Supplementary Materials: The following are available online at www.mdpi.com/xxx/s1, Figure S1: Share of land that was converted to sugarcane from 2004 to 2015; Figure S2. Average LUC-related CO2 emissions with 2 standard deviations from the expansion of sugarcane from 2004 to 2015; Figure S3: Average annual difference in mean species abundance with 2 standard deviations from the expansion of sugarcane from 2004 to 2015; Figure S4: Average annual difference in soil loss with 2 standard deviations from the expansion of sugarcane from 2004 to 2015; Figure S5: Average annual water shortage with 2 standard deviations from the expansion of sugarcane from 2004 to 2015; Table S1: Parameters to estimate spatially explicit biomass carbon stock for each land use/cover category; Table S2: Soil organic carbon (SOC) stock change factors valid for each land use/cover category, derived from IPCC 2006 guidelines; Table S3: Mean species abundance (MSA) index assigned to each land use/cover; Table S4: Cover management (C) factor for the relevant land use/cover categories; Table S5: Conservation support practice factor according to slope thresholds; Table S6: Evapotranspiration coefficients (Kc).[75–100]

1. Biomass carbon stocks

Table S1. Parameters to estimate spatially explicit biomass carbon stock for each land use/cover category**.**

Land use/cover	Above ground biomass (AGB), range of values t ha^{-1}	Root to shoot ratios (R)	Carbon Fraction (CF)
Forest	40 - 300. Established spatially explicitly[A]	Tropical – Wet = 0.221[B]	0.5[B]
		Tropical – Moist = 0.284[B]	
		Tropical – Montane = 0.348 for ≤ AGB 125 t ha^{-1} and 0.283 for > AGB 125 t ha^{-1}[B]	
		Temperate = 0.46 for ≤ AGB 125 t ha^{-1} and 0.19 for AGB 125 t ha^{-1}[B]	
Eucalyptus	Tropical – Wet = 200[B]	Tropical – Wet = 0.221[B]	0.5[B]
	Tropical – Moist = 90[B]	Tropical – Moist = 0.284[B]	
	Tropical – Montane = 75[B]	Tropical – Mountain = 0.348[B]	
	Temperate = 60[B]	Temperate = 0.464[B]	
Shrubland	26 - 78. Established spatially explicitly[A]	1.80[c]	0.5[B]
Grassland	1.6-6.2. Established spatially explicitly[A]	Tropical – Wet & Moist = 1.6[B]	0.47[B]
		Warm Temperate – Wet = 4[B]	
Sugarcane	15-62. Established spatially explicitly[A]	0.15[D]	0.43[D]

[A] See supplementary material, section: Biomass carbon stocks
[B] [42]
[C] [75]
[D] [76]

<u>Forest</u>

The improved pan-tropical map of aboveground woody biomass [49] was used to estimate AGB for forest. With an overlay assessment, AGB values were assigned from the pan-tropical map to each specific location categorized as forest.

<u>Grassland</u>

The FAO/IIASA suitability map for low-input level rain-fed alfalfa [48] was used to assess the spatial variation in biomass for grasslands. This approach was selected given the lack of biomass spatially explicit grassland data for Sao Paulo state. With an overlay assessment, alfalfa suitability values were assigned to each location categorized as grassland. The maximum alfalfa suitability value was assumed to be correlated with the IPCC climate zone specific peak AGB coefficients [42]. The AGB in grasslands was assessed for each location from the specific suitability value by considering the link between maximum alfalfa suitability and AGB peak biomass coefficients.

Shrubland

A similar process as the one used for grasslands was used to estimate AGB spatially explicit for shrublands. The FAO/IIASA suitability map for low-input level rain-fed alfalfa [48] was also used to assess the spatial variation in biomass for shrublands. Suitability values were assigned to each location categorized as shrubland. Then, it was assumed that the average suitability value was correlated with the average AGB in shrublands for the Brazilian savanna woodland [75]. AGB for shrublands was assessed for each location from the specific suitability value while considering the established link between average suitability and average AGB for shrublands in the Brazilian savanna woodland.

Sugarcane

The FAO/IIASA suitability map for intermediate-input level rain-fed sugarcane was used to determine the spatial variation in sugarcane biomass. Sugarcane suitability values were assigned to each location with sugarcane land use. Then, it was assumed that the average suitability value was correlated with the sugarcane average yield (average sugarcane yield between 2004 and 2015, 80.6 t ha^{-1}). Sugarcane yields were estimated from each location-specific suitability value by considering the established link between average suitability and average yield. Sugarcane yields were retrieved fromUNICA [7,77]. AGB was assessed considering a 29% dry matter content [76] for sugarcane and a yield to AGB ratio of 1.40 [78].

2. Soil organic carbon stocks

Table S2. Soil organic carbon (SOC) stock change factors valid for each land use/cover category, derived from IPCC 2006 guidelines [42].

Land use/cover categories	Climate region	IPCC relative soil stock change factors		
		F_{LU}	F_{MG}	F_{I}
Forest	All	1[A]	1[A]	1[A]
Eucalyptus	Tropical—All	1.01[B]	1.10[c]	1[D]
	Temperate—Wet	0.72[B]	1.10[c]	1[D]
Shrublands[E]	All	1[F]	1[G]	1[H]
Grassland	Tropical—Wet & Moist	1[F]	0.97[I]	1[H]
	Tropical—Montane		0.96[I]	
	Temperate—Wet		0.95[I]	
Sugarcane	Tropical—Wet & Moist	0.83[J]	1.04[K]	1.11[L]
	Tropical—Montane	0.83[J]	1.04[k]	1.11[L]
	Temperate—Wet	0.69[J]	1.05[k]	1.08[L]
Annual crops	Tropical—Wet & Moist	0.83[J]	1.04[M]	1.11[L]
	Tropical—Montane	0.83[J]	1.04[M]	1.11[L]
	Temperate—Wet	0.69[J]	1.05[M]	1.08[L]

[A] Forest is assumed to have the same soil carbon stock as the reference condition. Therefore, all stock change factors are 1

[B] Value for long-term perennial tree crops

[C] Value for management without primary tillage, with only minimal soil disturbance in the seeding zone. Eucalyptus is harvested every 7 years and very limited tillage practices are applied [79]

[D] Assumed for medium input with mineral fertilization

[E] All stock change factors for Shrubland are assigned from IPCC chapter 6 Grasslands given that there are no specific values for Shrubland

[F] Value for permanent grassland

[G] Value for grasslands without significant management improvements

[H] Value for grassland where no additional management practices have been used

[I] Value for overgrazed or moderately degraded grassland. The definition of grassland for this research includes rangelands
[J] Value for long-term cultivated area
[K] Value for primary and/or secondary tillage but with reduced soil disturbance. Sugarcane plantations have reduced till practices due its ratoon cycle and 6-year harvest cycle [80]
[L] Value for high-input crops with significantly larger crop residue input. In addition, sugarcane plantations are characterized by high inputs and mechanized harvesting, which leaves a high amount of residues on the land [81]
[M] Value for primary and/or secondary tillage but with reduced soil disturbance. In Brazil, approximately 50% of annual cropland is no-till and the rest incorporates tillage practices [82]

3. Mean Species abundance Mean Species abundance

Table S3. Mean species abundance (MSA) index assigned to each land use/cover [43,53].

Land use/cover	MSA value
Forest	1[A]
Eucalyptus	0.5[B]
Shrubland	0.75[C]
Grassland	0.6[D]
Sugarcane	0.3[E]
Annual crops	0.1[F]

[A] Assumed for forest land cover category and primary vegetation
[B] Assumed for secondary forest land cover category
[E] Assumed for mean value between grass or shrubland, livestock grazing, and man-made pastures land cover categories
[F] Assumed for mean value between grass or shrubland and agroforestry land cover categories
[G] Assumed for Low-input agriculture land cover category and perianal bioenergy crop
[H] Assumed for intensive agriculture land cover category

4. Soil erosion

a. Rainfall erosivity

The rainfall erosivity (R) factor is normally assessed by summing for each rainstorm the product of total storm energy and the maximum 30-min intensity [56]. However, this method requires pluviometry data on high spatial and temporal resolution, which is not available for Sao Paulo state. It is common to employ equations that determine rainfall erosivity values based on region-specific precipitation patterns [83]. Equation S1 was applied to determine the rainfall erosivity spatially explicitly for Sao Paulo state. Equation S1 is derived from Neto and Moldenhauer [71], which considered more than 20 years of precipitation data for Sao Paulo state. Monthly precipitation data between 2004 and 2015 were gathered from 23 meteorological stations from the Instituto Nacional de Metereologia (INMET). Monthly erosivity values were calculated for each station and summed over the year. The average erosivity value for the period 2004-2015 was determined for each station and spatially interpolated between stations to obtain average rainfall erosivity maps that cover the extent of Sao Paulo state for the time period 2004-2015:

$$R = \sum_{i=1}^{12} 68.730 * \left(\frac{M_i^2}{P}\right)^{0.841}, \quad \text{(S1)}$$

where

R = Rainfall-runoff erosivity factor, $MJ\ mm\ ha^{-1}\ h^{-1}\ year^{-1}$;
i= Month of the year;
M = Average monthly precipitation in month i, mm;

P = Average annual precipitation, mm.

b. Soil erodibility

To determine the soil erodibility (K) factor, the soil map of Brazil [84] was used to assign the appropriate k value from the soil erodibility database [85] to each soil type within Sao Paulo state, based on soil characteristics.

c. Slope length and slope steepness

The slope length and slope steepness (LS) factor is commonly determined with empirical methods [56]. However, over the last decades, several algorithms have been developed to model this component in a GIS environment [86]. It is suggested that Equation S2 [87,88] is an adequate alternative to empirical measurements to estimate the sloe length/steepness factor [89]. The flow accumulation and slope gradient were derived from digital elevation models (DEM); the Brazilian DEM was used in this study [90].

$$LS = \left(\frac{\lambda}{22.13}\right)^{0.6} * \left(\frac{\sin\theta}{0.0896}\right)^{1,3} \qquad \text{(S2)}$$

$$\lambda = Flow\ accumulation * Cell\ size$$

where

LS = combined slope length and slope steepness factor, unitless;

Flow accumulation = accumulated upslope contributing area for a given cell, unitless;

Cell size = size of grid cell, $meter$;

θ = slope gradient, $degree$.

d. Cover management

The cover management (C) factor was assigned to each land use/cover category based on a literature review while considering biophysical conditions in Sao Paulo state (Table S4). The cover management factors are generally time dependent and vary in accordance to plant growth stages [56]. However, for this study, it was assumed that the cover management factor is constant over time.

Table S4. Cover management (C) factor for the relevant land use/cover categories**.**

Land use/cover	C value
Forest	0.03[A]
Eucalyptus	0.12[B]
Shrubland	0.0219[C]
Grassland	0.16[D]
Sugarcane	0.17[E]
Annual crops	0.172[F]

[A] Assumed for "native forest" category [43,91]

[B] Assumed for "eucalyptus plantations" category [92]

[C] Assumed for "transitional woodland-shrub" category [93]; this category was assumed from European conditions given the lack of data from Brazil

[D] Assumed for "pastures" category [94]

[E] Assumed for "sugarcane plantations" [68]

[F] Assumed for "annual crops", corn and soy bean fields [94]

e. Conservation support practice

The conservation support practice (P) factor for erosion control was assigned based on slope (%) thresholds [56] (Table S5). The slope % was calculated from the Brazilian DEM [90].

Table S5. Conservation support practice factor according to slope thresholds [56]**.**

Slope Threshold (%)	p-Value
1–2	0.6
3–5	0.5
6–8	0.5
9–12	0.6

13–16	0.7
16–20	0.8
21–25	0.9

5. Water shortage

Given data availability, ET_0 was assessed with the Turc approach [95], described in Equation S3. Kc values were assigned to each month based on land use/cover growing cycles. For sugarcane, it was assumed that the sugarcane growth cycle is completed in 12 months and is harvested in April [96]. For annual cropland, an annual rotation cropping system (common in Brazil), including soy beans and wheat, was considered [97]. For eucalyptus, grasslands, shrublands, and forest, kc values were assigned based on Sao Paulo state characteristics [98]. The kc values for each land use/cover in line with specific land uses'/covers' growing stages can be found in Table S6.

Effective precipitation (Equation S4) is the share of precipitation that is stored in the soil and is available for the crop, and is derived from actual precipitation [45]. Precipitation, insolation, temperature, and humidity data from 2004 to 2015 were retrieved from 23 meteorological stations in Sao Paulo state from INMET [99] to determine ET_0 and effective precipitation. The selection of the stations was carried out based on the location of each station and the completeness of data. Evapotranspiration (ET) and effective precipitation (EP) were calculated on a monthly basis for each station and summed over the year for each year. The average evapotranspiration and effective precipitation for the time period 2004–2015 were calculated for each station and spatially interpolated to obtain coverage for the whole Sao Paulo state. The WS shortage difference between sugarcane and land use/cover prior to conversion is expressed in mm/year.

$$ET_0 = a_T\, 0.013\, \frac{T°_{mean}}{T°_{mean} + 15}\, 23.8856\, R_s + 50 * 0.408 \quad \text{(S3)}$$

where:

ET_0 = Reference evapotranspiration, $mm\ day^{-1}$;

a_T = 1 for RH ≥ 50, where RH is mean daily relative humidity, %. When RH < 50, then $a_T = 1 + 50 - RH/70$;

$T°$ = mean daily air temperature, °C;

R_s = Solar radiation, $MJ\ m^{2-1} day^{-1}$;

0.408 = Radiation conversion factor from $MJ\ m^{2-1} day^{-1}$ to $mm\ day^{-1}$.

$$\boldsymbol{EP_i = P_i * \left(\frac{125 - 0.2 * P_i}{125}\right) for\ P_i < 250\ mm} \quad \text{(S4)}$$

Or

$$EP_i = 125 + 0.1 * P_i\ for\ P_i > 250\ mm$$

where:

EP = Effective precipitation in month *i*, $mm\ month^{-1}$;

P= Precipitation in month i, $mm\ month^{-1}$;

i= *Month* of the year.

Table S6. Evapotranspiration coefficients (Kc).

Land Use/Cover	Evapotranspiration Coefficients (Kc)											
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Forest[A]	1.15[B]	1.11	1.07	1.11[C]	1.15	1.25	1.21[D]	1.17	1.16	1.15[B]	1.15[B]	1.15[B]
Eucalyptus[E]	1.35[B]	1.26	1.18	1.24[C]	1.30	1.56	1.51[D]	1.42	1.29	1.35[B]	1.35[B]	1.35[B]
Shrubland[F]	0.75[B]	0.62	0.63	0.64[C]	0.65	0.94	0.88[D]	0.81	0.61	0.75[B]	0.75[B]	0.75[B]
Grassland[F]	0.75[B]	0.62	0.63	0.64[C]	0.65	0.94	0.88[D]	0.81	0.61	0.75[B]	0.75[B]	0.75[B]
Sugarcane[G]	0.75	0.75	0.75	0.40	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Annualcrops[H]	1.15	1.15	0.5	0.3	1.2	1.2	1.2	0.6	-	-	-	0.4

[A] Assumed for forests in Sao Paulo state [98]

[B] Average from the months with measurement
[C] Average between March and May
[D] Average between June and Augustus
[E] Assumed for Eucalyptus plantations in Sao Paulo state [98]
[F] Assumed for pastures in Sao Paulo state [98]
[G] [100]
[H] [100]

6. Land use change dynamics

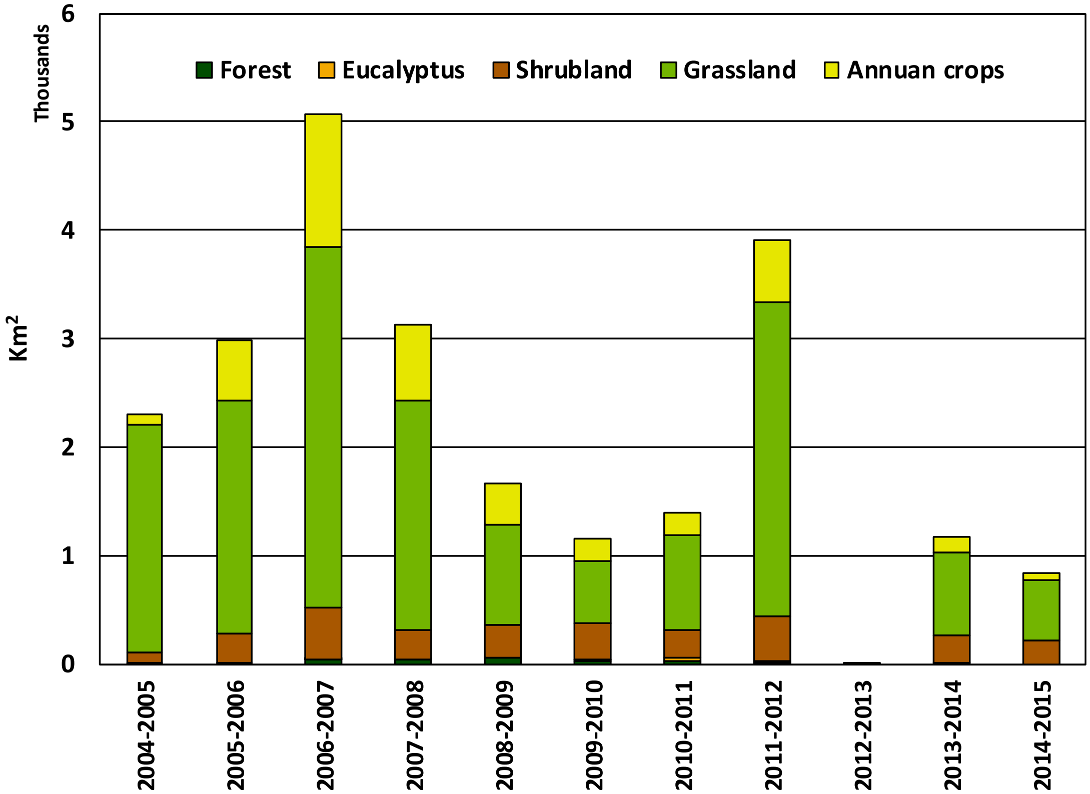

Figure S1. Share of land that was converted to sugarcane from 2004 to 2015.

7. LUC-related CO_2 emissions

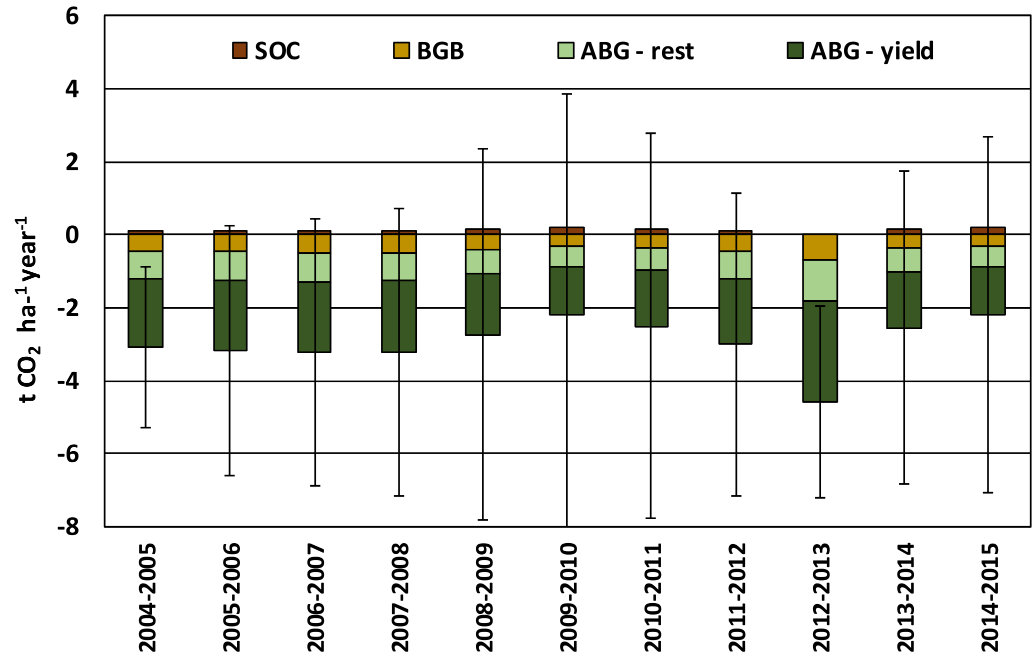

Figure S2. Average LUC-related CO_2 emissions with 2 standard deviations from the expansion of sugarcane from 2004 to 2015.

8. Mean species abundance

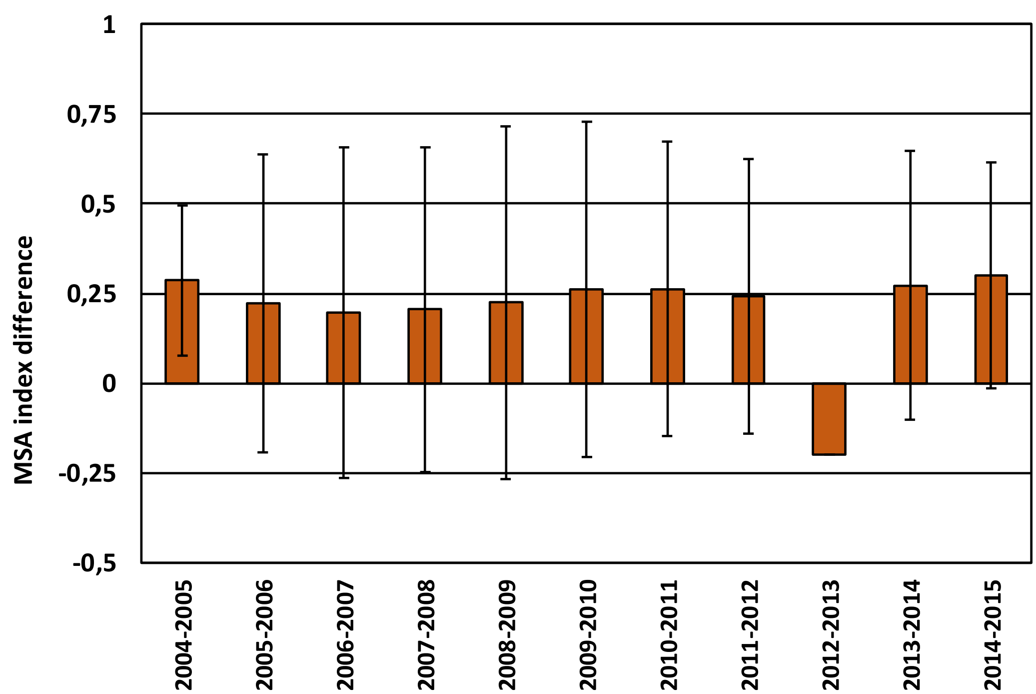

Figure S3. Average annual difference in mean species abundance with 2 standard deviations from the expansion of sugarcane from 2004 to 2015.

9. Soil erosion

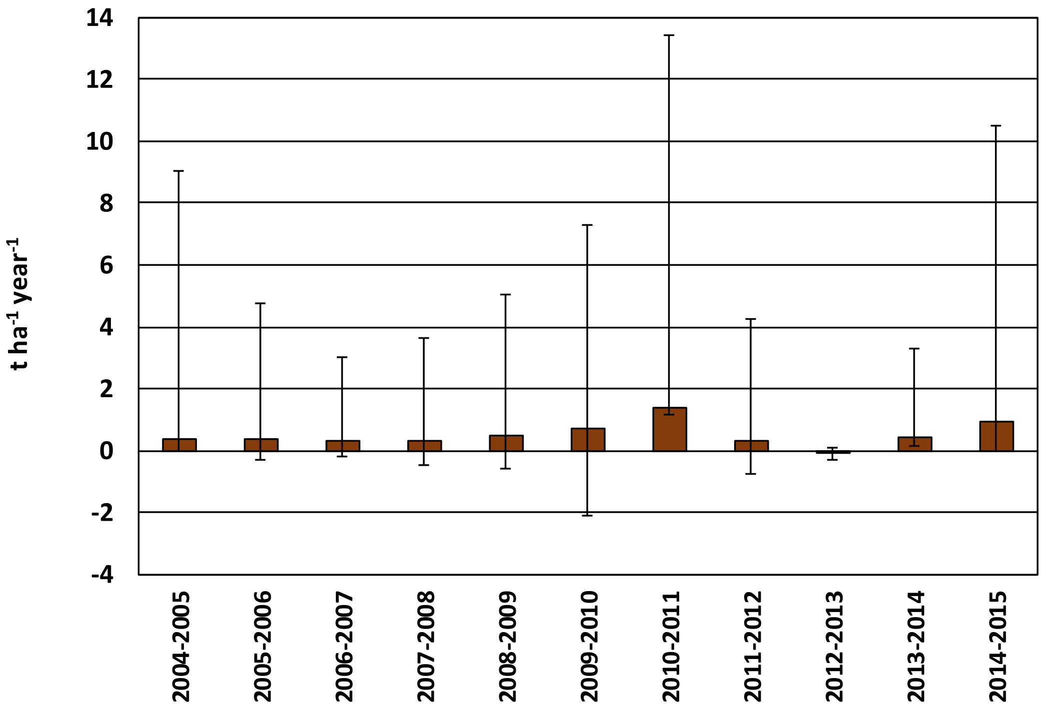

Figure S4. Average annual difference in soil loss with 2 standard deviations from the expansion of sugarcane from 2004 to 2015.

10. Water shortage

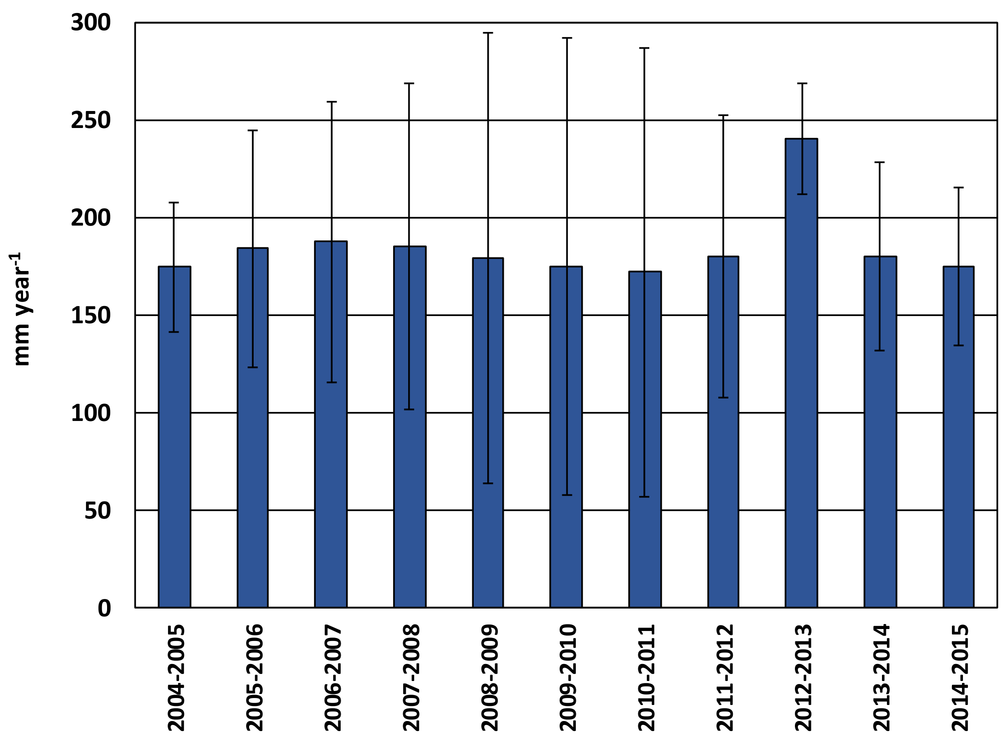

Figure S5. Average annual water shortage with 2 standard deviations from the expansion of sugarcane from 2004 to 2015**.**