Supplementary material for

Potential effects of climate change on inundation patterns in the Amazon basin

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S1. Detailed description of the calculation of routing velocity

Based on the DEM we calculate the east-west elevation gradient $\delta Z/\delta X$ (Eq. S1) and the north-south elevation gradient $\delta Z/\delta Y$ (Eq. S2) for each cell$_{i,\,j}$ with i and j defining the cell's spatial position using

$$\left[\frac{\delta Z}{\delta X}\right]_{i,j} = \frac{(Z_{i+1,j+1}+2Z_{i+1,j}+Z_{i+1,j-1})-(Z_{i-1,j+1}+2Z_{i-1,j}+Z_{i-1,j-1})}{N\times\delta x} \qquad \text{(Eq. S1)}$$

$$\left[\frac{\delta Z}{\delta Z}\right]_{i,j} = \frac{(Z_{i+1,j+1}+2Z_{i,j+1}+Z_{i-1,j+1})-(Z_{i+1,j-1}+2Z_{i,j-1}+Z_{i-1,j-1})}{N\times\delta y} \qquad \text{(Eq. S2)}$$

where X, Y [radians] are coordinate axes and Z [m] is elevation of the cell$_{i,j}$; $N = 8$ is the number of neighboring cells, δx and δy [m] are the distances between cell centers; $j+1$ and $j-1$ are the adjacent cells to the north and south, respectively and $i+1$ and $i-1$ are the adjacent cells to the east and west, respectively. Values are calculated using a 3 × 3 cell window.

The calculation of the high resolution slope S [degree] is based on the work of Burrough (1986). Using equation Eq. S1 and Eq. S2 we calculate

$$S = \arctan\sqrt{\left(\frac{\delta Z}{\delta X}\right)^2 + \left(\frac{\delta Z}{\delta Y}\right)^2} \times c \qquad \text{(Eq. S3)}$$

with c set to 57.29 to convert from radian to decimal degree. We apply the median of all subcell values to aggregate the high resolution slope to a 0.5° × 0.5° cell slope.

Subsequently we calculate slope dependent routing velocity v [ms^{-1}] (Figure S1) based on the Manning-Strickler formulation

$$v = \left(\tan\left(S \times \frac{\pi}{180}\right)\right)^{\frac{1}{2}} \times k \times R^{\frac{2}{3}} \qquad \text{(Eq. S4)}$$

Where k is the Manning-Strickler coefficient [$\mathrm{m}^{1/3}\mathrm{s}^{-1}$] describes the roughness of the area. For natural rivers this value ranges between 30 $\mathrm{m}^{1/3}\mathrm{s}^{-1}$ and 40 $\mathrm{m}^{1/3}\mathrm{s}^{-1}$ (Patt, 2001). Due to the lack of detailed cell specific information we set $k = 35\ \mathrm{m}^{1/3}\mathrm{s}^{-1}$. Setting $k = 30\ \mathrm{m}^{1/3}\mathrm{s}^{-1}$ or $k = 40\ \mathrm{m}^{1/3}\mathrm{s}^{-1}$ would cause a change of the calculated routing velocities of about +10.8% and −8.5% in comparison to $k = 35\ \mathrm{m}^{1/3}\mathrm{s}^{-1}$, respectively. R is the hydraulic radius [m]. Since we have no detailed information about the river profile neither in headwater cells nor in main stem cells, we neglected the influence of this factor and set $R = 1.0$ m.

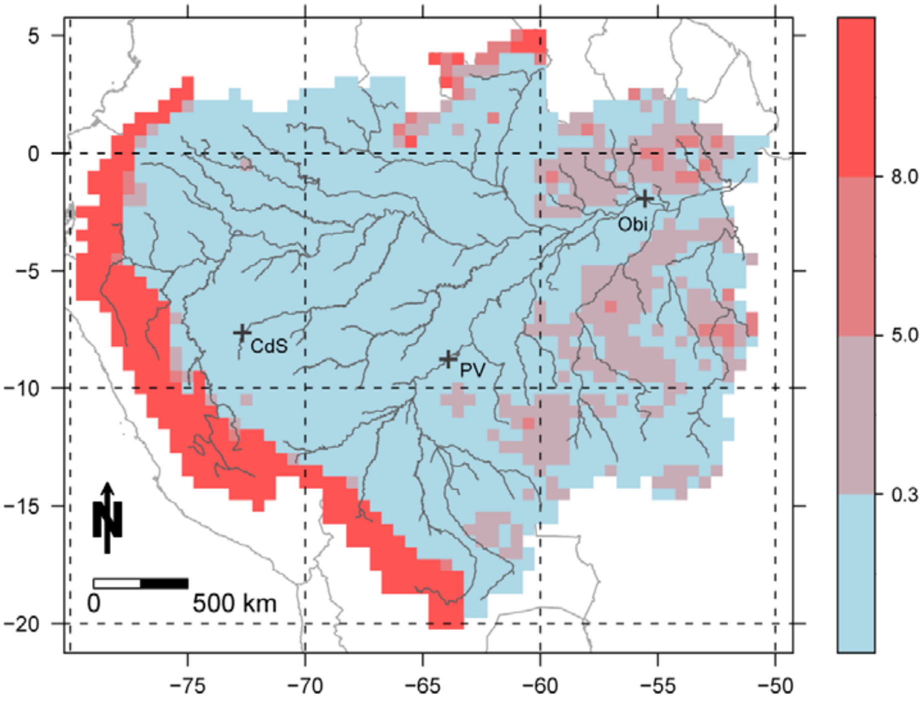

Figure S1. Slope-dependent routing velocity [ms^{-1}] in the Amazon catchment, with river network shown in grey. The black crosses indicate the test sites Cruzeiro do Sul (CdS), Porto Velho (PV), and Óbidos (Obi).

We included an analysis to estimate the sensitivity of the calculated routing velocity to k and R. We ranged k from 28 $\mathrm{m}^{1/3}\mathrm{s}^{-1}$ and 40 $\mathrm{m}^{1/3}\mathrm{s}^{-1}$ (with a constant $R = 1.0$ m), which lead to median routing velocities between 0.20 ms^{-1} (−20.0%) and 0.29 ms^{-1} (+16%). We ranged R from 0.2 m to 1.2 m (with a constant $k = 35$ $\mathrm{m}^{1/3}\mathrm{s}^{-1}$), which lead to median routing velocities between 0.09 ms^{-1} (−64%) and 0.29 ms^{-1} (+169%). Additionally we changed the k and R values in all combinations (see Figure S2).

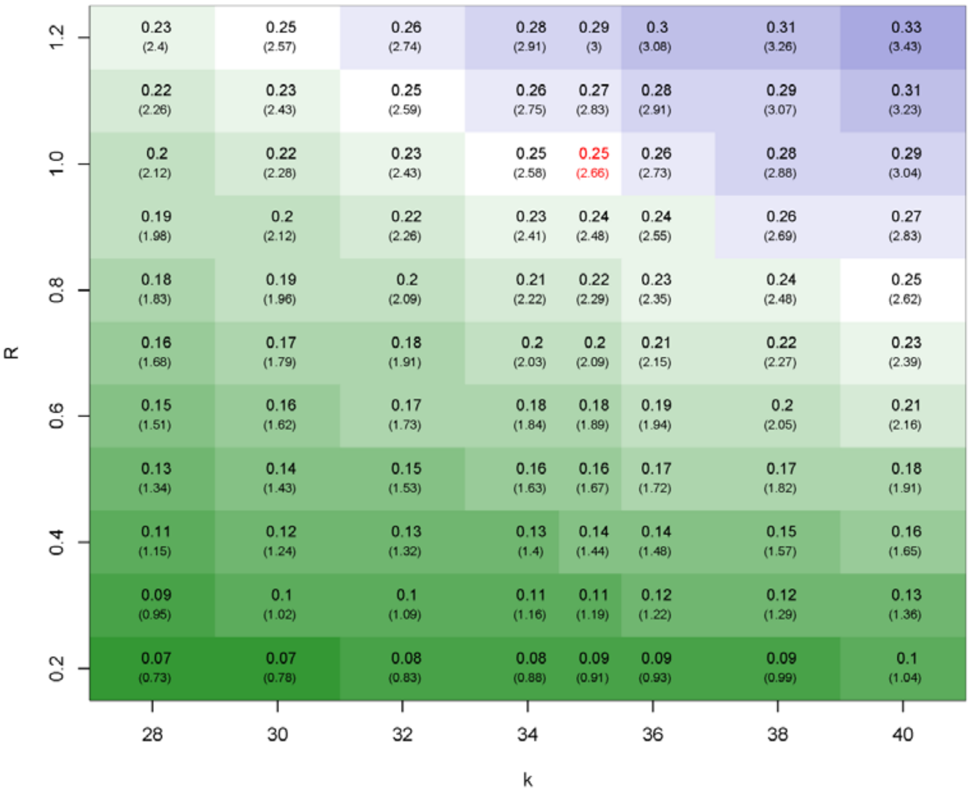

Figure S2: Routing velocity calculated with k values between 28 and 40 and R values between 0.2 and 1.2. Basin wide median and mean (in brackets) routing velocity. Results of standard setting in red.

S2. Detailed description of the calculation of floodable area

In this study, the mTRMI is the sum of classified slope, classified slope configuration and classified relative slope position.

The first summand is classified slope (S_{class}). We use the previously calculated slope values and slice them in six slope classes (Table 1 in main document).

The second summand is classified slope configuration ($Sconf_{class}$). Slope configuration describes the convexity or concavity of the land surrounding any grid cell, based on the change in elevation Z [m] from cell$_{i,j}$ to all cells located at the edge of the 5 × 5 cell window. We determine slope configuration, both diagonally (Eq. S5) and orthogonally (Eq. S6) ($Z_{Meandia}$, $Z_{Meanortho}$), directly from the DEM.

$$Z_{Mean_{dia}} = \frac{Z_{i-2,j+2}+Z_{i+2,j+2}+Z_{i-2,j-2}+Z_{i+2,j-2}}{E} \qquad \text{(Eq. S5)}$$

$$Z_{Mean_{ortho}} = \frac{Z_{i,j+2}+Z_{i-2,j}+Z_{i+2,j}+Z_{i,j-2}}{E} \qquad \text{(Eq. S6)}$$

with $E = 4$ as the number of edge cells. Since the distance between the target cell and the diagonal corner cells of the window is larger (and its influence is smaller) than the distance between the target cell and the orthogonal edge cells, we weight the influence of the values for the different distances (Eq. S7 and Eq. S8) between the target cell and a cell at the edge of the window depending on the orientation ($Z_{Diffdia}$, $Z_{Diffortho}$).

$$Z_{Diff_{dia}} = 100 \times \frac{Z_{Mean_{dia}} - Z_{i,j}}{\delta x_{dia}} \quad \text{(Eq. S7)}$$

$$Z_{Diff_{ortho}} = 100 \times \frac{Z_{Mean_{ortho}} - Z_{i,j}}{\delta x_{ortho}} \quad \text{(Eq. S8)}$$

where δx_{dia} and δx_{ortho} are the distances [m] between cell centers. We calculate the slope configuration as follows.

$$slope_{config} = \frac{Z_{Diff_{dia}} + Z_{Diff_{ortho}}}{2} \quad \text{(Eq. S9)}$$

Afterwards we slice the full range of resulting values equally into 10 parts and assign these parts into 3 slope configuration classes: slices 0-4 to class −1 (convex topography); slice 5 to class 0 (flat topography); slices 6-10 to class 1 (concave topography).

The third summand is relative slope position ($Spos_{class}$). It describes the distance of the $cell_{i,j}$ to the closest ridges and streams. To calculate this distance, we determine the flow direction (Eq. S10) by finding the steepest descent from the cell to any of its neighbors

$$flow_{cell} = 100 \times \frac{\delta Z}{\delta x} \quad \text{(Eq. S10)}$$

where δZ is the difference in elevation and δx the difference between the cell centers. We code its direction with eight values. The resulting flow direction map is used to compute the flow accumulation which is the number of cells draining into each cell. To define the river network we use all cells to which at least 100 cells drain. Afterwards we reduce the channel width to 1 cell to define the actual riverbed. We then define the ridges by creating a smoothed elevation grid over a 20 × 20 cell window

$$Z_{smooth} = \frac{\sum_{n=-9}^{10} \sum_{m=-9}^{10} Z_{i+n,j+m}}{400} \quad \text{(Eq. S11)}$$

in which extraordinary peaks and sinks are removed, and subtracting it from the elevation map. The difference map between the smoothed grid and the elevation grid is used to calculate the ridge lines (difference < 10 m) which are afterwards reduced to 1 cell ridge width to define the actual ridge line. Now the relative distance [cells] between riverbed and ridge is calculated. We assign these values to 6 relative slope position classes (Table 2 in main document).

References

Burrough, P. A.: Digital elevation models, in Principles of geographical information systems for land resources assessment, edited by P. A. Burrough, pp. 39–55, Oxford University Press, New York., 1986.

Patt, H.: Hochwasser-Handbuch Auswirkungen und Schutz, Springer Verlag, Berlin., 2001.