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Modelling large-scale seasonal variations in water table depth over tropical peatlands in Riau, Sumatra

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Water table depth (WTD) is the predominant biophysical control over the occurrence of peat and forest fires and greenhouse gas emissions in tropical peatlands. In Indonesia, prolonged droughts caused by El-Niño and/or positive Indian Ocean Dipole, exacerbated by extensive peat drainage for agriculture and plantation establishment, can promote severe peatland fires by lowering WTD and hence desiccating surface and sub-surface peats. These peatland fires create local health hazards and cause irreversible damages to peatland ecosystems. 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). However, such systems have not yet been developed. While an operational early warning system for forecasting dangerous burning conditions is currently within reach using state-of-the-art modelling tools, such as the ECMWF's System 5 seasonal forecast model (SEAS5), development is still hampered 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 were: i) initialise and run the process-based ecosystem model "ecosys" to study how 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. "Ecosys" has been rigorously tested against high resolution site-level observations over tropical peatlands. Model spin-up from 2008-2014 was driven by inputs from ECMWF's climate reanalysis data (ERA5), followed by a comparison of three model runs for 2015, driven by i) ERA5, ii) ERA5 climatology, and iii) SEAS5 hindcasts. Model inputs for peat soil properties, peat depths and land use and land cover (LULC) details were gathered by using several mosaics from published regional and global soil and LULC datasets. The modelled landscape for Riau province was divided into 5kmx5km grid-cells excluding open water bodies, and seasonally-flooded and urban areas. Model inputs were up- or down-scaled according to grid cell size of the modelled landscape. The model outputs of peat moisture profiles and WTD showed how peat moisture and WTD were significantly affected by weather and land uses during the dry season of 2015, and these results were predictable based on SEAS5.

Our work is a pioneering attempt to perform large-scale process-based modelling to predict seasonal variations in tropical peatland WTD. We report on the benchmarking of "ecosys" outputs against remotely sensed datasets e.g. Soil Moisture Active Passive and site-level monitoring networks. This study forms part of the Towards a Fire Early Warning System for Indonesia (ToFEWSI) project (2017-2020), funded by UK's National Environment Research Council (NERC) and Indonesia Endowment for Education (LPDP).