Appendix S1. Modelling inundation under climate change

**Climate forcing**

To model inundation under climate change, we drew on simulations from two climate models (HadGEM2-ES and IPSL-CM5A-LR), each using the Representative Concentration Pathway RCP 6.0 for climate forcing. The selected climate forcing follows RCP 6.0 as a medium stabilization scenario that corresponds to a long-term trend in global greenhouse gas emissions without explicit mitigation measures to reduce greenhouse gas emissions (Masui et al., 2011). The continuing rise in emissions lead us to the selection of the medium stabilization scenario as the large-scale deployment of negative emission technologies (NETs) is still at the beginning (Smith et al., 2016). With regards to future climate change, under RCP 6.0 the global mean surface temperature is likely to exceed 2°C compared to the average from year 1850 to 1900 yet unlikely to exceed 4°C. The projected change in global mean surface air temperature was calculated in a likely range between 0.8°C to 1.8°C for the 2050s compared to the reference period 1986-2005 (IPCC, 2013). As temperature increases, the contrast between dry and wet regions as well as the contrast between wet and dry seasons will be more pronounced. Climate change is expected to alter renewable freshwater resources in many regions of the world, some regions get drier, other regions wetter and some experience no considerable changes. In summary, the expected climate change impacts of an RCP 6.0 driven climate forcing are likely higher compared to the mitigation pathway (RCP 2.6).

**Simulation of river discharge**

Most global hydrological models that simulate river discharge into the future do not produce spatially explicit inundation estimates. To address this problem, we developed a new inundation model (Anand 2018) that builds on simulated future river discharge estimates to produce high resolution maps of predicted future changes to annual inundation patterns. As a result, our new approach links the simulated river discharge with their likely change in inundated area.

River discharge estimates from the global integrated water balance model WaterGAP (Döll *et al*. 2003), accounting for anthropogenic water abstractions, served as inputs to the new inundation model. Long-term monthly averages for the years 1971-2000 from WaterGAP version 2.2 (Müller Schmied *et al*. 2014) were used as the baseline present-day river discharge values. These estimates were spatially downscaled from their original ~50 x 50 km grid cell resolution to the 500 x 500 m cells of the HydroSHEDS river network (Lehner *et al*. 2008) using geo-statistical techniques (Lehner and Grill 2013). For the simulation of future conditions, average monthly river discharge changes (in percent) between the present day (1971-2000) and the future scenario of 2050 (2036-2065) were obtained from the WaterGAP version 3 model at ~9 x 9 km grid cell resolution (Eisner 2016, Flörke *et al*. 2018) and downscaled to the 500 x 500 m resolution of analysis using similar geo-statistical techniques. These percent changes were then applied to the present-day river discharge from WaterGAP 2.2, for which the inundation model was calibrated, to produce future river discharge estimates for use in the inundation model.

**Discharge-inundation threshold in ‘floodsheds’**

We divided the present-day maximum observed inundated extent from GIEMS-D15 (Fluet-Chouinard *et al*. 2015) into discrete spatial zones, termed ‘floodsheds’, which were delineated as areas that vary coherently in their inundation dynamics and thus likely share a common source of inundation (Anand 2018). For each floodshed, a representative discharge sampling location on the HydroSHEDS river network (typically at the zone’s outlet) was determined to establish an association between modelled discharge estimates and observed flooding. In each of the floodsheds, the monthly GIEMS-D15 inundation extent was then correlated with monthly river discharges (1971-2000) to identify local streamflow thresholds that corresponded with observed abrupt changes in the inundation and drying regimes. Finally, the floodshed-threshold model was applied to produce monthly maps of inundation for the present day and for both future scenarios, and three environmental predictors were derived to estimate deviations from the present-day annual inundation patterns; i.e., the extent of permanently inundated areas, the extent of seasonally inundated areas, and the standard deviation of inundation duration; see also Table 1).

We used a threshold approach rather than fitting statistical discharge-inundation relationships to avoid potentially erratic estimates over regions where inundation and discharge do not tightly covary. In a validation, the resulting model was able to correctly simulate present-day inundation within one month of the GIEMS-D15 inundation durations (months year-1) for 92% of the flyway area, demonstrating its ability to predict variation in inundation over large regions.

**Limitations**

The floodshed-based inundation model is constrained to the area experiencing annual inundation under present conditions. This method thus cannot predict an expansion of inundation into areas that are currently dry year round, nor can it predict the loss of permanent inundation (e.g., drying of lakes). Moreover, although WaterGAP simulates the effect of anthropogenic water abstractions on its estimated river discharge, neither GIEMS-D15 nor the floodshed-inundation model explicitly account for infrastructure and landscape modifications in their modelling approaches. In highly modified regions, direct anthropogenic impacts such as the construction of dams or flood protection infrastructure will likely have the largest impact on specific local inundation patterns. Despite the uncertainty arising from future modifications to the hydrological landscape, which cannot be known at present, we argue that the general patterns shown in the floodshed-inundation model can distinguish regional trajectories of inundated habitat.

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