Risks of carbon loss from the Congo Peatlands due to climate and land use change

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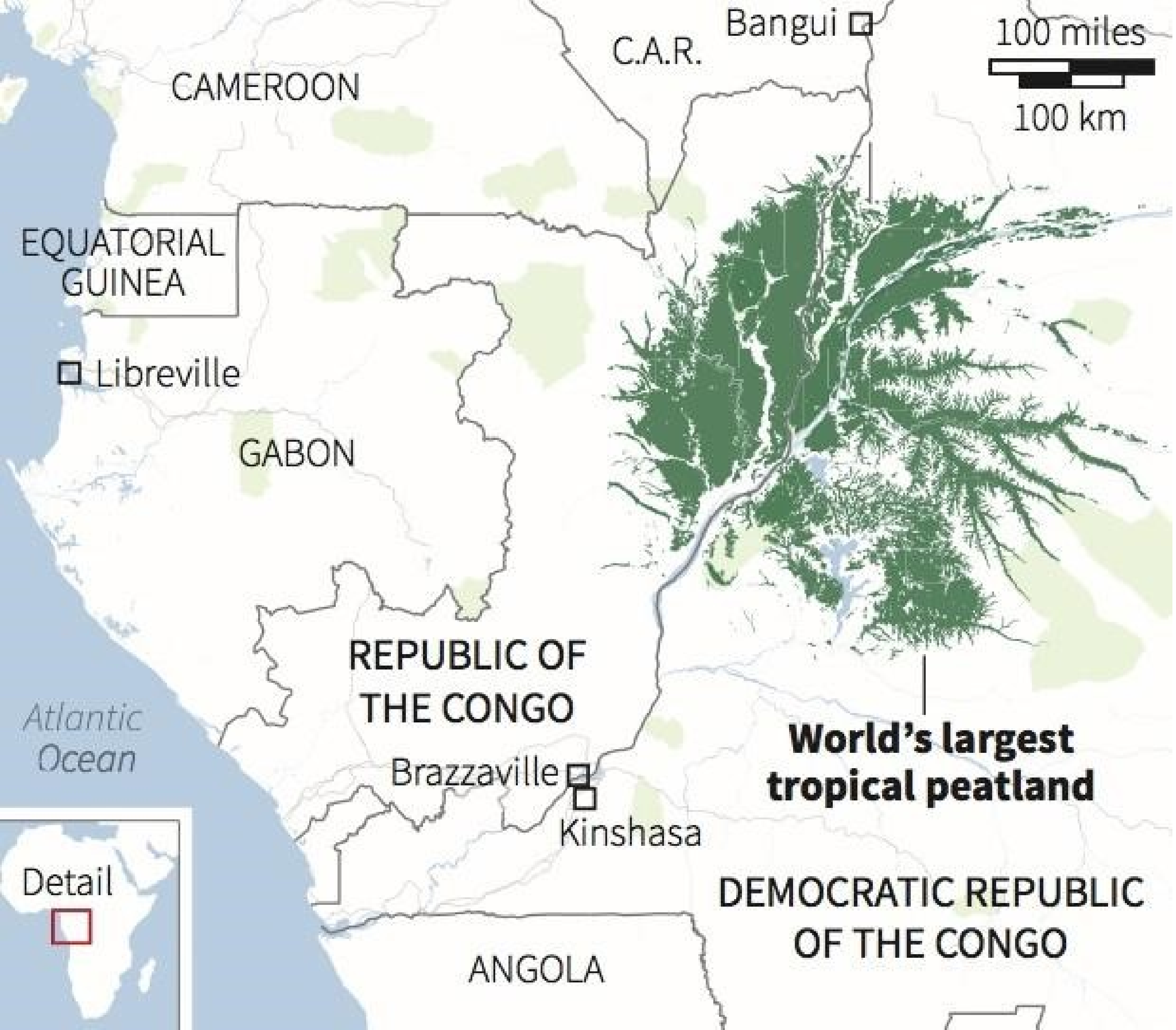
More information about CongoPeat is at: https://congopeat.net

Modelling the Central Congo Basin Peatlands

- The Central Congo Basin contains the largest peatland complex in the tropics, estimated to contain 29 Gt carbon and at present undisturbed
- JULES was used to simulate the development of the swamp forest and peatlands over 20,000 years and then investigate their possible future
- Measurements from soil cores obtained in the CongoPeat project contain a feature in the age-depth profile which implies that a lot of carbon was lost during a long period of reduced rainfall in the past
- A reconstruction of past rainfall from soil core measurements was used to drive JULES and this recreated the growth of the peatlands, the large loss of carbon and the feature in the age-depth profile
- Simulations were then continued to the year 2100 having low or high climate change projections, increased or reduced rainfall from Global Climate Models, and including drainage from possible logging, road building or oil prospecting



Location of the Cuvette Centrale swamp forest and peatlands, with an area of 167,600 Km^2

Areas that are presently protected shown in light green

Image: Reuters

CongoPeat researchers obtaining a soil core during fieldwork in the swamp forest (KEVIN MCELVANEY / GREENPEACE)

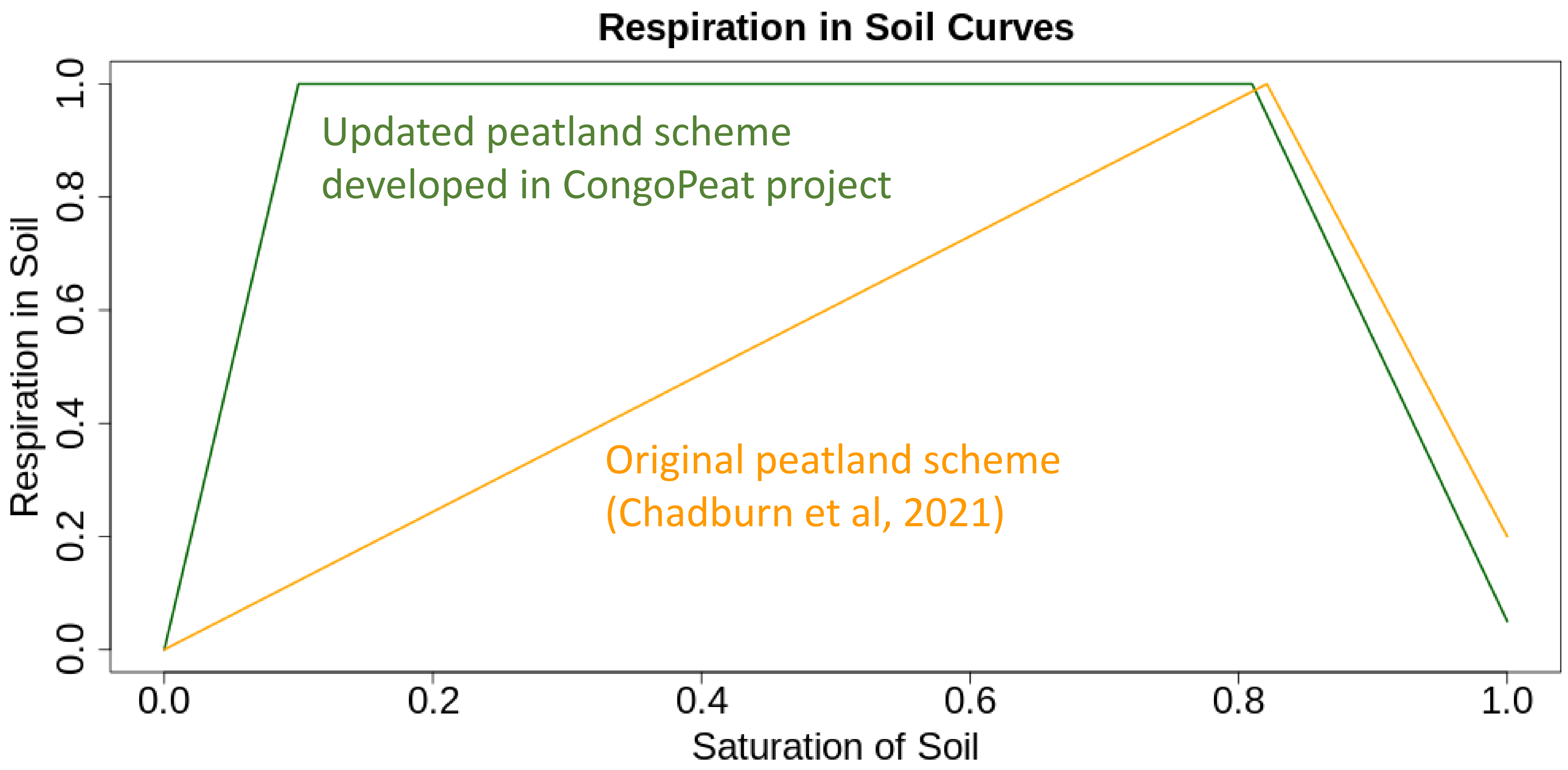
JULES CongoPeat Paleo Runs

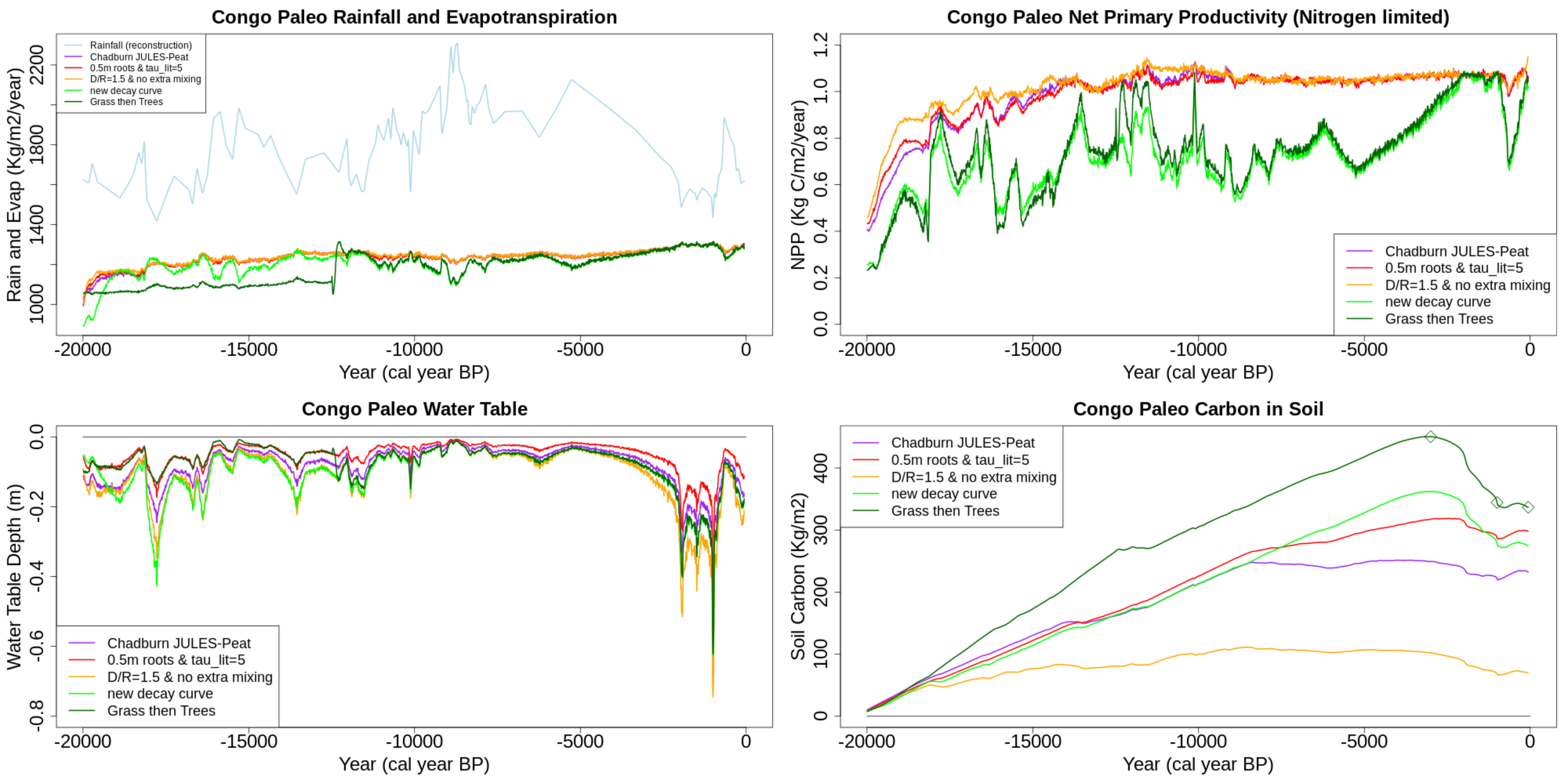
- Aiming to accurately simulate the formation and development of the Cuvette Centrale peatlands, as soil core measurements imply that a lot of peat was lost during drier conditions a few thousand years ago
- 20,000 year model runs at a single location (0N 18E)
- Using a paleo rainfall reconstruction obtained from leaf wax data
- Other meteorological inputs from a HadCM3 paleo climate run
- All runs include complex Nitrogen cycles which can limit the vegetation

Successive Changes to the JULES Paleo Runs

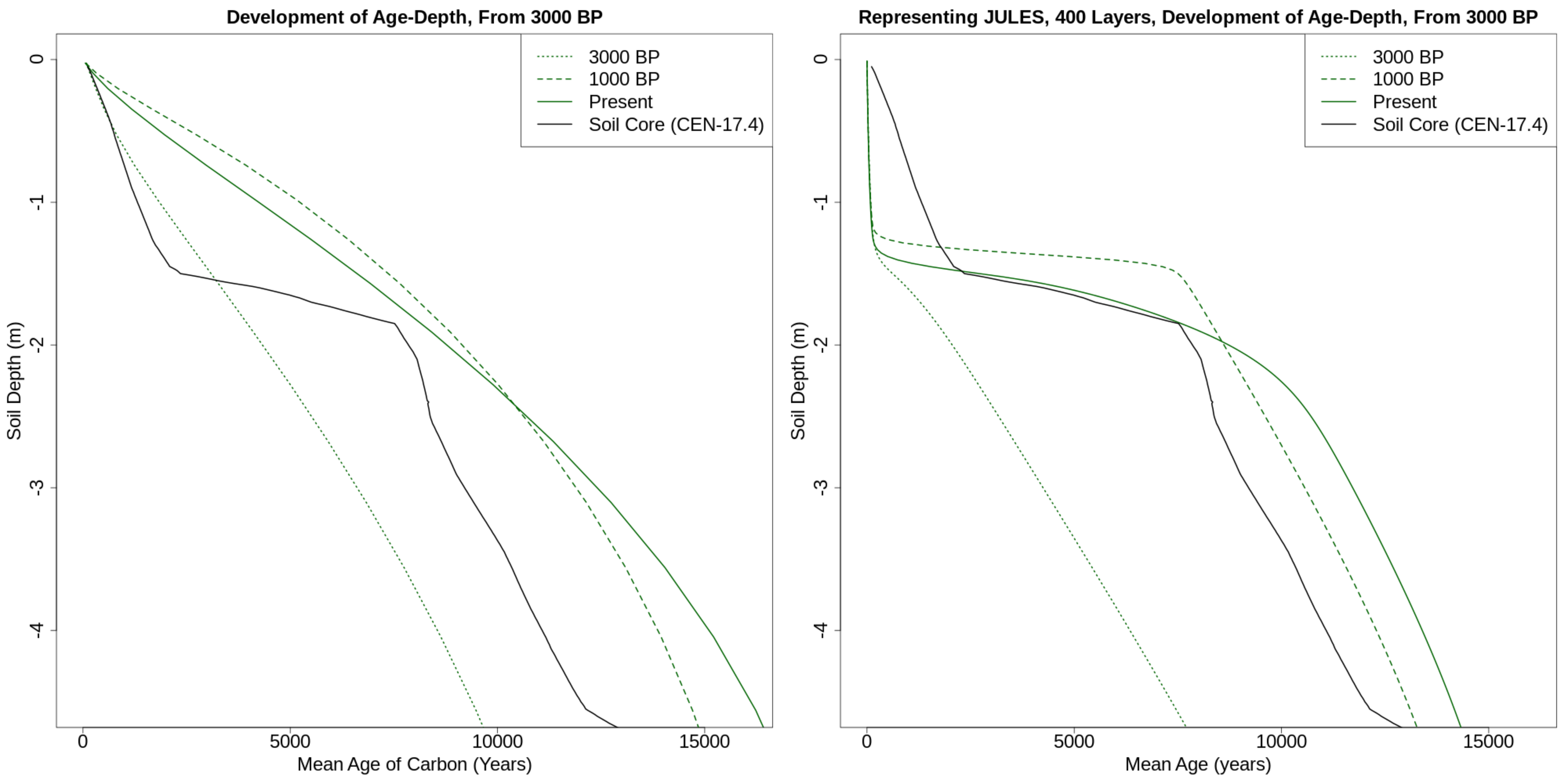
- First paleo run: Using JULES suite u-an231, developed by Sarah Chadburn and Eleanor Burke to accumulate carbon in the soil
- Have clay soil, as measured in the Congo Basin, with no baseflow
- Second paleo run: Short (0.5m) roots on all vegetation as in a swamp forest, with most litter put in near the surface (“tau_lit” is increased to 5)
- Third paleo run: Using litter as measured (60% Decomposable and 40% Recalcitrant), and no extra mixing in the soil from biological processes
- Fourth paleo run: New curve of peat decay (microbial respiration in the soil vs saturation) to give more peat loss in dry conditions and less peat loss in wet conditions
- Fifth paleo run: Begin with grasslands for 7500 years (as measured in some soil cores) followed by mixed vegetation (mostly trees)

Effect of soil saturation level on respiration in peat soils – original and updated scheme





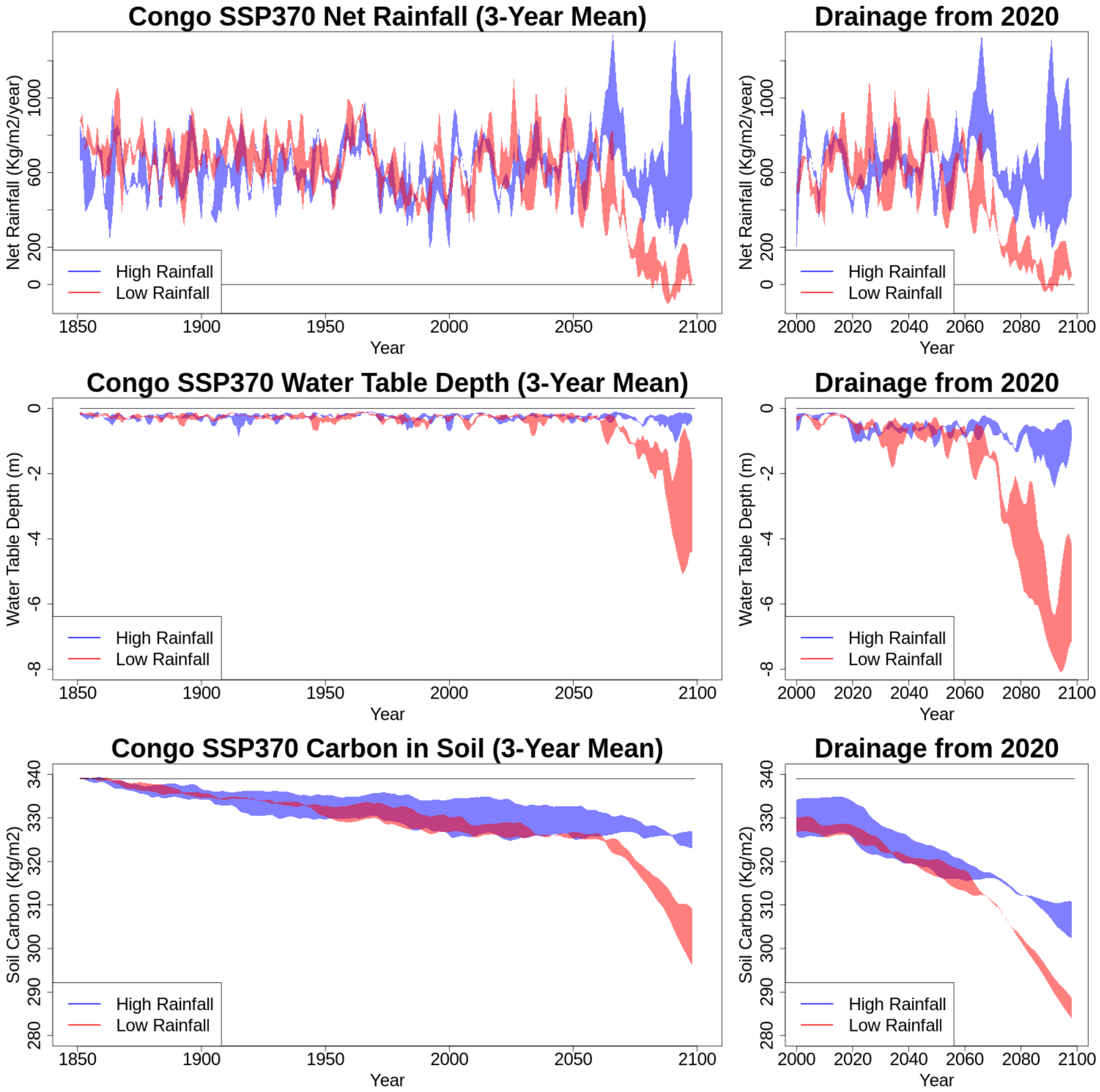
Results from the five JULES paleo simulations, effects from successive changes to the model setup



Development of the age-depth profile in JULES (20 soil layers), compared to a simple model (with 400 soil layers) driven by JULES annual litter and soil respiration, with radiocarbon measurements from a soil core (CEN-17.4)

Paleo Run Results

- Need a strong buildup of peat, but also a strong response to changes in the climate, with a big loss of peat near the end
- The new soil respiration curve leads to less vegetation and productivity due to complex Nitrogen feedbacks, but does result in more peat and a greater response to climate
- Able to recreate the feature in the age-depth profile by putting the annual inputs and losses of soil carbon from JULES into a simple model having much finer vertical resolution, the vertical resolution of JULES is too coarse to see the feature



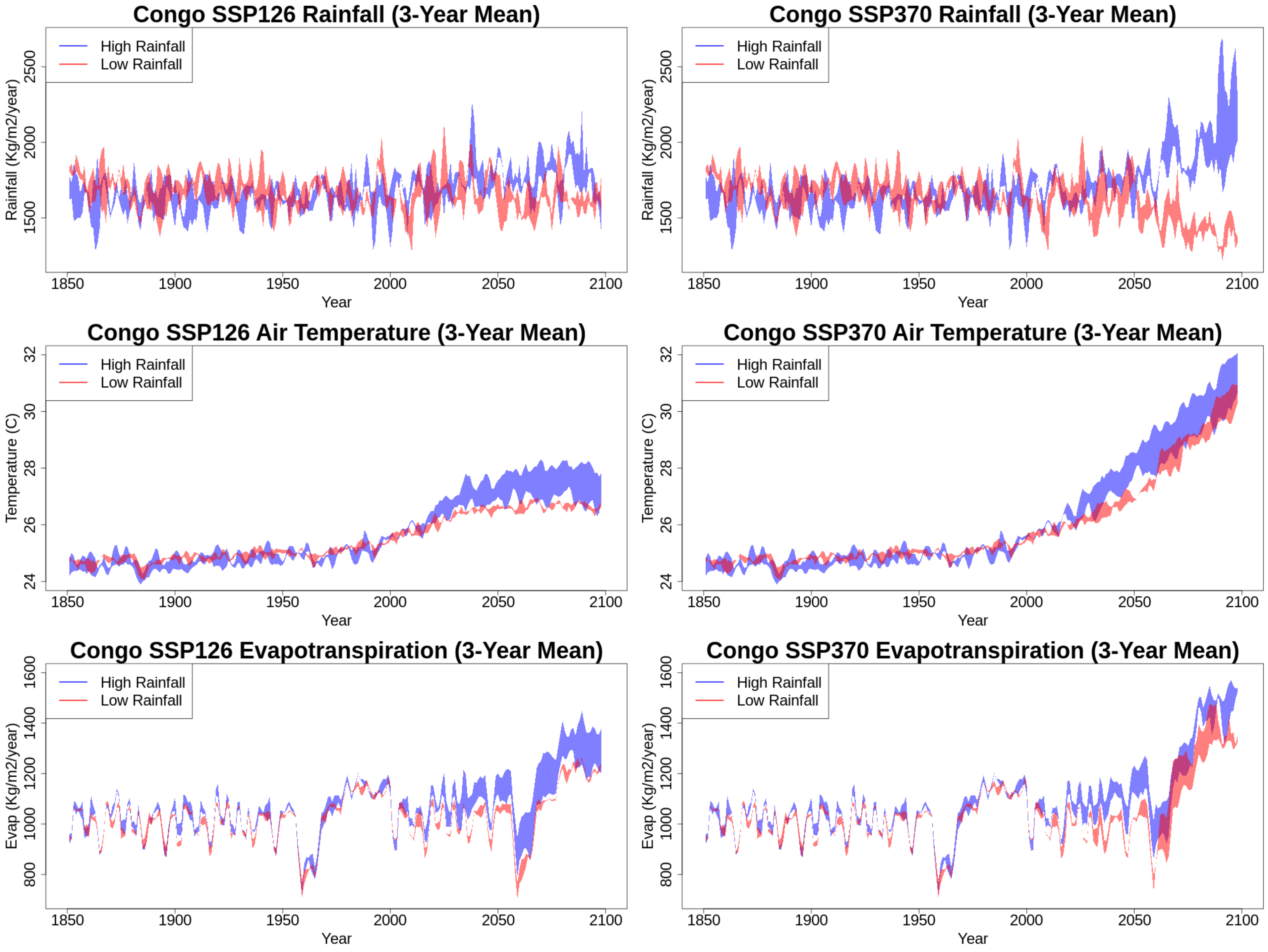
Future simulations starting from the final paleo simulation in 1850, driven by data from four ISIMIP3b global climate models using a high climate change projection (SSP370), examining the ranges from the two GCMs with increased rainfall in the Congo basin in the future (blue) and the two GCMs with reduced rainfall in the future (red), either no drainage throughout or drainage from 2020 to represent disruption of the swamp forest (by possible logging, road building or oil prospecting)

Summary

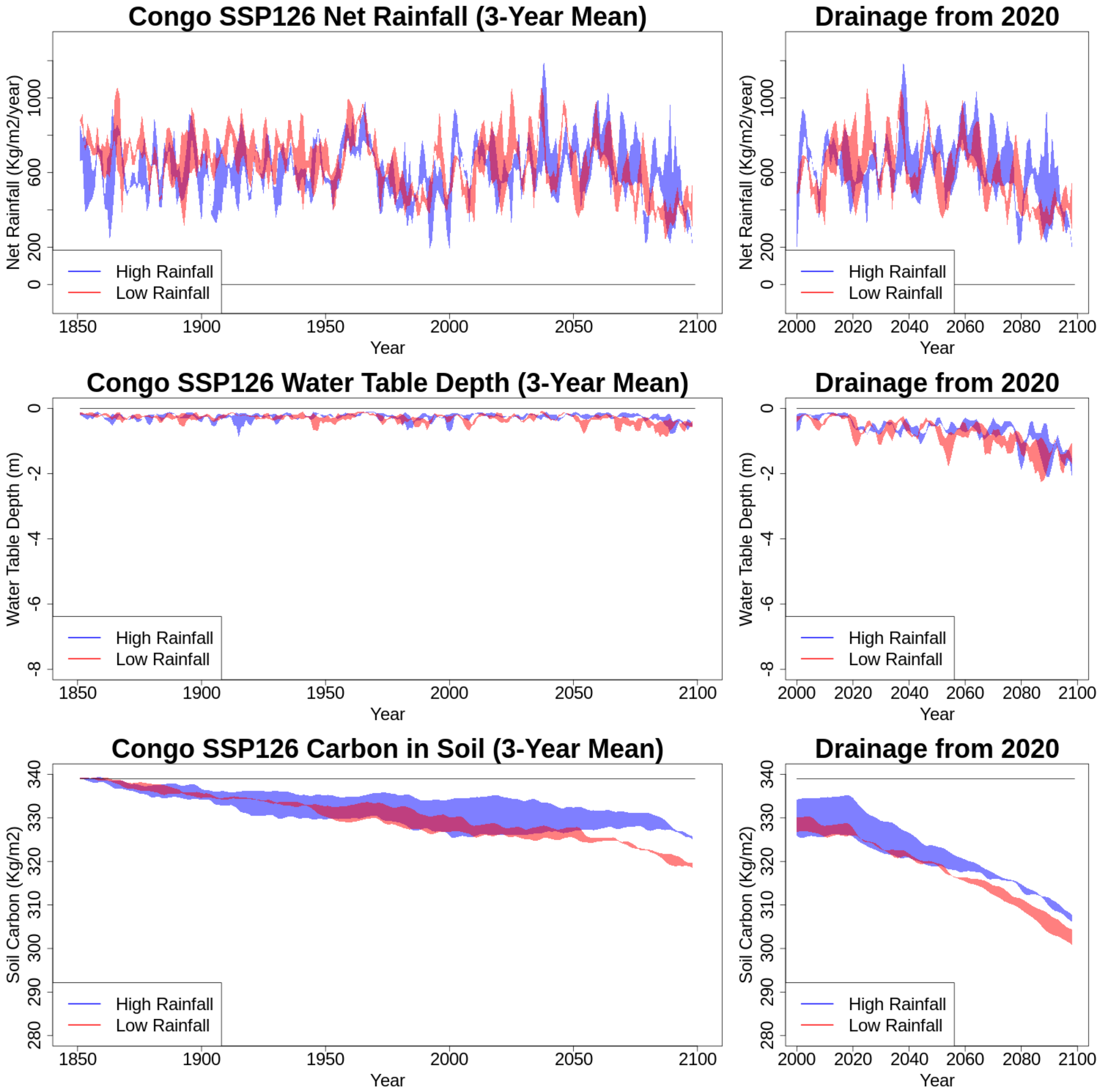
- Following some adjustments to JULES we have been able to recreate the development of the Cuvette Centrale peatlands over 20,000 years with a large loss of carbon in the past 3000 years
- Including the recreation of the feature in the age-depth profile by increasing the vertical resolution of the model
- With confidence in JULES we have examined a range of future scenarios
- All the future simulations have some loss of carbon before 2100, but the losses only become significant in either high climate change projections with reduced rainfall, or when drainage is introduced due to possible logging or oil prospecting
- The peatlands remain sensitive to drying/disruption of the swamp forest
- If the greatest fractional losses were to happen across the whole Cuvette Centrale as much as 5 Gt carbon could be emitted before 2100, which is equivalent to 6 months of global CO_2 emissions

JULES CongoPeat Future Runs

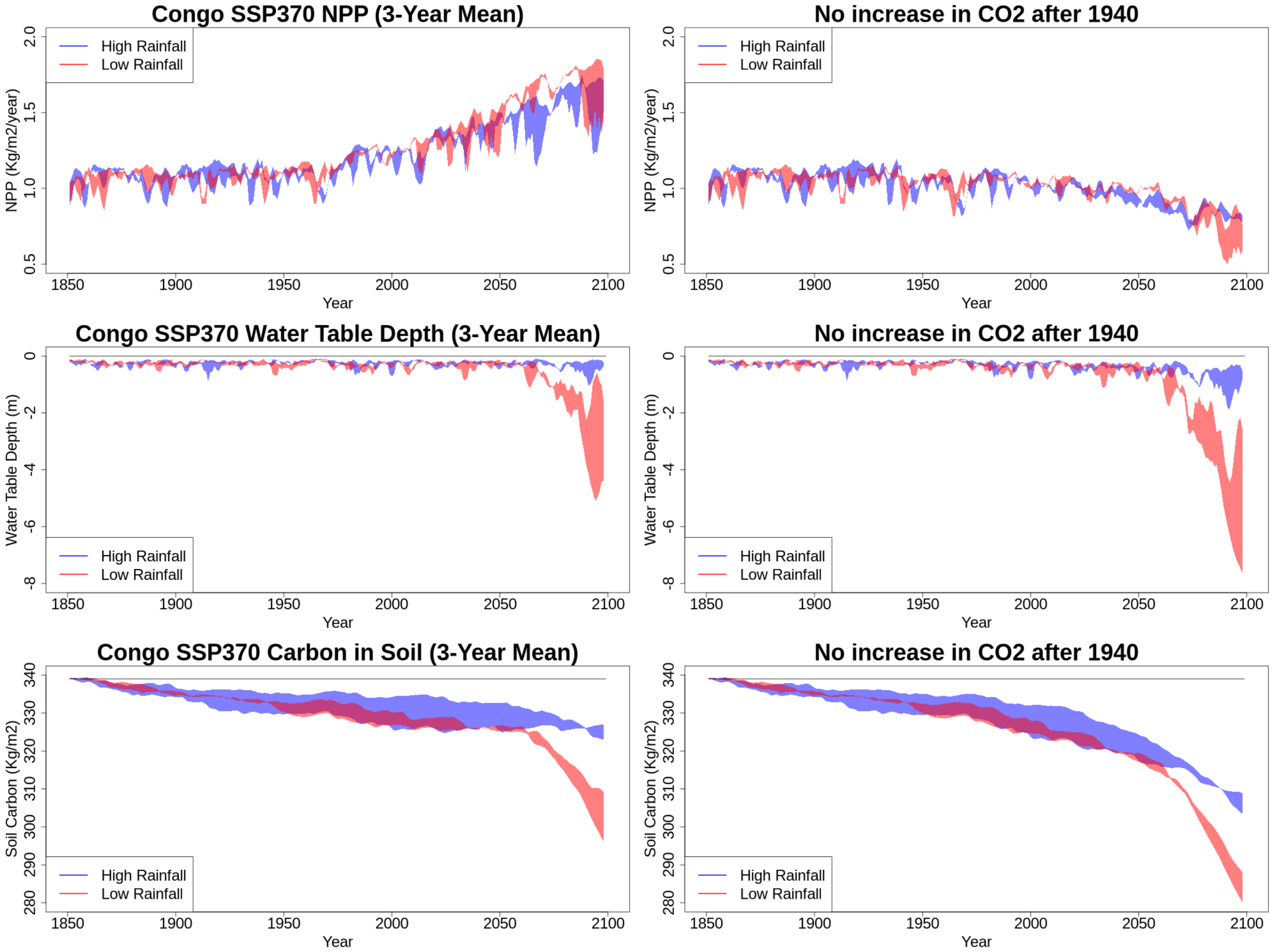
- Also examining the effects of future climate projections on the Cuvette Centrale peatlands, without any other disruption of the swamp forest
- Starting with a reasonable peat profile (339 Kg/m^2) and stable vegetation in 1850, JULES was driven with 251 years of data (1850-2100) from 4 ISIMIP GCM's (global climate models), at 2 climate projections (SSP126 and SSP370), and using the associated CO_2 concentrations and Nitrogen depositions
- Also examining the CO_2 fertilization effect by runs using a high climate projection (SSP370) but with no increases in CO_2 after 1940
- The 4 global climate models used here are: the UK Met Office Hadley Centre Earth System Model (UKESM), the Meteorological Research Institute of Japan Earth System Model (MRIESM), L'Institut Pierre-Simon Laplace in France (IPSL), and the NOAA Geophysical Fluid Dynamics Laboratory in the USA (GFDL)



Driving data from four ISIMIP3b global climate models using a low (left) or high (right) climate change projection, the ranges from the two GCMs with increased rainfall in the Congo basin in the future (blue) and the two GCMs with reduced rainfall in the future (red), showing the rainfall and temperature values used to drive JULES and the resulting evapotranspiration



Future simulations starting from the final paleo simulation in 1850, driven by data from four ISIMIP3b global climate models using a low climate change projection (SSP126), examining the ranges from the two GCMs with increased rainfall in the Congo basin in the future (blue) and the two GCMs with reduced rainfall in the future (red), either no drainage throughout or drainage from 2020 to represent disruption of the swamp forest (by possible logging, road building or oil prospecting)



Future simulations using a high climate change projection (SSP370), with or without CO_2 fertilization

Future Run Results

- All of the future runs show a drop in the water table and a decline in the amount of soil carbon
- Though the end of the paleo run also has a slow decline in soil carbon
- However, the losses in soil carbon only become significant in the high projections with decreased rainfall and/or introduced drainage, both of which lead to larger drops in the water table
- Runs using a high projection but no increase in CO_2 show that increased vegetation and productivity are largely due to increased CO_2 and that the drop in the water table and decline in soil carbon would be even greater without the vegetation responses to CO_2
- Hence peat loss occurs in-spite of the increased vegetation and litterfall due to the fertilisation from increased CO_2, and in-spite of some reduction in plant transpiration also due to increased CO_2