S1 Algorithms for constructing artificial rainfall scenarios

Here we provide a description of the algorithms that were used to construct the artificial rainfall scenarios employed in this study. We employed scenarios with an increase or decrease of two standard deviations of annual total precipitation. This increase or decrease was obtained by adjusting the intensity (TotInt), the frequency (TotFrq) or the rain season length (TotLen). The construction of these scenarios is explained below.

TotInt: total rainfall and event intensity

By multiplying the daily rainfall values by a factor f, the total rainfall will be increased (f>1) or decreased ($0<f<1$) together with the intensity, while the event frequency and season length remain invariant.

IntFrq: event intensity and frequency

Increasing the intensity by reducing the event frequency can be achieved by merging rain events. The top 33% of precipitation events are filtered out, in order to avoid the creation of unrealistically high precipitation peaks. On the other hand, in order to create a difference which is significant enough to have an impact in the model, the highest daily rainfall pair from the remaining events is summed. In order to preserve the timing of the season, only rainy days inside the rain season are merged. To decrease the intensity, the opposite is implemented: the highest rainfall events are split into two smaller events.

TotFrq: total rainfall and event frequency

First we modify the total rainfall to the desired value, together with the intensity (TotInt). Then we revert the intensity to its original value by changing the event frequency (IntFrq).

IntLen: event intensity and season length

To increase the intensity by decreasing the season length, we remove a rainy day at the edge (start or end) of the season and add its amount of rainfall to a rainy day inside the season. Decreasing the intensity by increasing the length is not needed in this study.

TotLen: total rainfall and season length

Increasing the total season rain together with the season length, while keeping the intensity and frequency invariant, can be done in two steps. First we add a rainy day inside the season, of an amount equal to the intensity. Next we increase the spread in events by an amount of 1/frequency, by either moving forward all days preceding our added event, or moving backward all following days. Decreasing the length can be accomplished by a combination of decreasing the total rain together with intensity (TotInt) and increasing the intensity again by decreasing the length (IntLen).

S2 Additional results

This section contains additional model validation results for the Agoufou, Wankama and Demokeya sites (Fig. S1), an overview of simulated surface runoff values (Fig. S2), an evaluation of different rainfall products against in-situ measurements (Fig. S3), and the impact of the disturbances on net primary productivity and heterotrophic respiration for the Dahra site (Fig. S4).

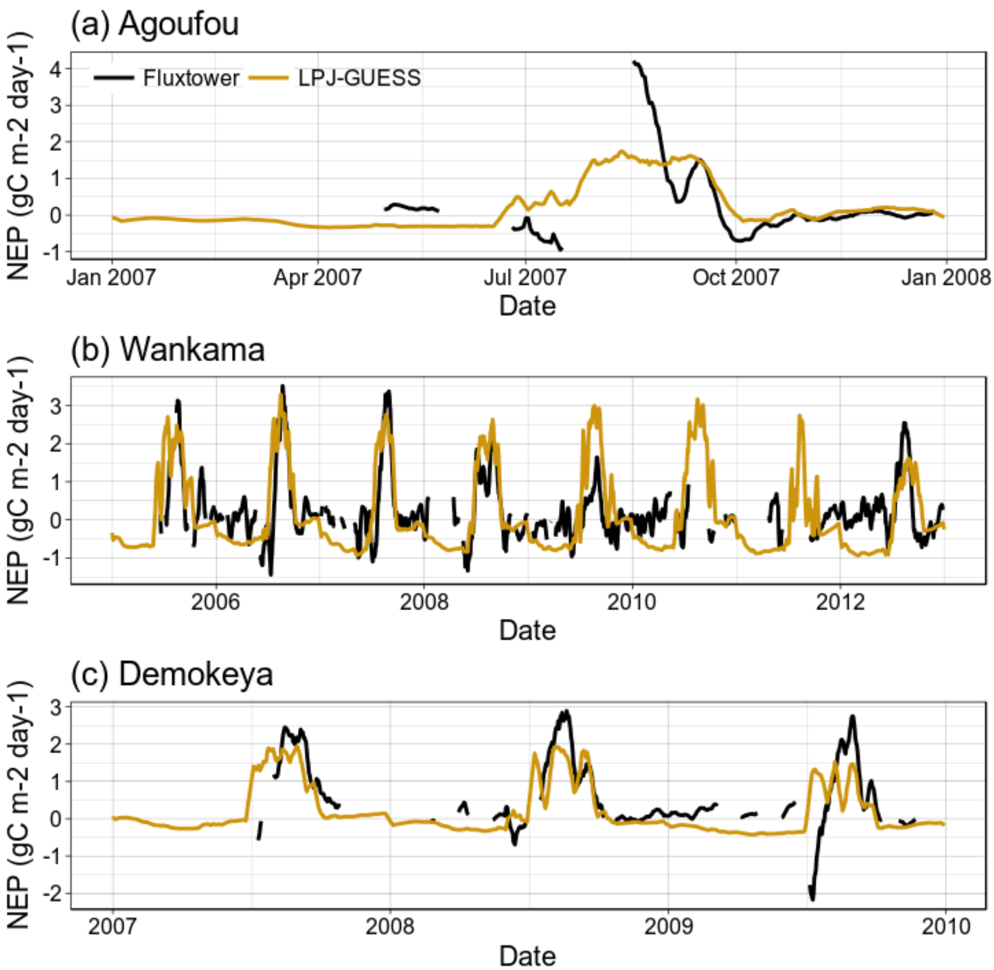

Figure S1. Time series of a 10-day moving average of daily net ecosystem productivity (NEP), comparing measurements from the flux towers near (**a**) Agoufou, (**b**) Wankama and (**c**) Demokeya with model results from LPJ-GUESS, using the Sahel-specific parameterization and WFDEI-MSWEP meteorological drivers.

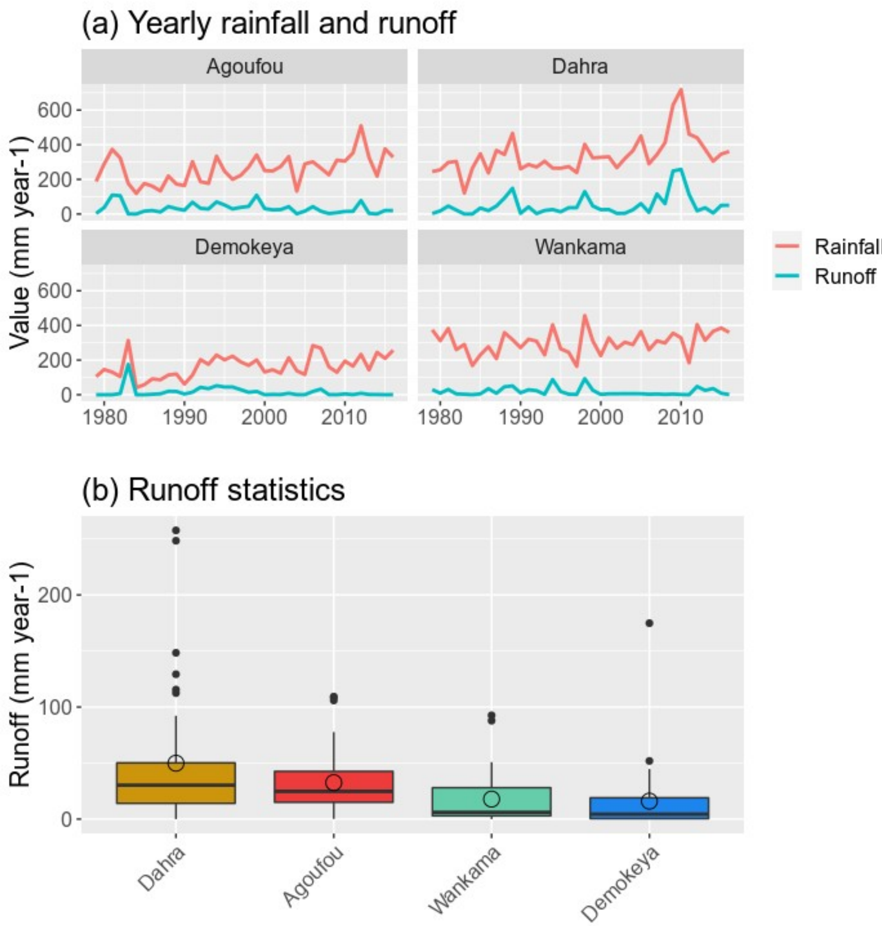

Figure S2. Simulated rainfall and runoff for each site. (**a**) Timeseries of simulated yearly rainfall. (**b**) Median and variability of the yearly runoff timeseries. The horizontal line presents the median value, while the empty circle (O) gives the time series average value. Hinges represent the first and third quartiles, whiskers represent the largest (smallest) value at most 1.5 times the interquartile range above (below) the hinges, and black filled dots represent outliers.

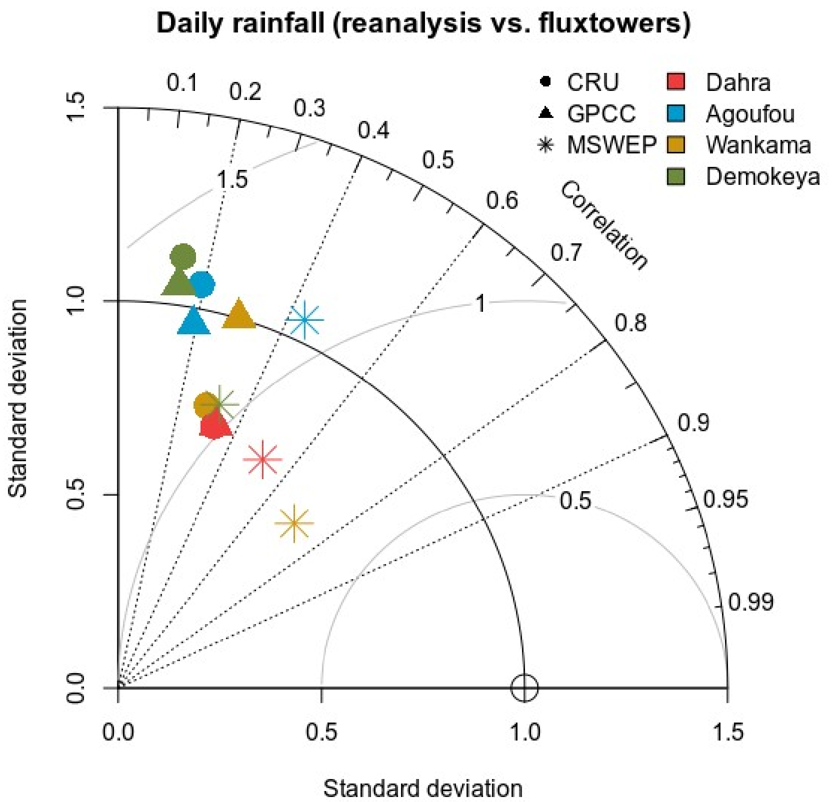

Figure S3. Taylor diagram showing the correspondence between daily reanalysis rainfall products and in-situ rainfall measurements for the Sahel flux tower sites. Reanalysis data compared are CRU-NCEP (●), Global Precipitation Climatology Centre (GPCC, ▲) and MSWEP (✳) rainfall. Values were normalized so that the standard deviations of the observations equal unity. Grey arcs represent the root mean square difference (RMSD) between reanalysis data and observations.

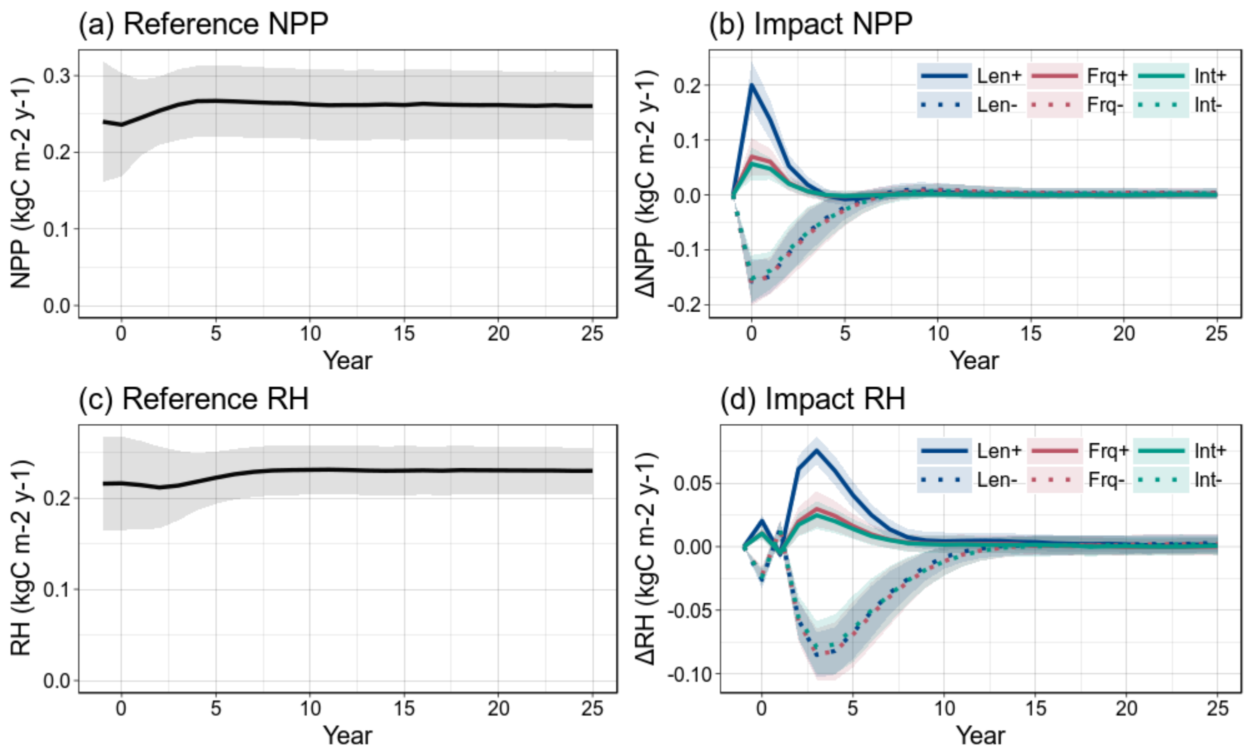

Figure S4. Impact of the rainfall disturbance scenarios on the total net primary productivity (NPP) and heterotrophic respiration (RH).

S3 Additional results of applying the scenarios to the other Sahel sites

This section contains the results of applying the different disturbance scenarios to the Agoufou, Wankama and Demokeya sites in the Sahel (Fig. S5-S16).

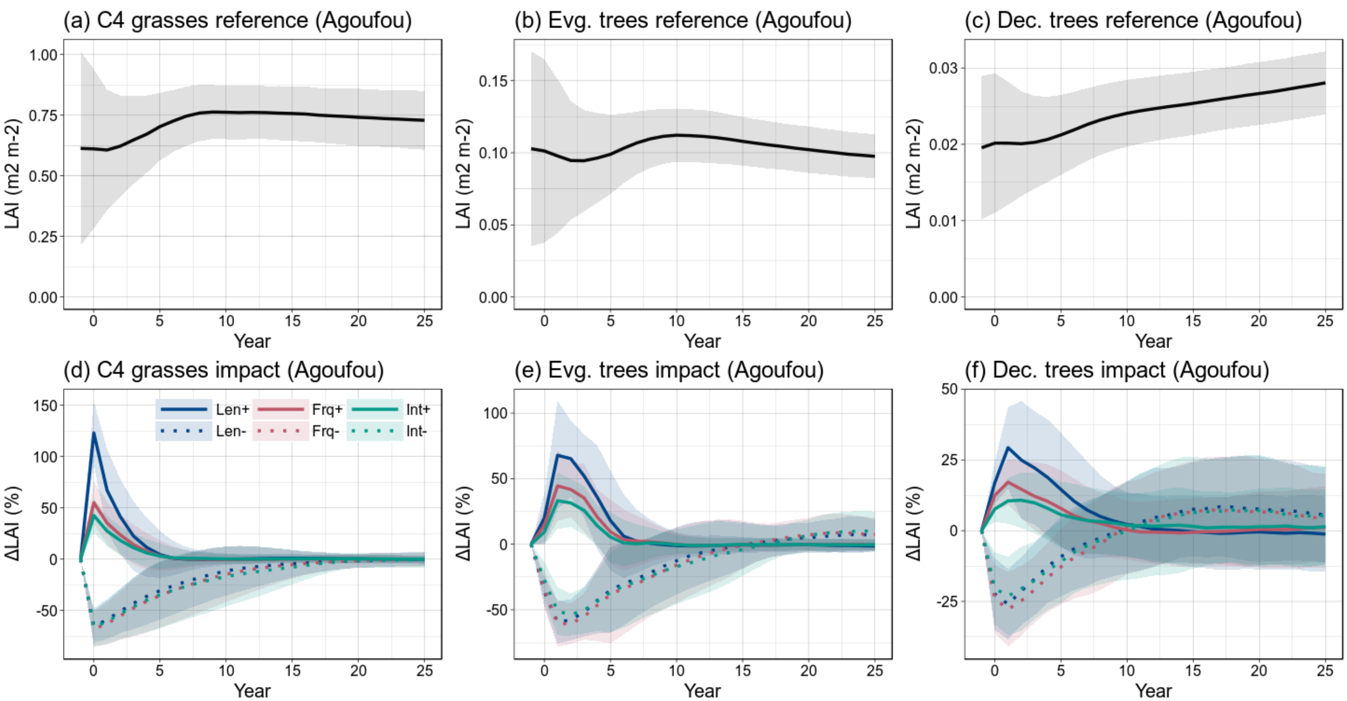

Figure S5. Response of the vegetation to the different rainfall scenarios for the Agoufou site, in function of years since the disturbance event. (**a-c**) reference LAI of each PFT, averaged over all ensemble members; (**d-f**) vegetation response as the mean relative LAI difference between the scenario runs and the reference runs. Shaded areas indicate variability of the model runs over all ensemble members (±1σ).

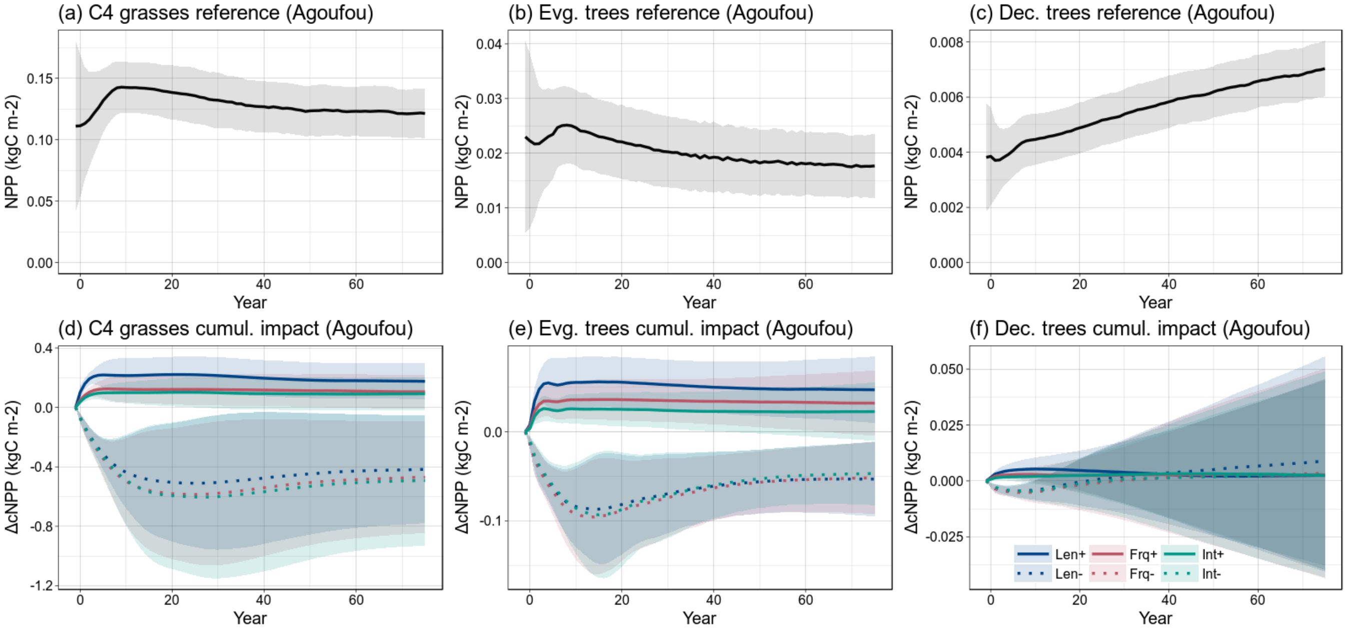

Figure S6. Impact on the cumulative net primary carbon uptake (NPP) for each PFT. (a-c) reference yearly NPP of each PFT; (d-f) difference in cumulative NPP with the reference run since the disturbance, divided by the average yearly NPP of the reference run. Expressed in units of years this gives how much years of typical production the PFT has lost or gained in the long run due to the perturbations. Shaded areas indicate variability of the model runs over all ensemble members (±1σ). Results shown for the Agoufou site simulations.

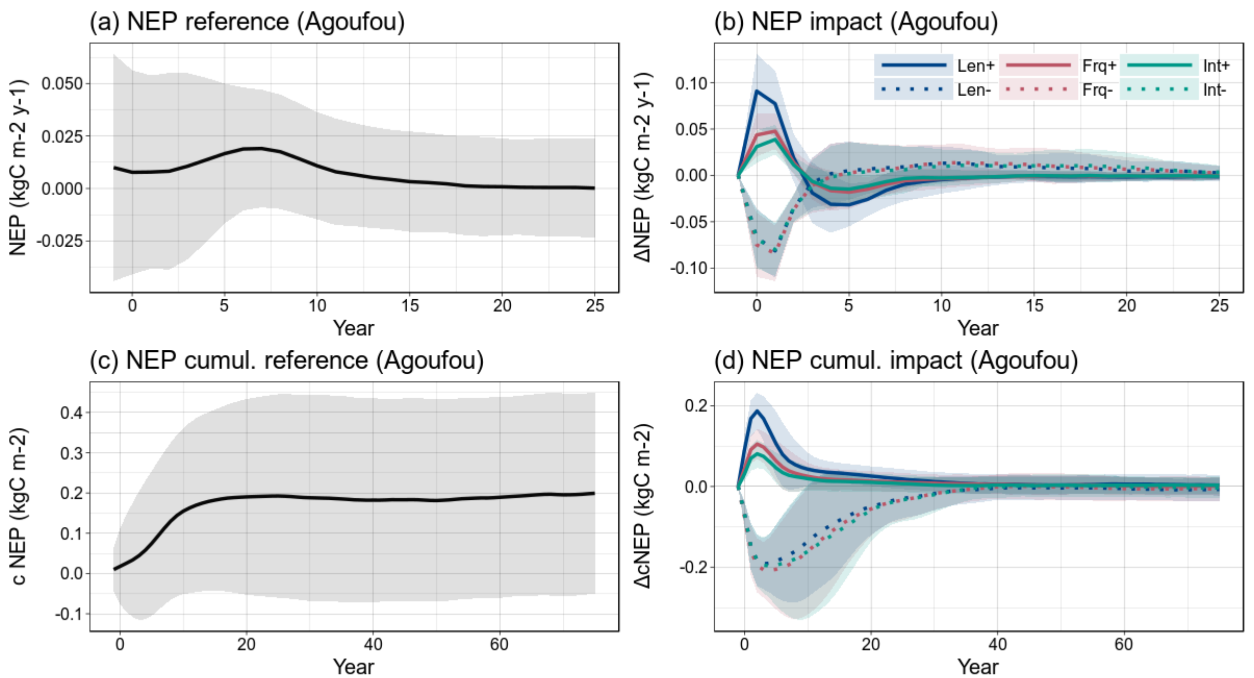

Figure S7. Impact of the different scenarios on the cumulative NEP. (a) Average reference yearly NEP over a period of 25 years after the disturbance. (b) Impact of the disturbances on yearly NEP. (c) Average reference cumulative NEP on a longer time scale (70 years). (d) Impact of the disturbances on the cumulative NEP. The year prior to the perturbations is used as a starting point for the cumulative sum. Shaded areas indicate variability of the model runs over all ensemble members (±1σ). Results shown for the Agoufou site simulations.

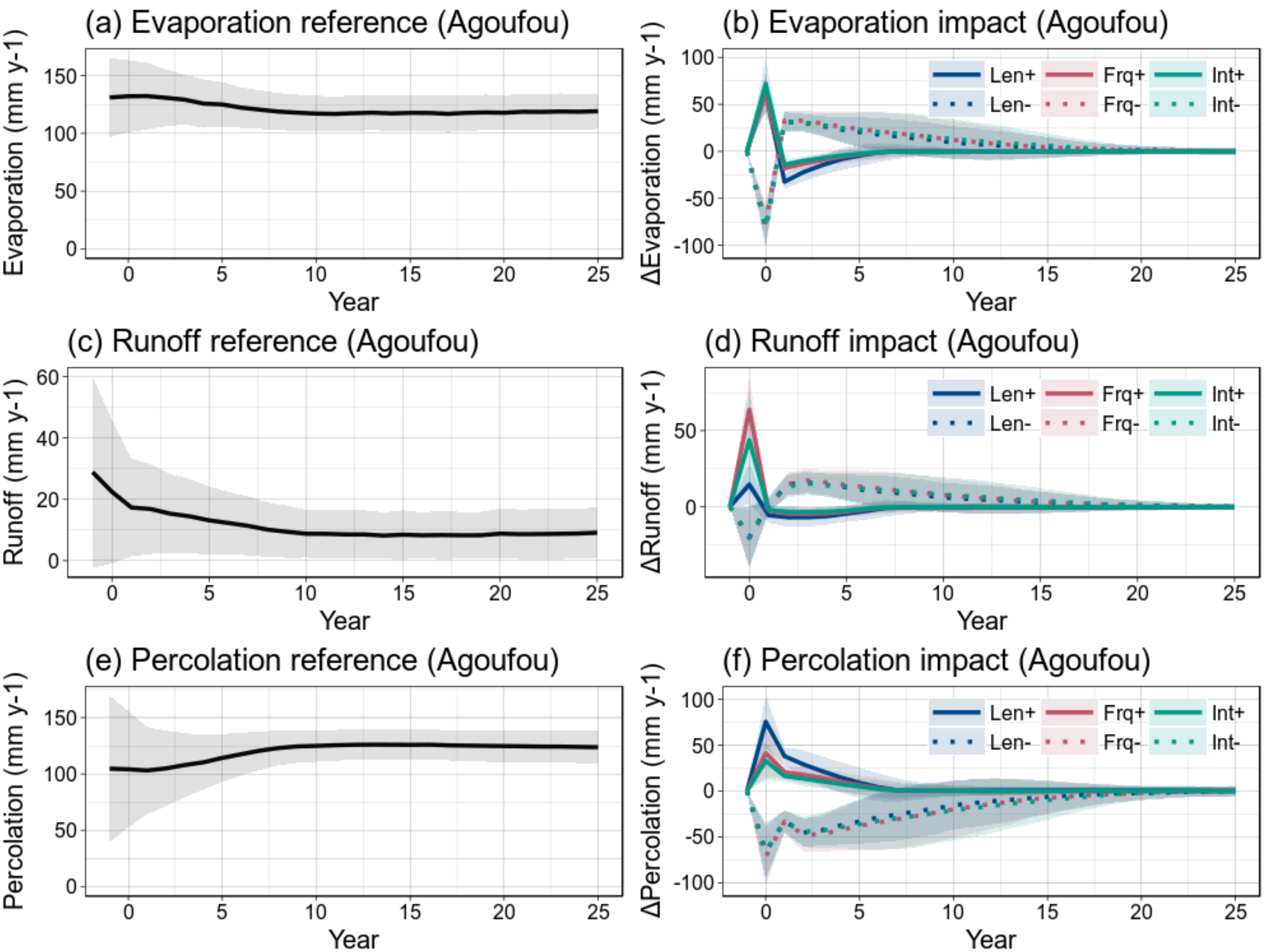

Figure S8. Impact of the different disturbance scenarios on surface water balance. Reference values and impact on (a,b) surface evaporation, (c,d) surface runoff, and (e,f) percolation of water to lower soil layers. Shaded areas indicate variability of the model runs over all ensemble members (±1σ). Results shown for the Agoufou site simulations.

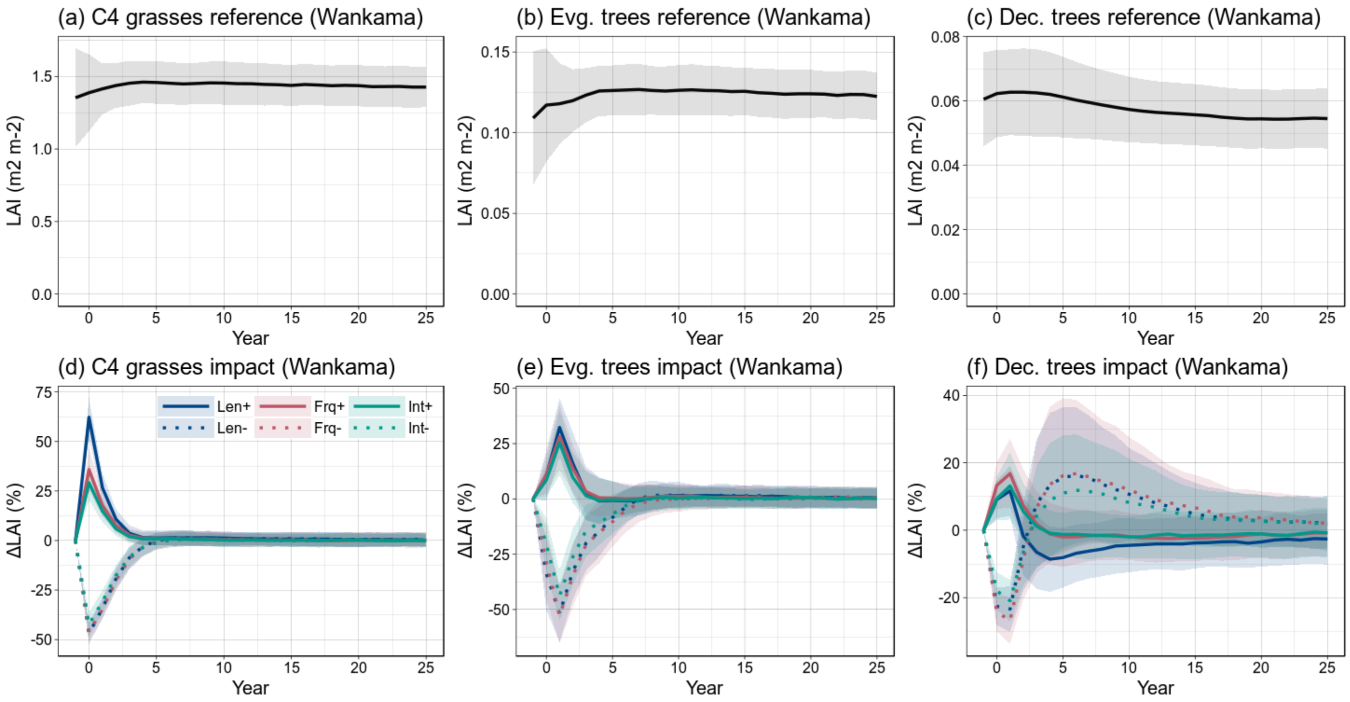

Figure S9. Response of the vegetation to the different rainfall scenarios for the Wankama site, in function of years since the disturbance event. (**a-c**) reference LAI of each PFT, averaged over all ensemble members; (**d-f**) vegetation response as the mean relative LAI difference between the scenario runs and the reference runs. Shaded areas indicate variability of the model runs over all ensemble members (±1σ).

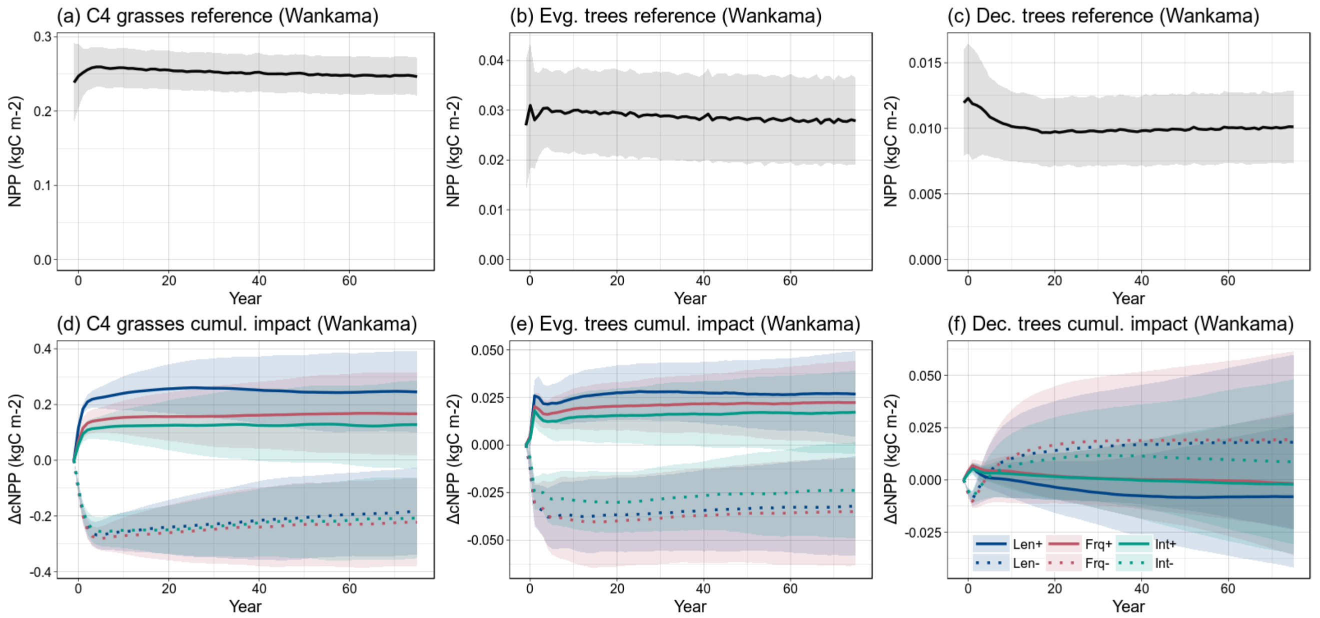

Figure S10. Impact on the cumulative net primary carbon uptake (NPP) for each PFT. (a-c) reference yearly NPP of each PFT; (d-f) difference in cumulative NPP with the reference run since the disturbance, divided by the average yearly NPP of the reference run. Expressed in units of years this gives how much years of typical production the PFT has lost or gained in the long run due to the perturbations. Shaded areas indicate variability of the model runs over all ensemble members (±1σ). Results shown for the Wankama site simulations.

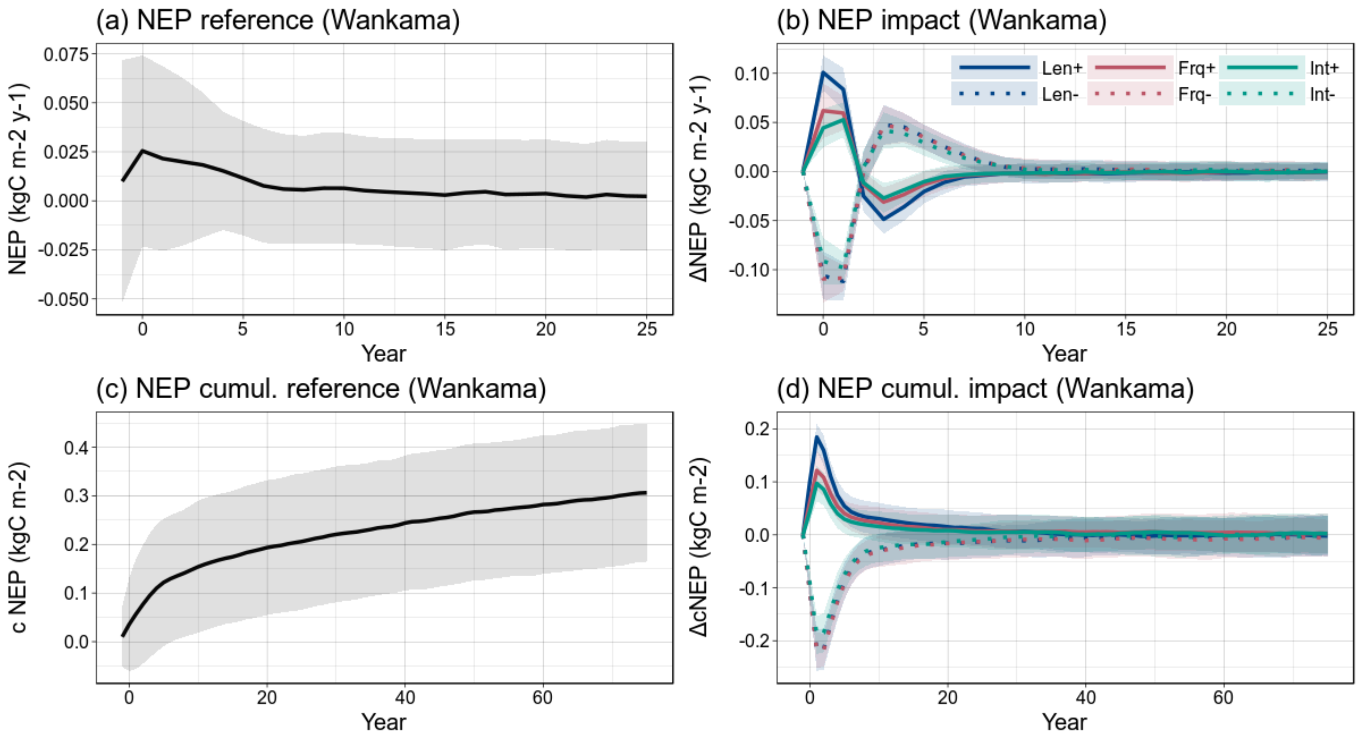

Figure S11. Impact of the different scenarios on the cumulative NEP. (a) Average reference yearly NEP over a period of 25 years after the disturbance. (b) Impact of the disturbances on yearly NEP. (c) Average reference cumulative NEP on a longer time scale (70 years). (d) Impact of the disturbances on the cumulative NEP. The year prior to the perturbations is used as a starting point for the cumulative sum. Shaded areas indicate variability of the model runs over all ensemble members (±1σ). Results shown for the Wankama site simulations.

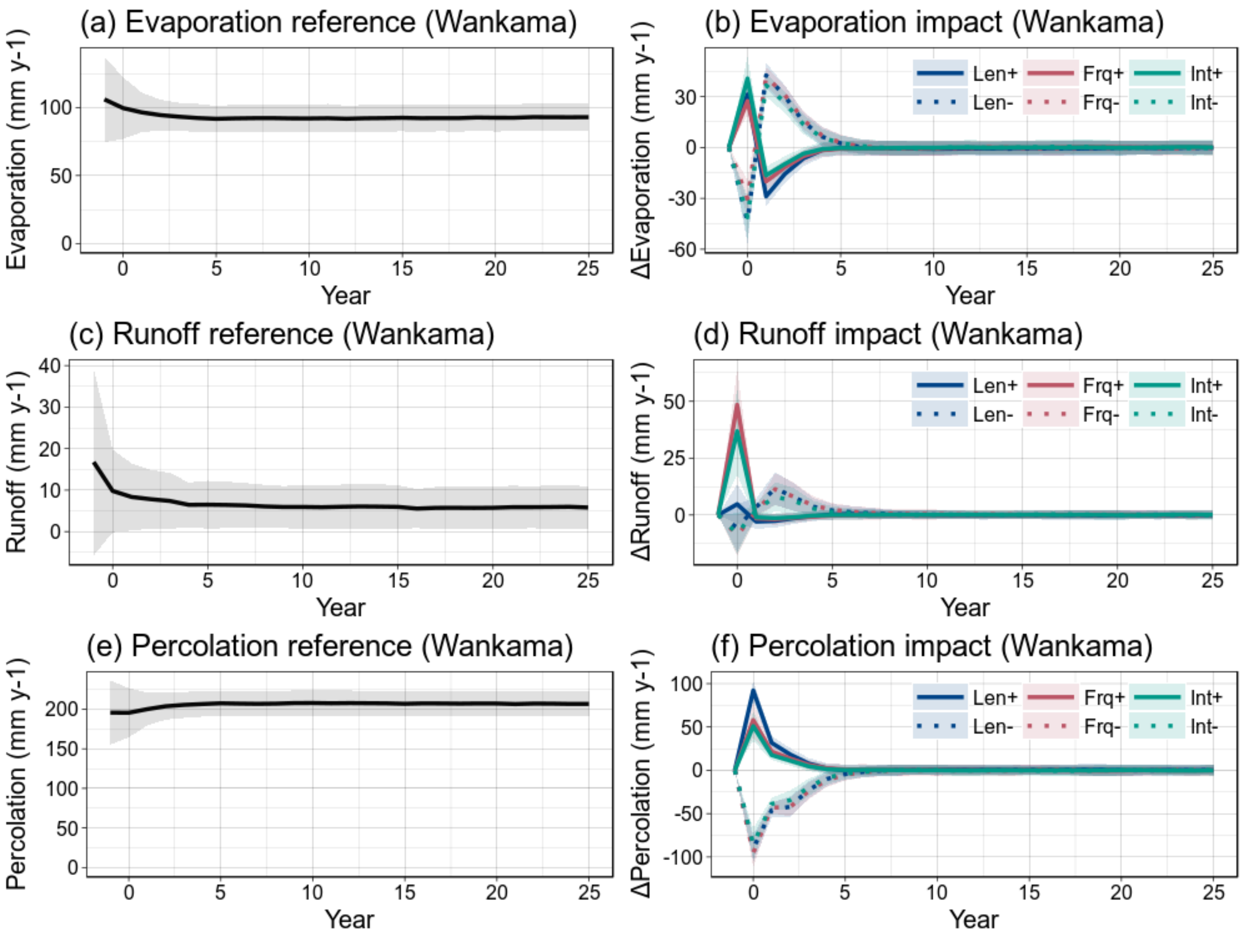

Figure S12. Impact of the different disturbance scenarios on surface water balance. Reference values and impact on (a,b) surface evaporation, (c,d) surface runoff, and (e,f) percolation of water to lower soil layers. Shaded areas indicate variability of the model runs over all ensemble members (±1σ). Results shown for the Wankama site simulations.

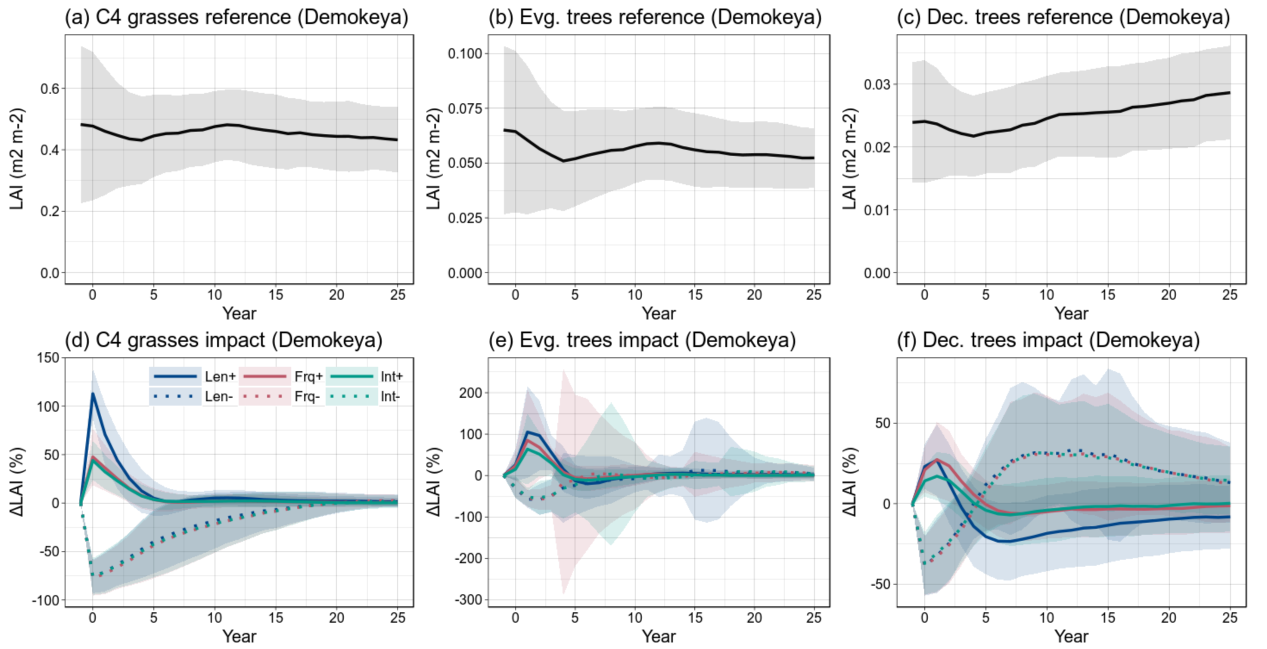

Figure S13. Response of the vegetation to the different rainfall scenarios for the Demokeya site, in function of years since the disturbance event. (**a-c**) reference LAI of each PFT, averaged over all ensemble members; (**d-f**) vegetation response as the mean relative LAI difference between the scenario runs and the reference runs. Shaded areas indicate variability of the model runs over all ensemble members (±1σ).

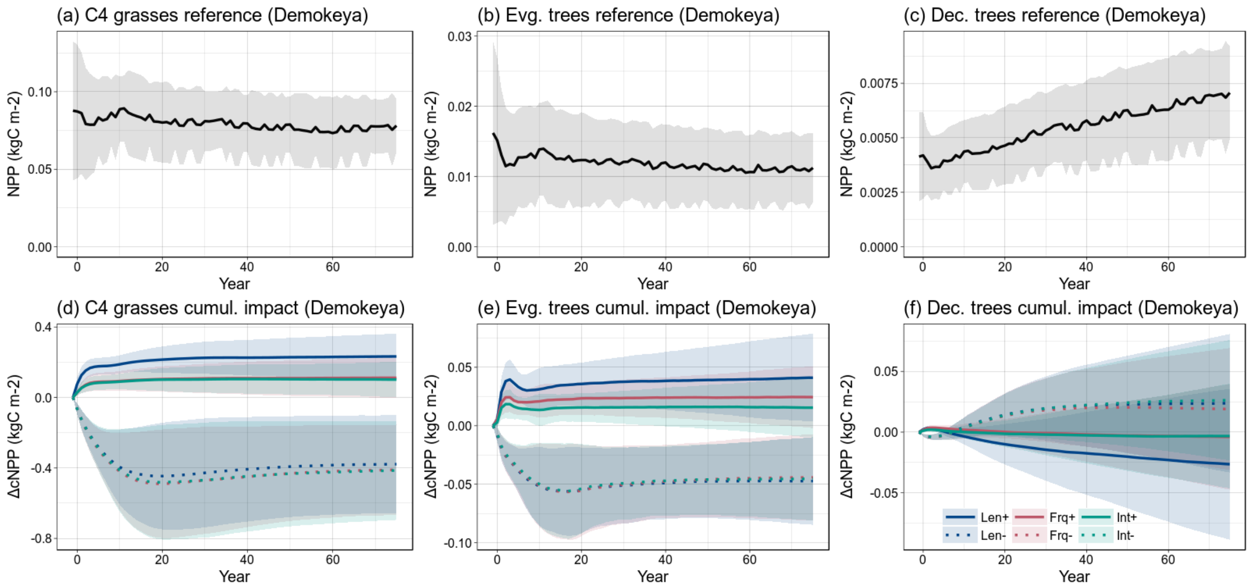

Figure S14. Impact on the cumulative net primary carbon uptake (NPP) for each PFT. (a-c) reference yearly NPP of each PFT; (d-f) difference in cumulative NPP with the reference run since the disturbance, divided by the average yearly NPP of the reference run. Expressed in units of years this gives how much years of typical production the PFT has lost or gained in the long run due to the perturbations. Shaded areas indicate variability of the model runs over all ensemble members (±1σ). Results shown for the Demokeya site simulations.

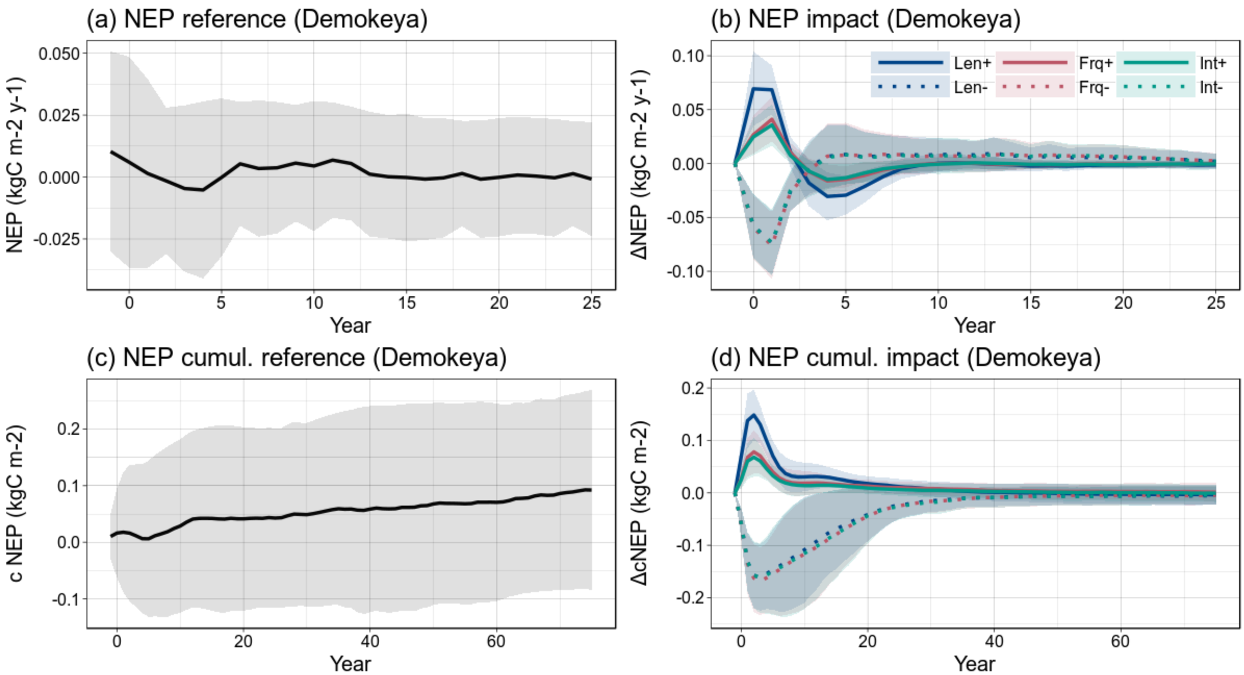

Figure S15. Impact of the different scenarios on the cumulative NEP. (a) Average reference yearly NEP over a period of 25 years after the disturbance. (b) Impact of the disturbances on yearly NEP. (c) Average reference cumulative NEP on a longer time scale (70 years). (d) Impact of the disturbances on the cumulative NEP. The year prior to the perturbations is used as a starting point for the cumulative sum. Shaded areas indicate variability of the model runs over all ensemble members (±1σ). Results shown for the Demokeya site simulations.

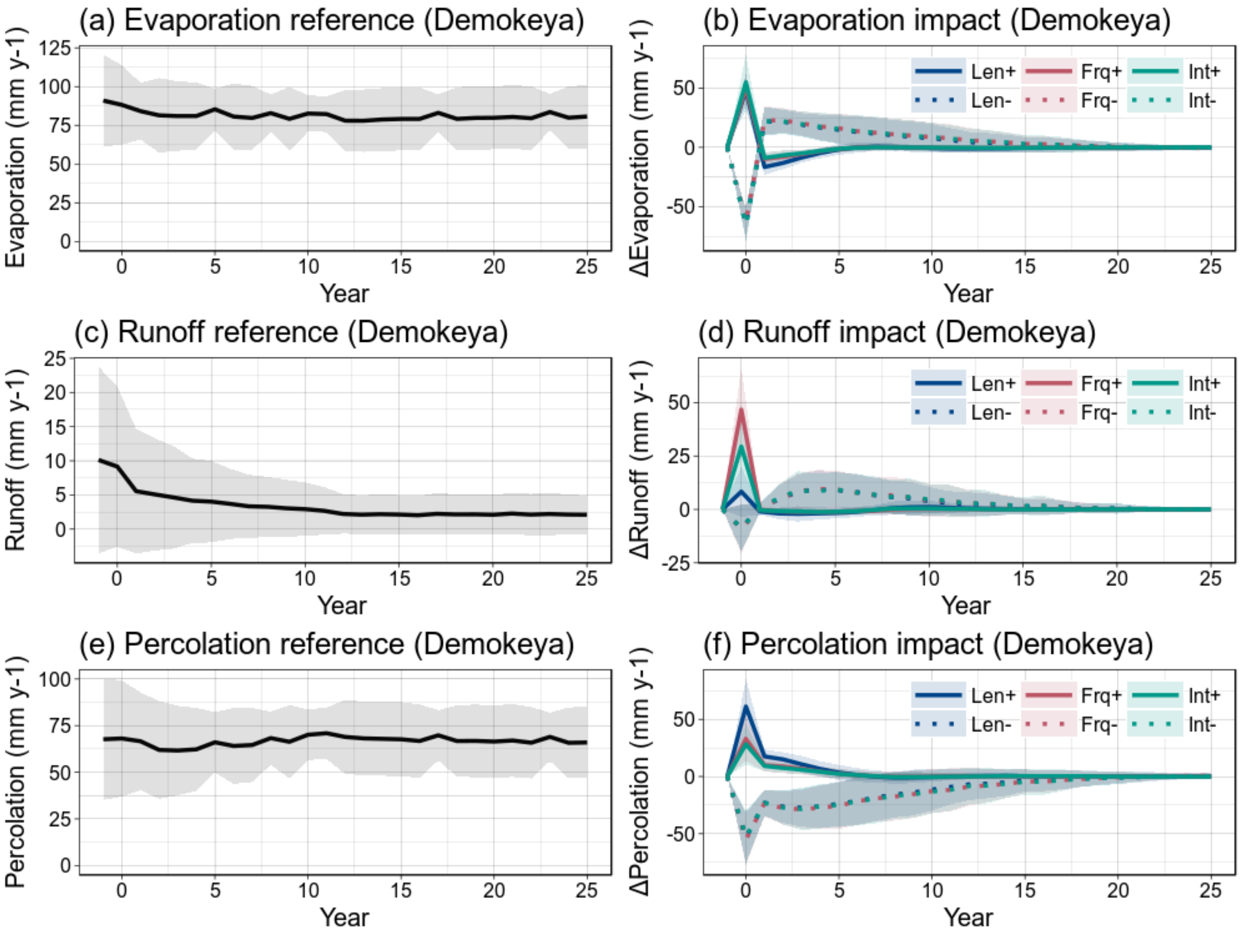

Figure S16. Impact of the different disturbance scenarios on surface water balance. Reference values and impact on (a,b) surface evaporation, (c,d) surface runoff, and (e,f) percolation of water to lower soil layers. Shaded areas indicate variability of the model runs over all ensemble members (±1σ). Results shown for the Demokeya site simulations.