Modelling Seasonal Variations in Water Table Depth over the Tropical Peatlands of Riau, Sumatra, Indonesia

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Introduction

- The severe El Niño episode of 2015 led to a major and damaging increase in Indonesian peatland fires, highlighting an urgent need to develop operational systems to forecast potentially severe fire events to mitigate the impacts of fire and haze.
- The 2002 *ASEAN Agreement on Transboundary Haze Pollution*, signed and ratified by a total of 10 ASEAN states, including Indonesia since 2014, identifies a critical need for such systems based on near-time climate projections (e.g. seasonal forecasts).
- We are developing an operational early warning system for forecasting fires across Indonesia through a project titled *Towards a Fire Early Warning System for Indonesia* (ToFEWSI). ToFEWSI uses state-of-the-art climate model data, in particular, outputs from the European Centre for Medium-Range Weather Forecasts' (ECMWF's) reanalysis system (ERA5) and System 5 seasonal forecast model (SEAS5).
- However, development of an early warning system is still hindered by insufficient knowledge about the influence of fluctuations in peat moisture on fire, particularly during periods of extreme drought (e.g. 1997-98 and 2015 El Niño episodes).
- **The main objectives of this study (which forms part of ToFEWSI) were to:**
  - **i. initialise and run the process-based ecosystem model *ecosys* to study how water table depth (WTD) and peat moisture profiles change in tropical peatlands across Riau province, Sumatra, in response to drought and land cover change, focusing on the 2015 El-Niño event; and**
  - **ii. examine whether those changes could have been predicted using SEAS5.**

Methods

- *Ecosys* is a process-based model that can simulate 3D water, carbon, nitrogen, phosphorus and heat balances of tropical peatlands (Figure 1), and it has been benchmarked against high resolution site-level observations over tropical peatlands (Figure 2).
- After successful site-level validation, the model was scaled up to the provincial level for Riau by using 5km x 5km grid scales (Figure 2).
- Model spin-up from 2008-2014 was driven by inputs from ECMWF's climate reanalysis data (ERA5) and Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) data, followed by a baseline simulation run for 2015 (Figure 2).
- Model inputs for peat soil properties for 9 vertical layers, peat depths and land use and land cover (LULC) details were gathered from published regional and global soil and LULC datasets (e.g. Figures 3 and 4) (Table 1). Peat/Mineral soil properties from 1-2 m depths were used as model inputs for depths below 2 m where there was no data available.

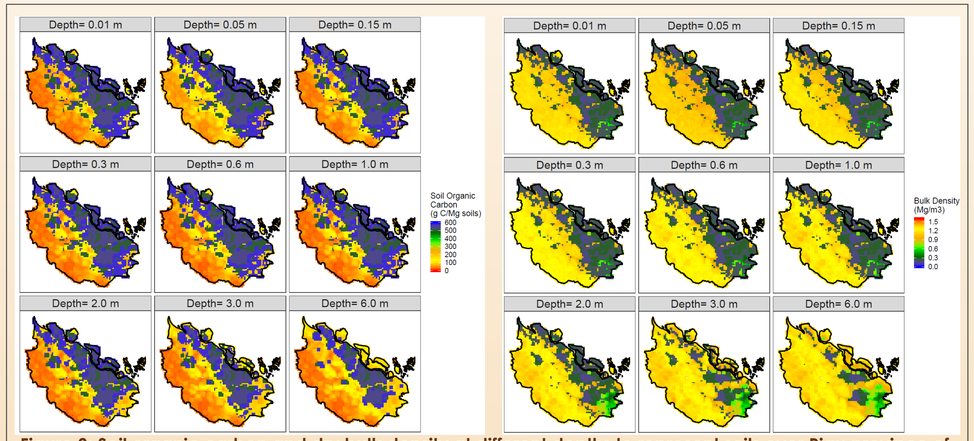

Figure 3: Soil organic carbon and dry bulk density at different depths to represent soils over Riau province of Indonesia in *ecosys* model

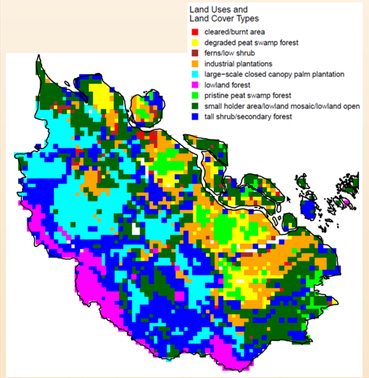

Figure 4: Land use and land cover types over Riau province of Indonesia as represented in ecosys model

Table 1: Dominant plant functional types in "ecosys" model to represent the land use and land cover types over Riau province of Indonesia as depicted in Figure 5

Land Use and Land Cover (LULC) types	Plant Functional Types (PFTs) representing the LULC types in "ecosys" model
Cleared/burnt areas	Bushy shrubs
Degraded peat swamp forest	Peat swamp species
Ferns/Low shrub	Bushy shrubs
Industrial plantations	Oil palm (60% area) + *Acacia* (40% area)
Lowland forest	Tropical evergreen tree species
Pristine peat swamp forest	Peat swamp species
Small holder area/lowland mosaic/lowland open	Upland rice (2 crops/year) + Lowland rice (1 crop/year) + Bushy shrubs; all three PFTs had equal area coverage.
Tall shrub/secondary forest	Tropical evergreen tree species

Preliminary Results

1. CHIRPS precipitation data showed distinct seasonality over Riau during the El Niño year of 2015 with
   - ❖ two brief dry seasons i.e., mid-January to mid-February and mid-June to end of July and
   - ❖ a prolonged and intense dry season from mid-August to end of October (Figure 5).
2. Ecosys outputs showed how soil(peat) moisture and WTD were significantly affected by weather and land uses during the dry season of 2015. Half-monthly averaged modelled water filled porosity (=soil or peat moisture content / total porosity*100) in near surface (0-5 cm depth) showed strong seasonality, similar to that of precipitation (Figures 5 and 6).
3. However, modelled water filled porosity also varied spatially reflecting spatial variation in precipitation, soil and land use types. Generally, peat soils under highly productive industrial plantations and closed canopy oil palm plantations (Figure 5) (Table 1) exhibited the highest rates of near surface soil (peat) drying during the dry spells (Figure 6).
4. Modelled water table depth (WTD) also showed temporal variability following the seasonal cycles in precipitation. Spatial variability in modelled WTD was predominantly controlled by the difference in soil physics properties (e.g. percolation rates) between peat versus mineral soils (Figure 7).
5. Modelled WTD in peat soils frequently dropped below 50 cm (and sometimes deeper) from the ground surface during the three dry spells (Figure 7).
6. Modelled WTD in mineral soils, however, dropped close to 3 m below the ground surface during the dry spells (Figure 7).

❖ **These preliminary results demonstrate the promise of using the process-based ecosystem model *ecosys* in understanding and predicting seasonal and spatial variations in tropical peatland subsurface hydrology, which would facilitate an operational early fire warning system for Indonesia.**

Next Steps…

- Validate the spatio-temporal variability in moisture and water table depth against available remotely sensed data products, e.g. Soil Moisture Active Passive (SMAP). Current outputs from the baseline model run would be compared with another parallel run by using SEAS5 weather data to examine whether these changes in soil moisture and water table depth could have been predicted using SEAS5. Continued site-level model validation as data becomes available.

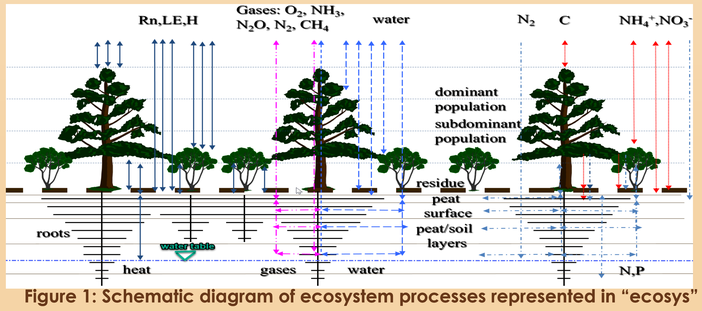

Figure 1: Schematic diagram of ecosystem processes represented in "ecosys"

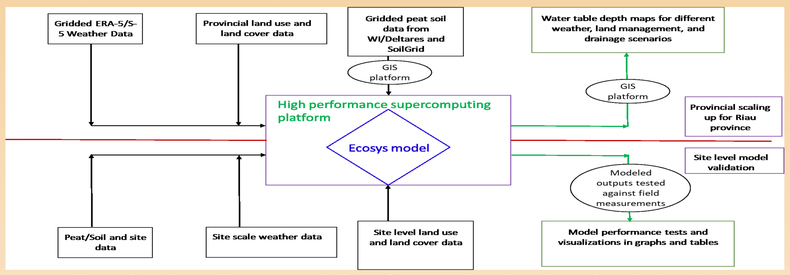

Figure 2: Schematic representation of research protocols and project activities

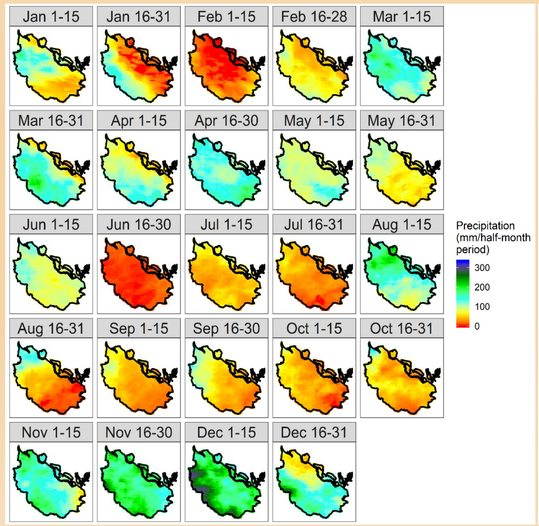

Figure 5: Half-monthly precipitation over Riau province of Indonesia used as inputs into *ecosys* model

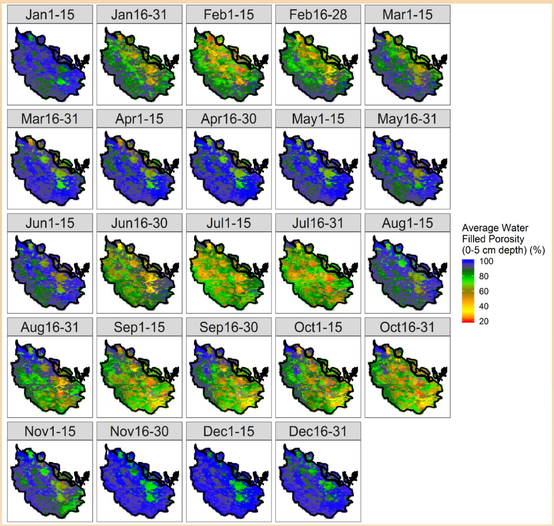

Figure 6: Half-monthly average modelled water filled porosity over Riau province of Indonesia

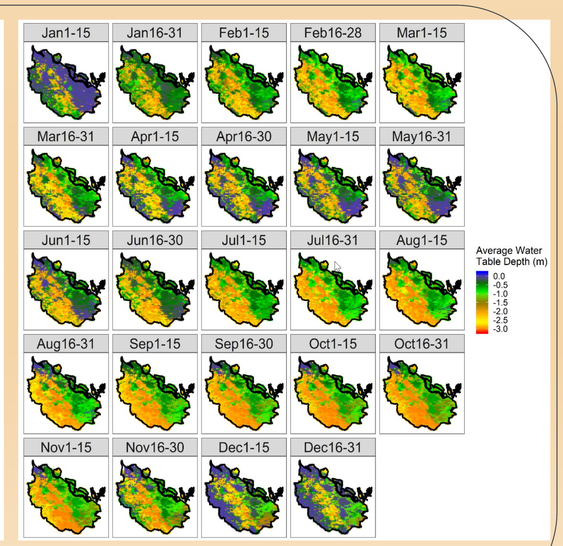

Figure 7: Half-monthly average modelled water table depth over Riau province of Indonesia. Negative values are depths below the ground