inventory of Finland. Springer, Managing Forest Ecosystems 21. 270 p.

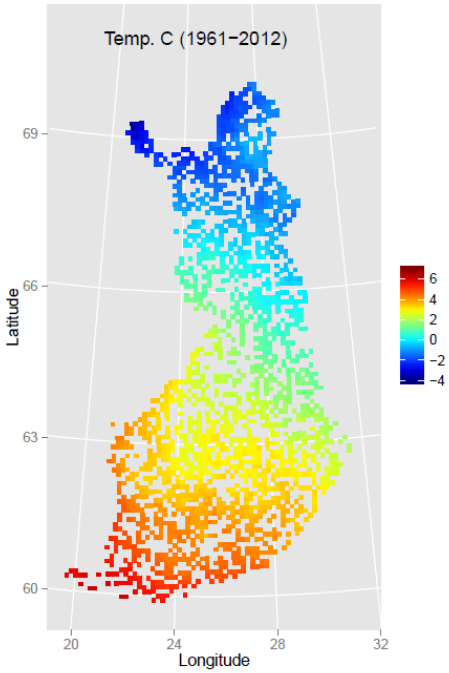
Material and methods



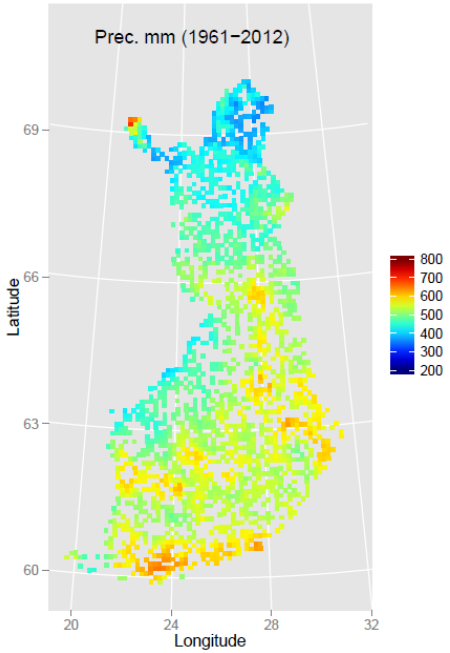
Total litter



Understorey litter



Mean temperature



Precipitation

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Material and methods – ROMUL

- Developed by Oleg Chertov and Alexander Komarov (and others)
- Decomposition of separate cohorts based on litter origins
- Decomposition driven by N and ash content, as well as daily/monthly temperature and soil moisture
- Impact of volumetric soil water content to decomposition by Linkosalo et al. (2013)

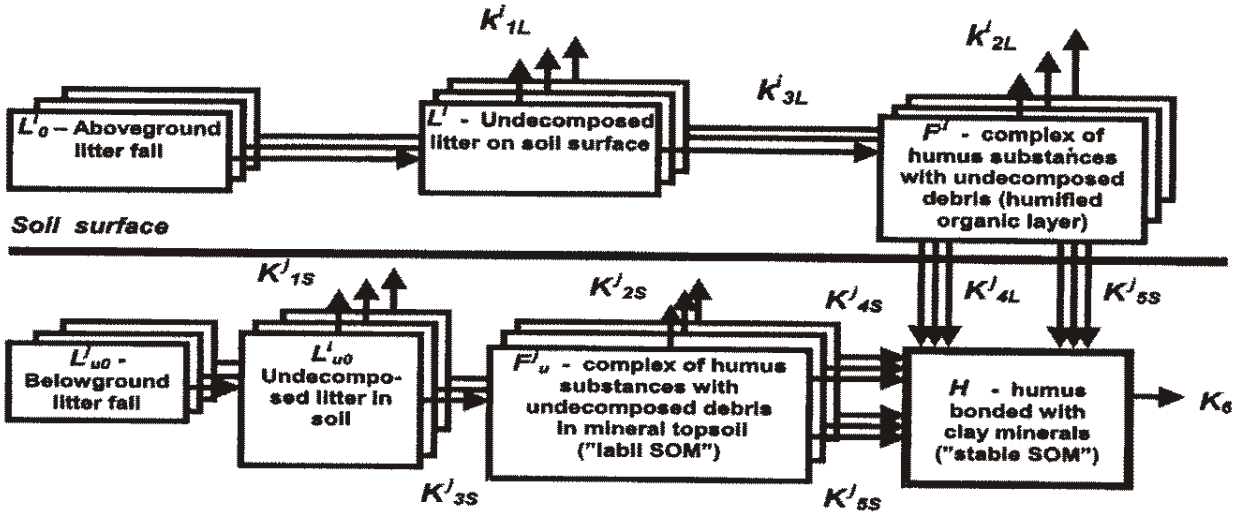

Fig. 1. Flow-chart of ROMUL model.

- Chertov, O. G., et al. "ROMUL—a model of forest soil organic matter dynamics as a substantial tool for forest ecosystem modeling." *Ecological Modelling*138.1 (2001): 289-308.
- Linkosalo, Tapio, Pasi Kolari, and Jukka Pumpanen. "New decomposition rate functions based on volumetric soil water content for the ROMUL soil organic matter dynamics model." *Ecological Modelling* 263 (2013): 109-118.

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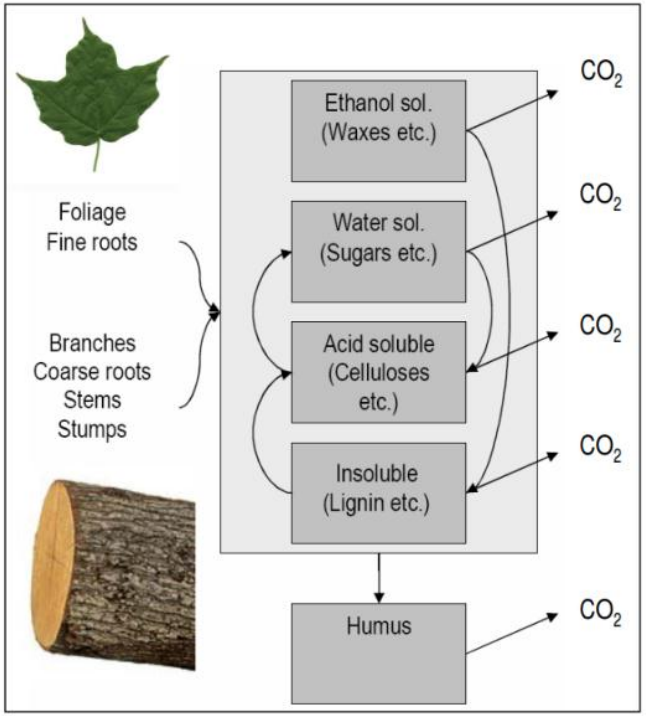
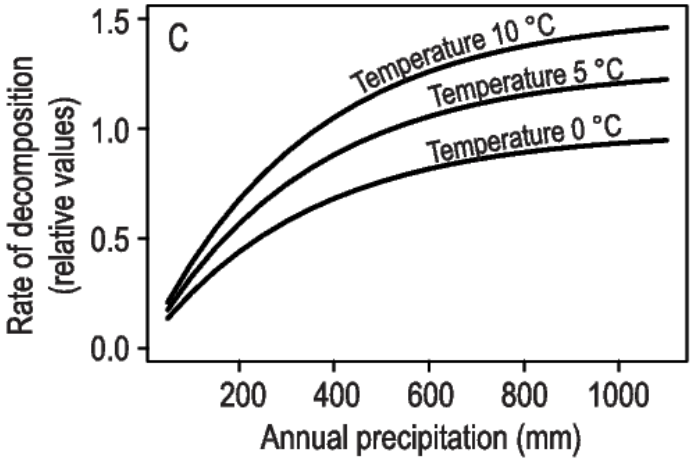
Material and methods – Yasso07

- Developed by Jari Liski and others (Tuomi et al. 2011)
- Markov chain Monte Carlo → uncertainty estimates
- Decomposition rates (5), Carbon fluxes between the pools (13), Climate effects (3), Woody litter decomposition (3) and Litterbag adjustment (2)
- Driven by litter quantity, litter quality, temperature and precipitation

- All transfers between boxes are possible, only significant ones are included (based on MCMC)





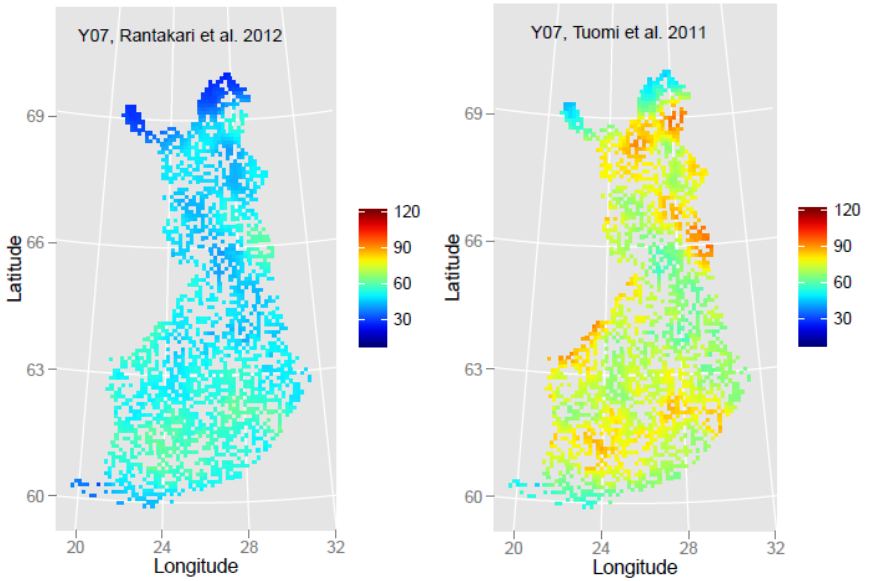
- Tuomi, M., Rasinmäki, J., Repo, A., Vanhala, P. & Liski. J. 2011. Soil carbon model Yasso07 graphical user interface. Environmental Modeling and Software 26 (11): 1358-1362.

Material and methods – soil models

We applied different variants of soil models

1. Yasso07 with Rantakari et al. 2012 parameters (Scandinavian data)
2. Yasso07 with Tuomi et al. 2011 parameters (Global data)
3. Yasso07 with Rantakari et al. 2012 parameters, without understorey vegetation
4. Yasso07 with Tuomi et al. 2011 parameters, without understorey vegetation
5. ROMUL models with constant soil water holding capacity
6. ROMUL models with variable soil water holding capacity
   - SWHC based digital soil map (water that is available for plants)

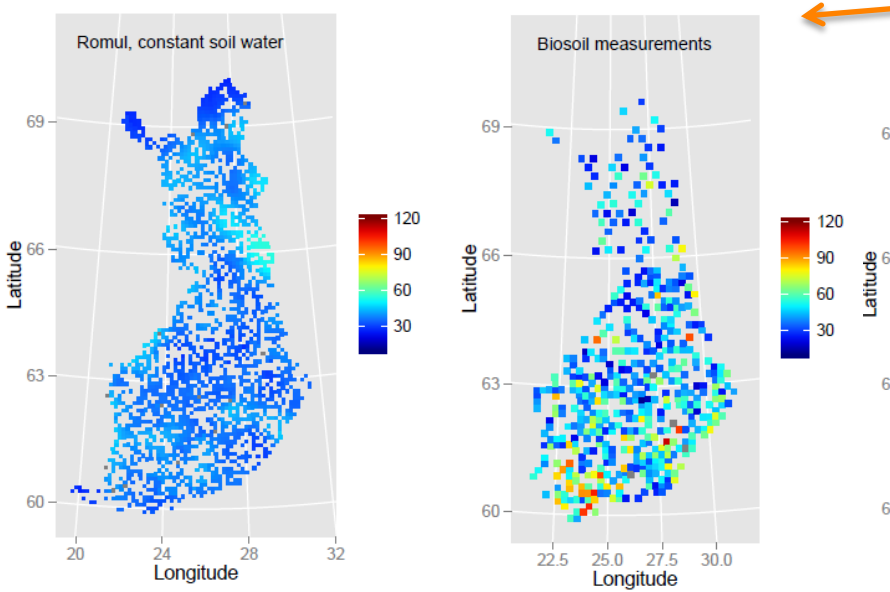
Results – soil carbon maps

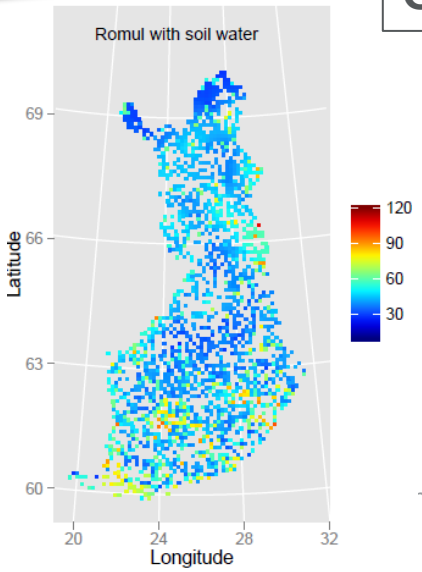


- Yasso07 with Tuomi et al. (2011), based on global data parameters overestimates soil C
- Yasso07 with Rantakari et al. (2012) based on Scandinavian data doing better

- ROMUL with soil water data resemples measurements from Biosoil

Biosoil data, soil C measurements





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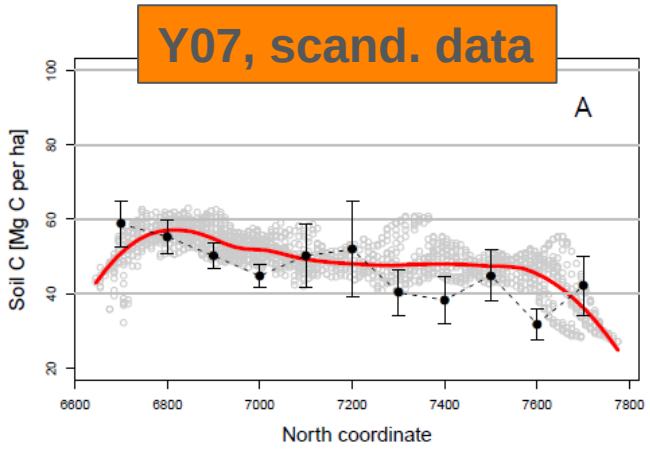
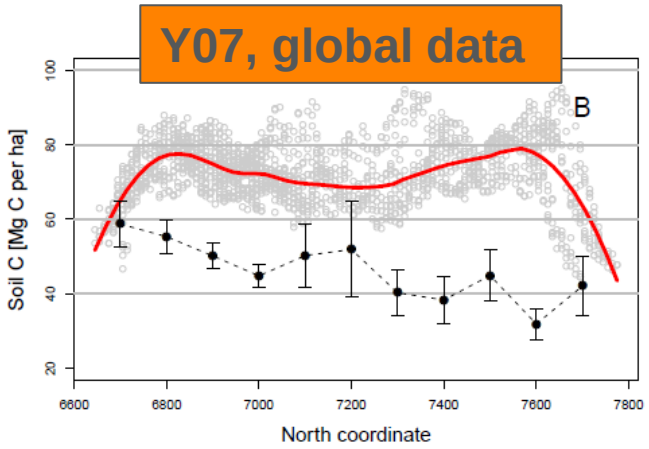
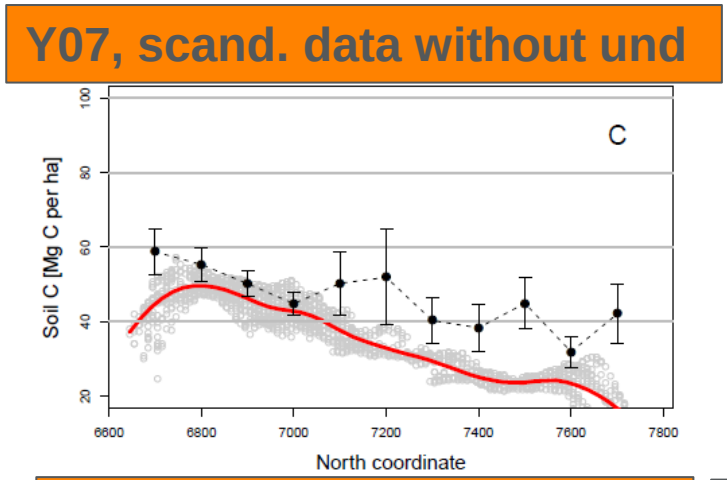
Results – soil carbon by 11 Latitude bands

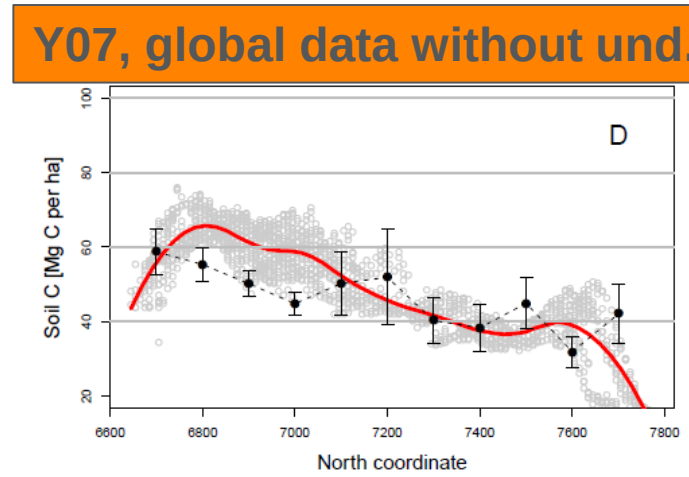
- Grey dots are model esimates
- Red line = mean of model estimates
- Black dots are biosoil means for soil carbon stock

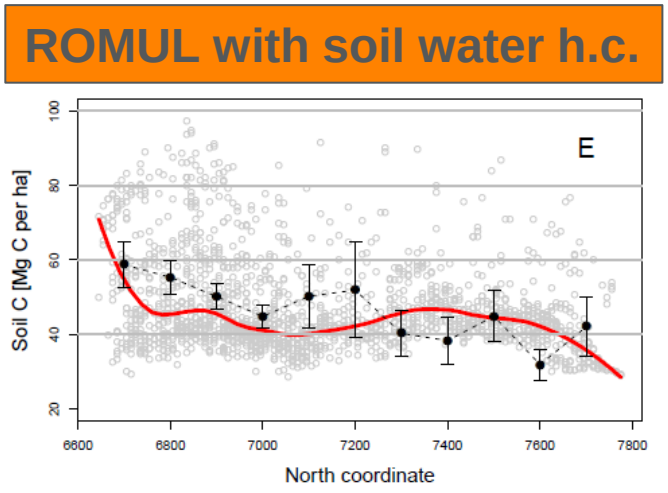
- Yasso07, Tuomi et al. 2011 fails (**B**)
- ROMUL with constant soil water fails (**F**)

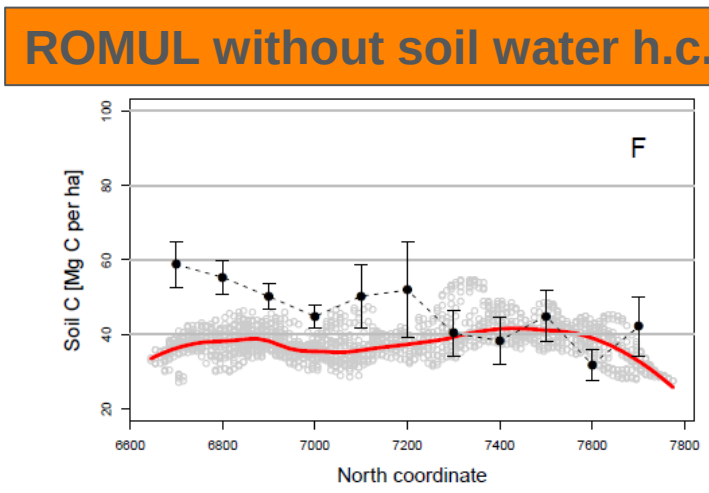






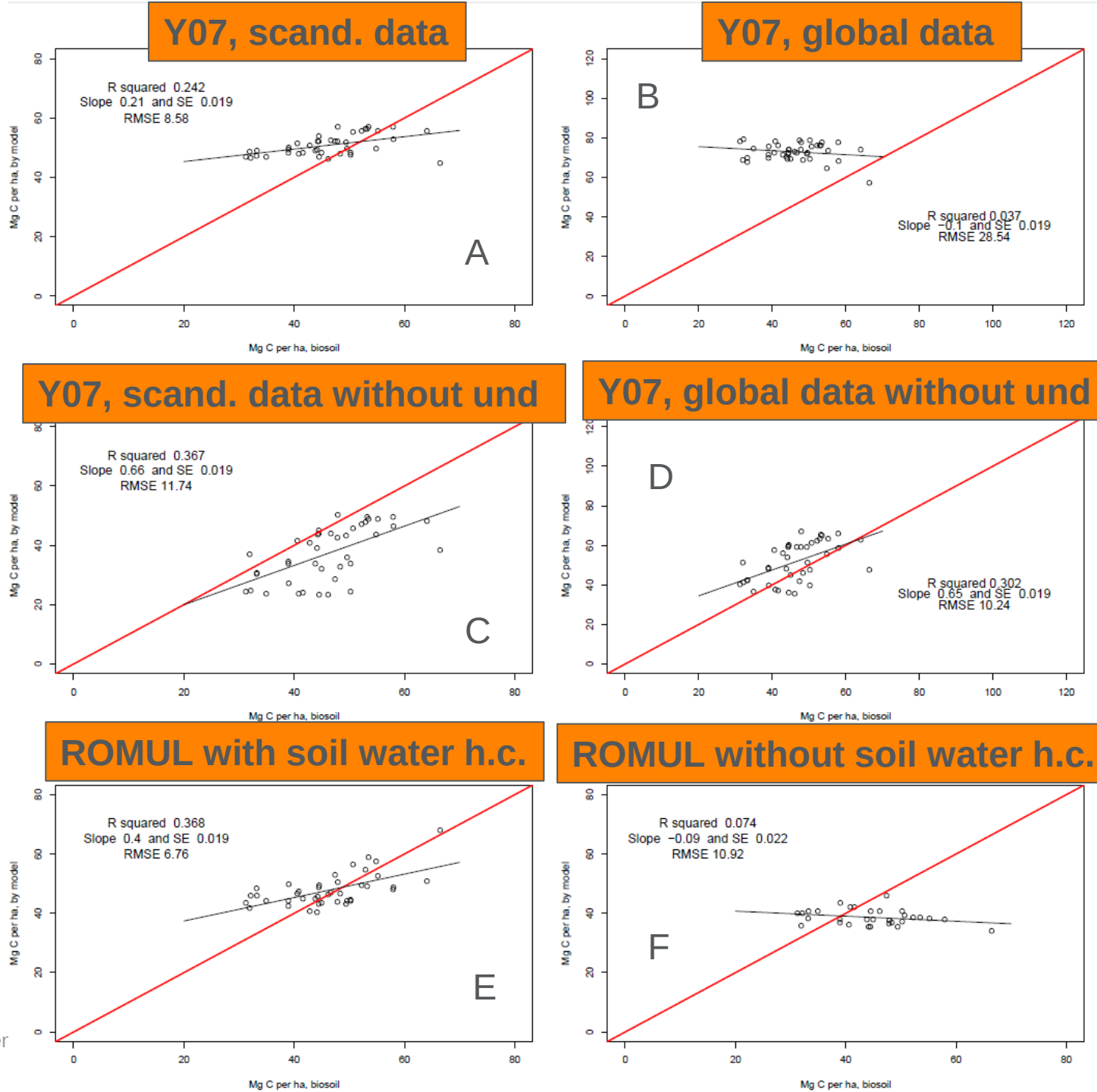






Results – soil carbon by ~40 Latitude bands, one-to-one

- Yasso07, model without understorey vegetation has best slopes (**C** & **D**)
- ROMUL with soil water holding capacity data has the lowest RMSE (**E**)



Results & Conclusions

- Best results against latitudinal trends were obtained with Yasso07 model when understorey litter was excluded
  - Likely understorey litter input has been overlooked when Yasso07 was been parametrised, especially in Northern latitudes

- The litter input of understorey vegetation plays a critical role when estimating soil C stocks, especially in Northern Finland
  - More studies needed for belowground production for understorey vegetation

- Soil water holding capacity data improved ROMUL performance, and the variability of estimated soil C stocks increased substantially

  - It seems that decomposition slows down especially in Southern Finland on soils where have low water holding capacity

- Yasso07 with local parametrisation (Rantakari et al. 2012) was superior when estimating soil carbon stocks on Finnish uplands compared to global parametrisation (Tuomi et al. 2011)

Take home message

Why soil C stocks do not match with measurements ?

- Biased dependency between climate and decomposition (especially with slow carbon)
- Biased litter input - soil carbon stock pairs when models have calibrated (underestimation of undertorey vegetation in North)
- Probably Finnish soils are not in steady state (e.g. due to shifting cultivation history)

Thank you !

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