Global assessment of landscape pattern changes from 1992 to 2020

Landscape Ecology

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Landscape metric	**Abbreviation**	**Units**	**Description**	**Treatment of missing values**
Aggregation Index	AI	Percent	Number of edges shared by the same LULC class divided by the hypothetical maximum possible number of edges that could be shared by that class.	NA
Coefficient of variation of patch area	AREA_CV	Hectares	Coefficient of all patch areas that belong to a given LULC class.	NA
Mean of patch area	AREA_MN	Hectares	Mean of all patch areas that belong to a given LULC class.	NA
Standard deviation of patch area	AREA_SD	Hectares	Standard deviation of all patch areas that belong to a given LULC class.	NA
Class area	CA	Hectares	Total area of a LULC class in a landscape.	Zero
Coefficient of variation of core area index	CAI_CV	Percent	Coefficient of core area index for all patches that are classified as a given LULC class. Core area index is core area as a percentage of patch area.	NA
Mean of core area index	CAI_MN	Percent	Mean of core area index for all patches that are classified as a given LULC class. Core area index is core area as a percentage of patch area.	NA

Landscape metric	**Abbreviation**	**Units**	**Description**	**Treatment of missing values**
Standard deviation of core area index	CAI_SD	Percent	Standard deviation for all patches that are classified as a given LULC class. Core area index is core area as a percentage of patch area.	NA
Coefficient of variation of related circumscribing circle	CIRCLE_CV	None	Coefficient of variation of the related circumscribing circle for all patches that are classified as a given LULC class. The related circumscribing circle is a ratio between patch area and the smallest circumscribing circle of a patch.	NA
Mean of related circumscribing circle	CIRCLE_MN	None	Mean of the related circumscribing circle for all patches that are classified as a given LULC class. The related circumscribing circle is a ratio between patch area and the smallest circumscribing circle of a patch.	NA
Standard deviation of related circumscribing circle	CIRCLE_SD	None	Standard deviation of the related circumscribing circle for all patches that are classified as a given LULC class. The related circumscribing circle is a ratio between patch area and the smallest circumscribing circle of the patch.	NA

Landscape metric	**Abbreviation**	**Units**	**Description**	**Treatment of missing values**
Clumpiness index	CLUMPY	None	The proportional deviation of the number of edges shared by the same LULC class from the number of edges expected to be shared by that class under a random spatial distribution.	NA
Patch Cohesion Index	COHESION	Percent	Describes the connectedness of patches which belong to a given LULC class.	NA
Coefficient of variation of Contiguity index	CONTIG_CV	None	Coefficient of variation of the Contiguity index for all patches of a given LULC class. Contiguity index describes the spatial connectedness of the cells which make up a patch based on a focal filter approach.	NA
Mean of Contiguity index	CONTIG_MN	None	Mean of the Contiguity index for all patches of a given LULC class. Contiguity index describes the spatial connectedness of the cells which make up a patch based on a focal filter approach.	NA

Landscape metric	**Abbreviation**	**Units**	**Description**	**Treatment of missing values**
Standard deviation of Contiguity index	CONTIG_SD	None	Standard deviation of the Contiguity index for all patches of a given LULC class. Contiguity index describes the spatial connectedness of the cells which make up a patch based on a focal filter approach.	NA
Coefficient of variation of core area	CORE_CV	Hectares	Coefficient of variation of the core area of all patches classified as a given LULC class. Core area is the area of grid cells within a patch that are not adjacent to a cell of a different LULC class.	NA
Mean of core area	CORE_MN	Hectares	Mean of the core area of all patches classified as a given LULC class. Core area is the area of grid cells within a patch that are not adjacent to a cell of a different LULC class.	NA
Standard deviation of core area	CORE_SD	Hectares	Standard deviation of the core area of all patches classified as a given LULC class. Core area is the area of grid cells within a patch that are not adjacent to a cell of a different LULC class.	NA

Landscape metric	**Abbreviation**	**Units**	**Description**	**Treatment of missing values**
Core area percentage of landscape	CPLAND	Percent	The core area of a given LULC class as a percentage of the total area of the landscape. Core area is made up of grid cells within patches that are not adjacent to a cell of a different LULC class.	Zero
Disjunct core area density	DCAD	Number per 100 hectares	The number of disjunct core area patches per 100 hectares and in relation to the total area of the landscape. A disjunct core area patch has no neighbouring cells of another LULC class.	Zero
Coefficient of variation of number of disjunct core areas	DCORE_CV	None	Coefficient of variation of the number of disjunct core area patches for a given LULC class. A disjunct core area patch has no neighbouring cells of another LULC class.	NA
Mean of number of disjunct core areas	DCORE_MN	None	Mean of the number of disjunct core area patches for a given LULC class. A disjunct core area patch has no neighbouring cells of another LULC class.	NA
Standard deviation of number of disjunct core areas	DCORE_SD	None	Standard deviation of the number of disjunct core area patches for a given LULC class. A disjunct core area patch has no neighbouring cells of another LULC class.	NA

Landscape metric	**Abbreviation**	**Units**	**Description**	**Treatment of missing values**
Landscape division index	DIVISION	Proportion	Defines the probability that two grid cells selected at random are not in the same patch of a specific LULC class.	NA
Edge density	ED	Metres per hectare	The sum of all edges of a given LULC class in a landscape as a proportion of the total landscape area.	Zero
Coefficient of variation of Euclidean nearest-neighbour distance	ENN_CV	Metres	Coefficient of variation of the distance to the nearest neighbouring patch of the same LULC class for all patches of a given LULC class.	NA
Mean of Euclidean nearest-neighbour distance	ENN_MN	Metres	Mean of the distance to the nearest neighbouring patch of the same LULC class for all patches of a given LULC class.	NA
Standard deviation of Euclidean nearest-neighbour distance	ENN_SD	Metres	Standard deviation of the distance to the nearest neighbouring patch of the same LULC class for all patches of a given LULC class.	NA

Landscape metric	**Abbreviation**	**Units**	**Description**	**Treatment of missing values**
Coefficient of variation fractal dimension index	FRAC_CV	None	Coefficient of variation of the fractal dimension index of all patches classified as a given LULC class. Fractal dimension index characterises the complexity of a patch according to the patch perimeter and area.	NA
Mean of fractal dimension index	FRAC_MN	None	Mean of the fractal dimension index of all patches classified as a given LULC class. Fractal dimension index characterises the complexity of a patch according to the patch perimeter and area.	NA
Standard deviation of fractal dimension index	FRAC_SD	None	Standard deviation of the fractal dimension index of all patches classified as a given LULC class. Fractal dimension index characterises the complexity of a patch according to the patch perimeter and area.	NA
Coefficient of variation of the radius of gyration	GYRATE_CV	Metres	Coefficient of variation of the radius of gyration across all patches classified as a given LULC class. The radius of gyration quantifies the distance between a each cell in a patch and the patch centroid.	NA

Landscape metric	**Abbreviation**	**Units**	**Description**	**Treatment of missing values**
Mean of the radius of gyration	GYRATE_MN	Metres	Mean of the radius of gyration across all patches classified as a given LULC class. The radius of gyration quantifies the distance between each cell in a patch and the patch centroid.	NA
Standard deviation of the radius of gyration	GYRATE_SD	Metres	Standard deviation of the radius of gyration across all patches classified as a given LULC class. The radius of gyration quantifies the distance between each cell in a patch and the patch centroid.	NA
Interspersion and Juxtaposition index	IJI	Percent	Characterises the intermixing of LULC classes within a landscape.	NA
Largest Patch Index	LPI	Percent	Describes the percentage of the landscape covered by the largest patch of a given LULC class.	Zero
Landscape Shape Index	LSI	None	Ratio between the actual edge length of a LULC class in a landscape and its theoretical minimum edge length if it were as aggregated as possible.	NA
Effective Mesh Size	MESH	Hectares	The sum of squared patch areas for a given LULC class in relation to the total area of the landscape, which gives a measure of patch structure.	NA

Landscape metric	**Abbreviation**	**Units**	**Description**	**Treatment of missing values**
Number of disjunct core area patches	NDCA	None	Number of core area patches of a LULC class in a landscape, where a core area patch has no neighbouring cells of another LULC class.	Zero
Normalised Landscape Shape Index	NLSI	None	Characterises the ratio of the actual edge length of a given LULC class to the theoretical range of edge lengths if that class was minimally or maximally aggregated.	NA
Number of patches	NP	None	Number of patches of a LULC class in a landscape.	Zero
Perimeter-Area Fractal Dimension	PAFRAC	None	Characterises the patch complexity of a specific LULC class by dividing two by the slope of the relationship between the area and perimeter of that class.	NA
Coefficient of variation of the perimeter-area ratio	PARA_CV	None	Coefficient of variation of the perimeter to area ratio for all patches belonging to a given LULC class.	NA
Mean of the perimeter-area ratio	PARA_MN	None	Mean of the perimeter to area ratio for all patches belonging to a given LULC class.	NA
Standard deviation of the perimeter-area ratio	PARA_SD	None	Standard deviation of the perimeter to area ratio for all patches belonging to a given LULC class.	NA

Landscape metric	**Abbreviation**	**Units**	**Description**	**Treatment of missing values**
Patch density	PD	Number per 100 hectares	The number of patches of a given LULC class in relation to the total area of the landscape.	Zero
Percentage of Like Adjacencies	PLADJ	Percent	Quantifies how often grid cells of a given LULC class are adjacent to one another.	NA
Percentage of landscape of class	PLAND	Percent	The percentage of a landscape covered by a specific LULC class.	Zero
Coefficient of variation of shape index	SHAPE_CV	None	Coefficient of variation of the shape index for all patches of a given LULC class, where the shape index is the ratio of the perimeter of a patch and the square root of patch area.	NA
Mean of shape index	SHAPE_MN	None	Mean of the shape index for all patches of a given LULC class, where the shape index is the ratio of the perimeter of a patch and the square root of patch area.	NA
Standard deviation of shape index	SHAPE_SD	None	Standard deviation of the shape index for all patches of a given LULC class, where the shape index is the ratio of the perimeter of a patch and the square root of patch area.	NA

Landscape metric	Abbreviation	Units	Description	Treatment of missing values
Splitting index	SPLIT	None	Gives the hypothetical number of patches in a landscape if all the patches of a specific LULC class were split into patches of equal size.	NA
Total core area	TCA	Hectares	Total core area of a LULC class in a landscape, where core area is made up of grid cells with no neighbouring cells of a different LULC class.	Zero
Total edge length	TE	Metres	Total edge length of a LULC class in a landscape.	Zero

Table S 1 *Description of all landscape metrics tested for predictable scaling relationships with increasing landscape extent across Colombia. All landscape metrics were quantified using the 'landscapemetrics' R package (Hesselbarth et al. 2019), which gives further information as to how each metric is calculated. Description of landscape metrics based on Hesselbarth et al. (2019). LULC = land use and land cover. Treatment of missing values refers to the value used for that metric to represent that a LULC class was missing from a landscape. 'NA' indicates that it was not possible to calculate that metric when a LULC class was missing from a landscape. 'Zero' indicates that a value of 0 was used in calculations for that metric when a LULC class was missing from a landscape; for example, class area would be equal to 0 where a LULC class is not present in a landscape*

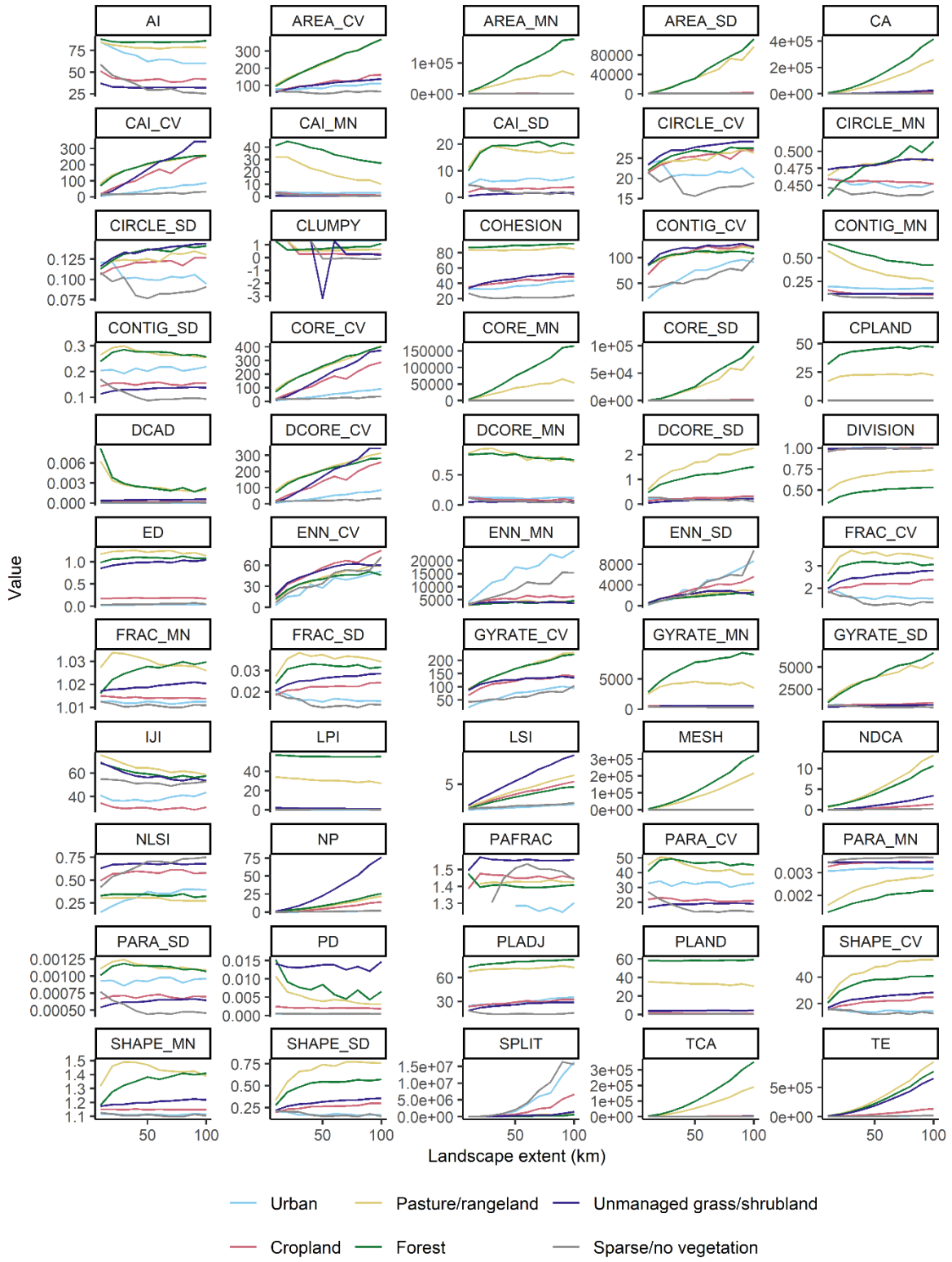


Fig. S 1 *Scaling relationships of landscape metrics with increasing landscape extent for 55 class-level metrics in Colombia in 1992. Landscape extent is the length of each side of a landscape in kilometres. All landscape metric definitions and units are described in Table S 1 and further information can be found in Hesselbarth et al. (2019). Lines give the mean value of a metric across landscapes of different extents for one land use and land cover class*

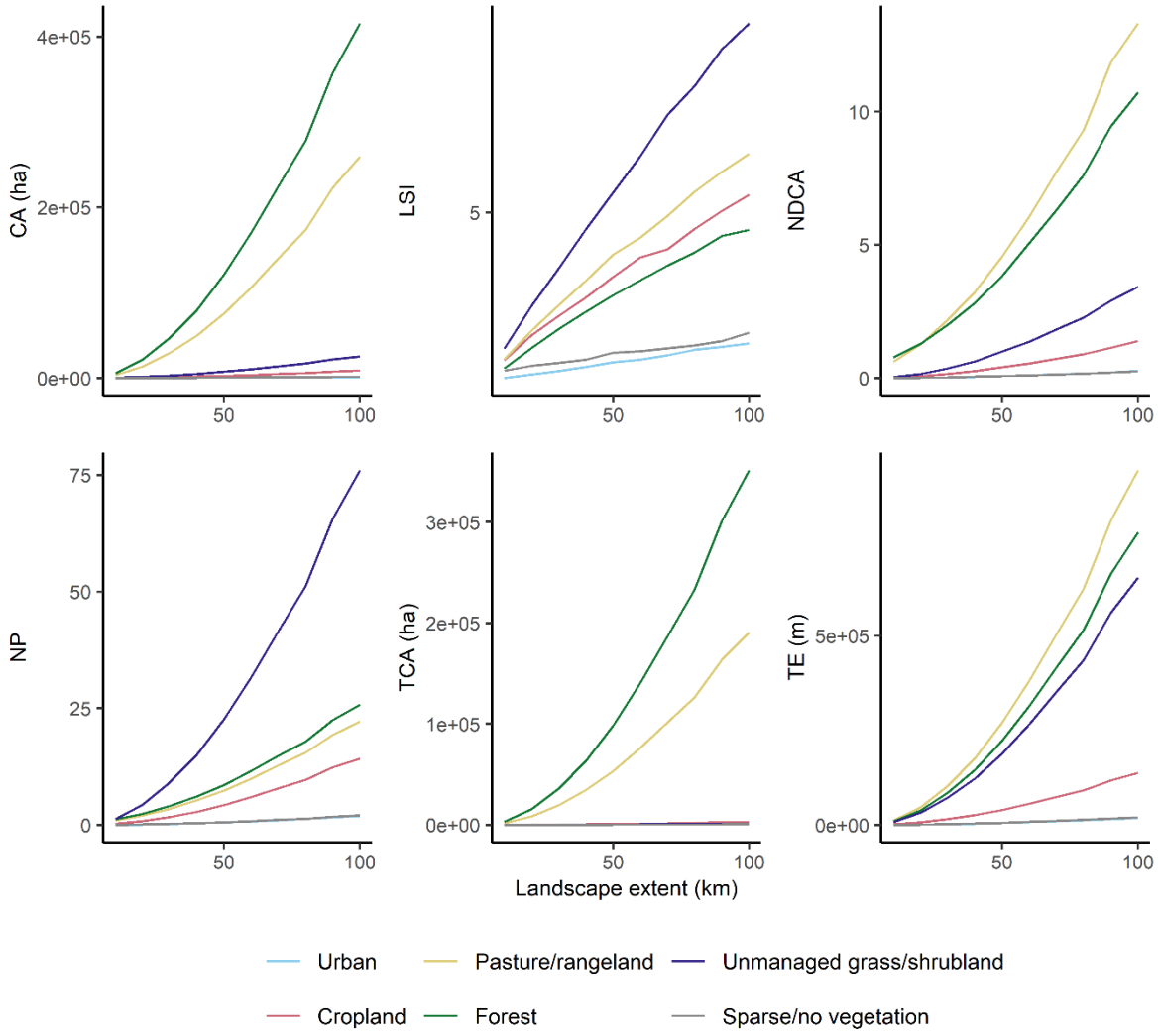


Fig. S 2 *Scaling relationships for six landscape metrics with increasing landscape extent across Colombia. All six metrics showed consistent scaling across increasing landscape extent in Colombia in 1992. Landscape extent is the length of each side of a landscape in kilometres. Lines give the mean value of a metric across landscapes of different extents for one land use and land cover class. See Fig. 2 and Table 1 for definitions of landscape metrics*

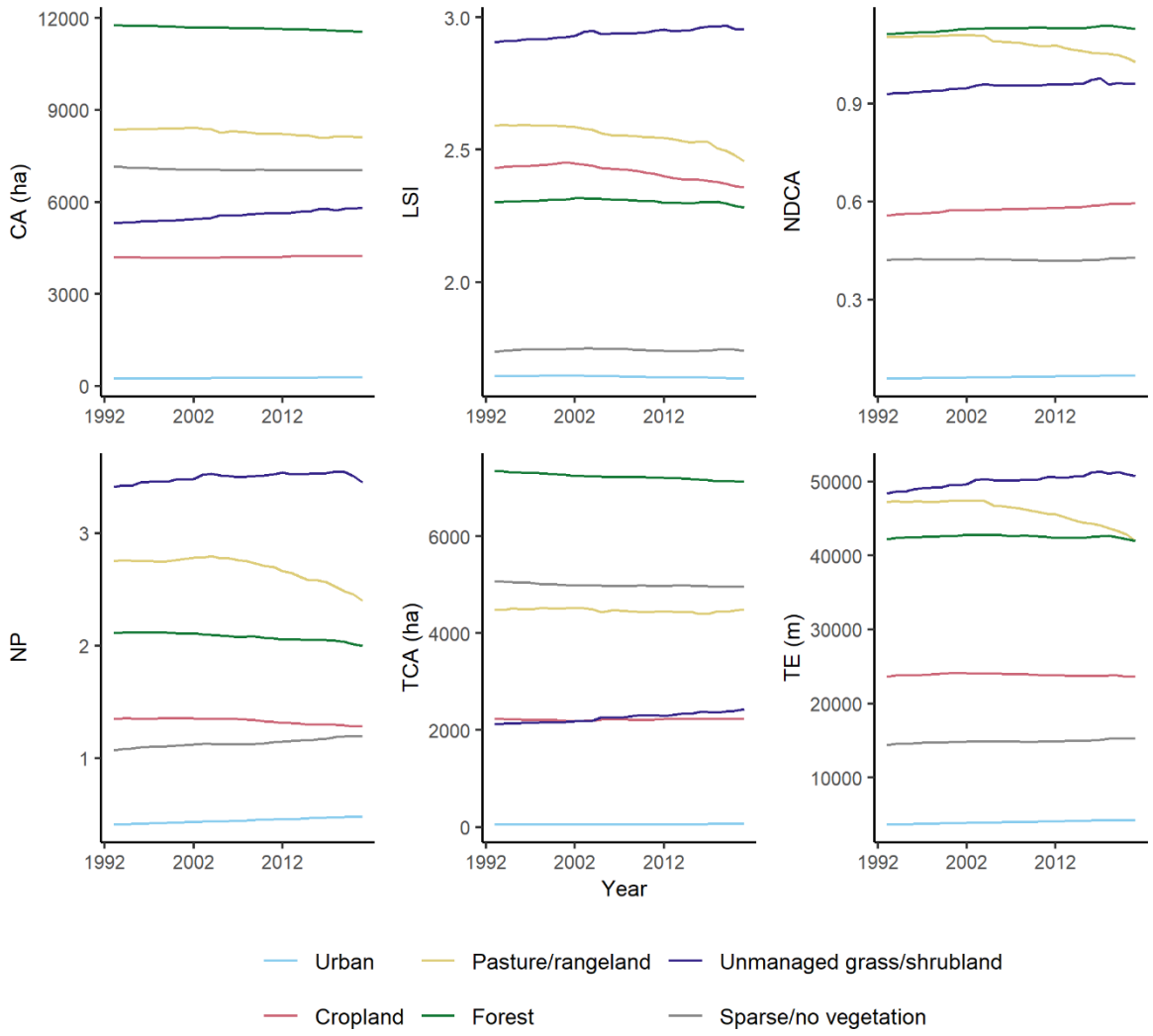


Fig. S 3 *Average of global-scale landscape patterns in 400 km² extent landscapes from 1992 to 2020. Lines give the mean of one landscape metric for one land use and land cover class across 400 km² landscapes in every year from 1992 to 2020. See Fig. 2 for landscape pattern definitions and units. Standard deviations are plotted separately in Fig. S 7*

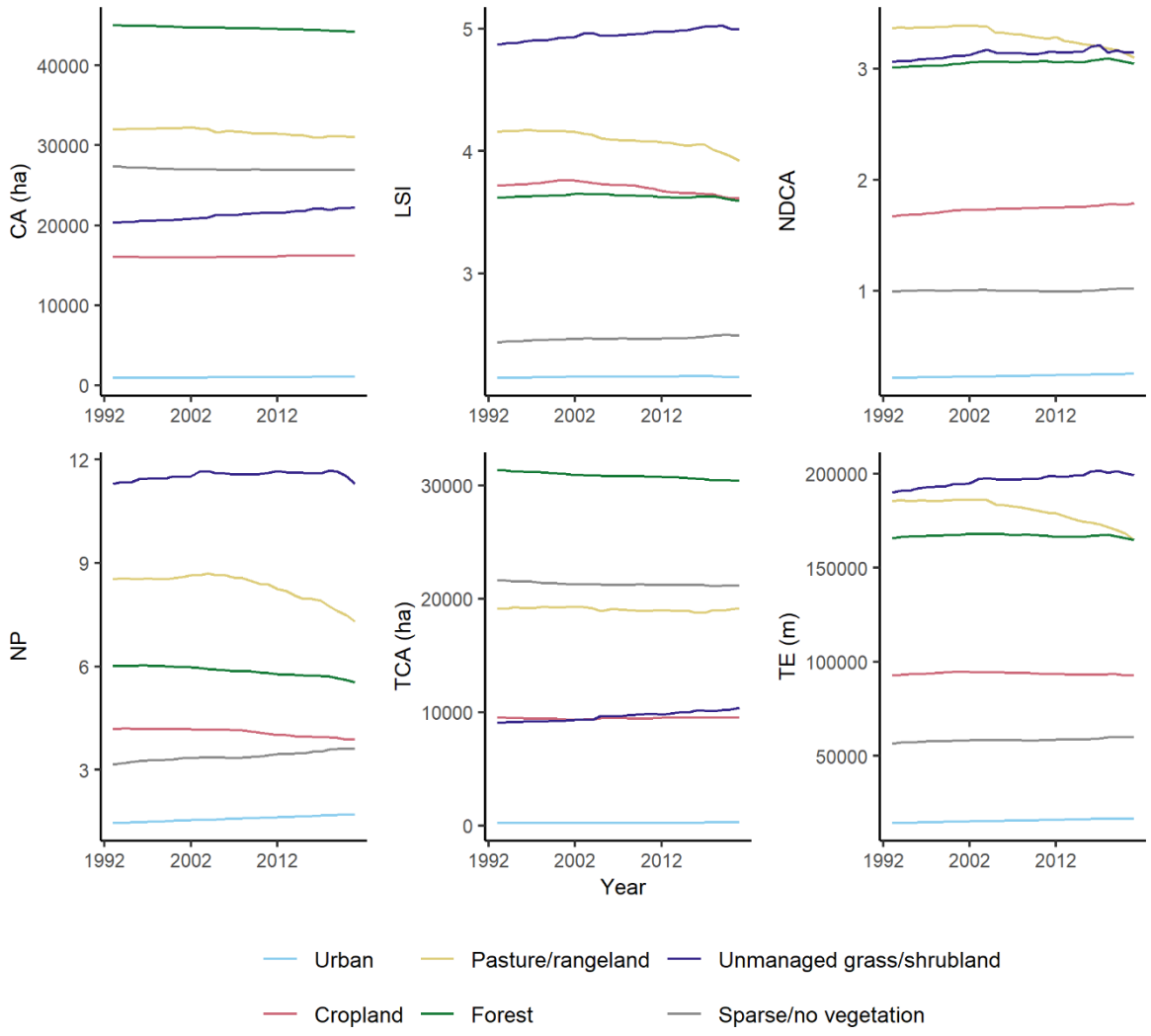


Fig. S 4 *Average of global-scale landscape patterns in 1600 km² extent landscapes from 1992 to 2020. Lines give the mean of one landscape metric for one land use and land cover class across 1600 km² landscapes in every year from 1992 to 2020. See Fig. 2 for landscape pattern definitions and units. Standard deviations are plotted separately in Fig. S 8*

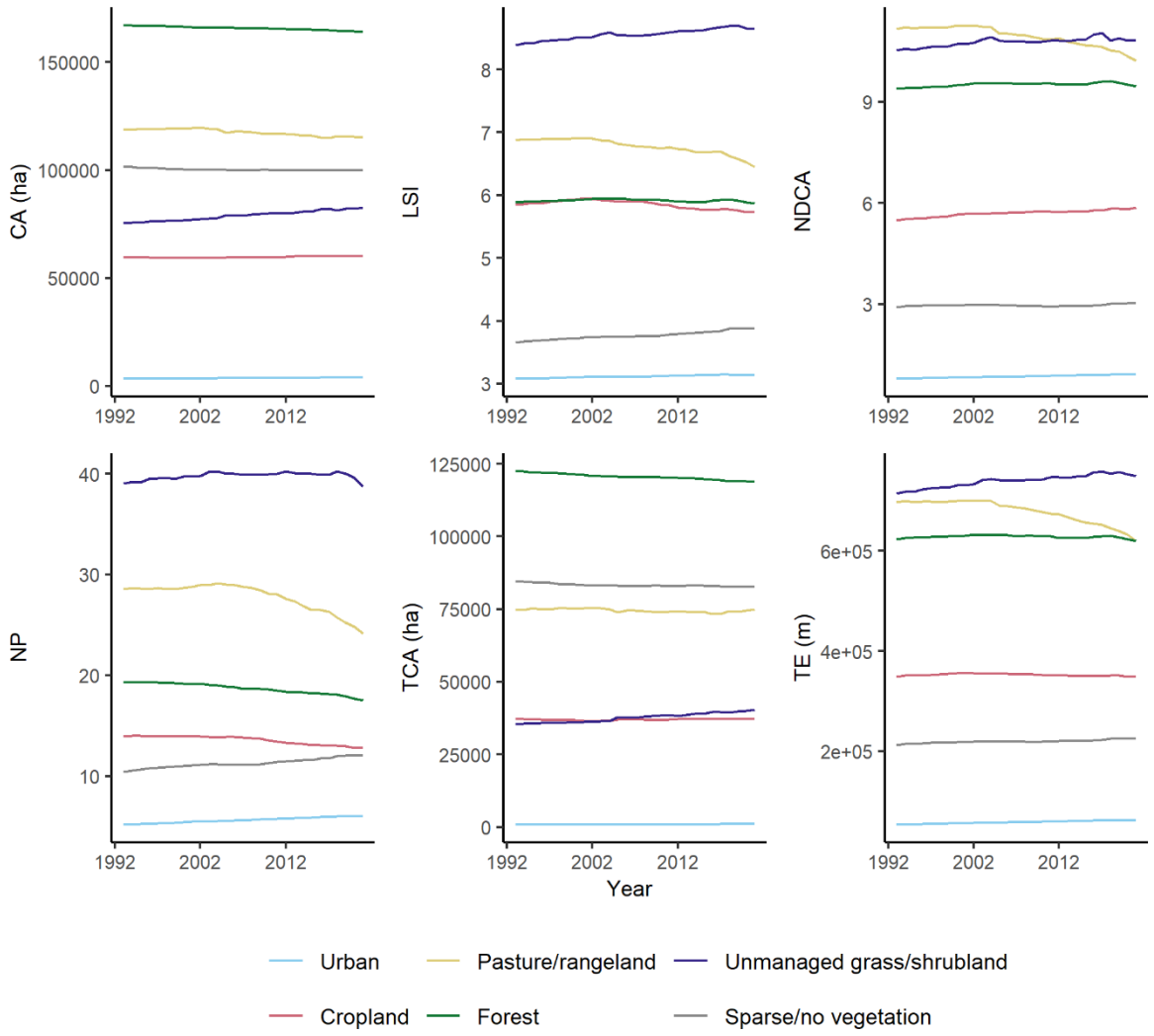


Fig. S 5 *Average of global-scale landscape patterns in 6400 km² extent landscapes from 1992 to 2020. Lines give the mean of one landscape metric for one land use and land cover class across 6400 km² landscapes in every year from 1992 to 2020. See Fig. 2 for landscape pattern definitions and units. Standard deviations are plotted separately in Fig. S 9*

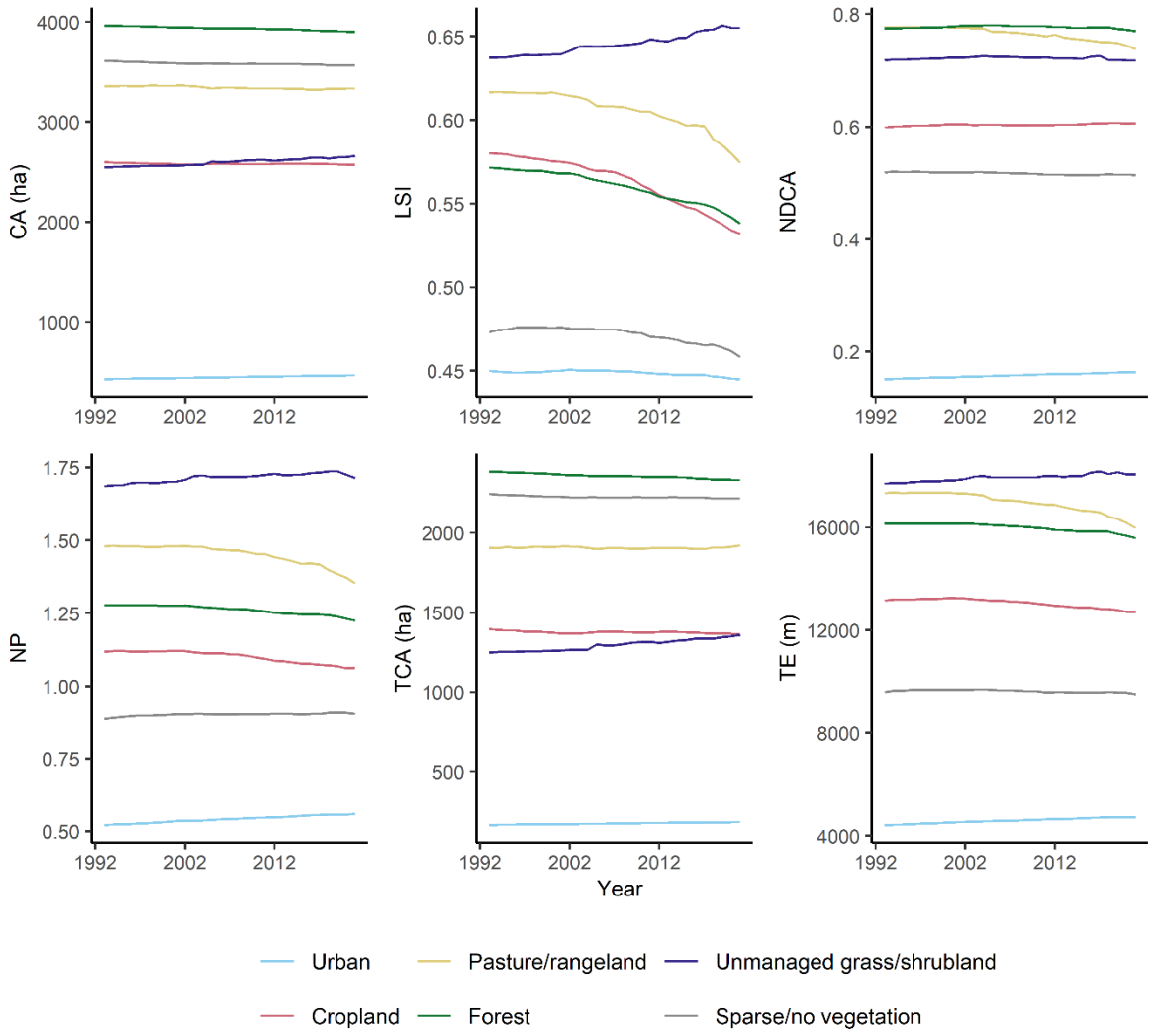


Fig. S 6 *Global-scale standard deviations in landscape metrics in 100 km² extent landscapes from 1992 to 2020. Lines give the standard deviation of one landscape metric for one land use and land cover class across landscapes of 100 km² extent in every year from 1992 to 2020. See Fig. 2 for landscape metric definitions and units*

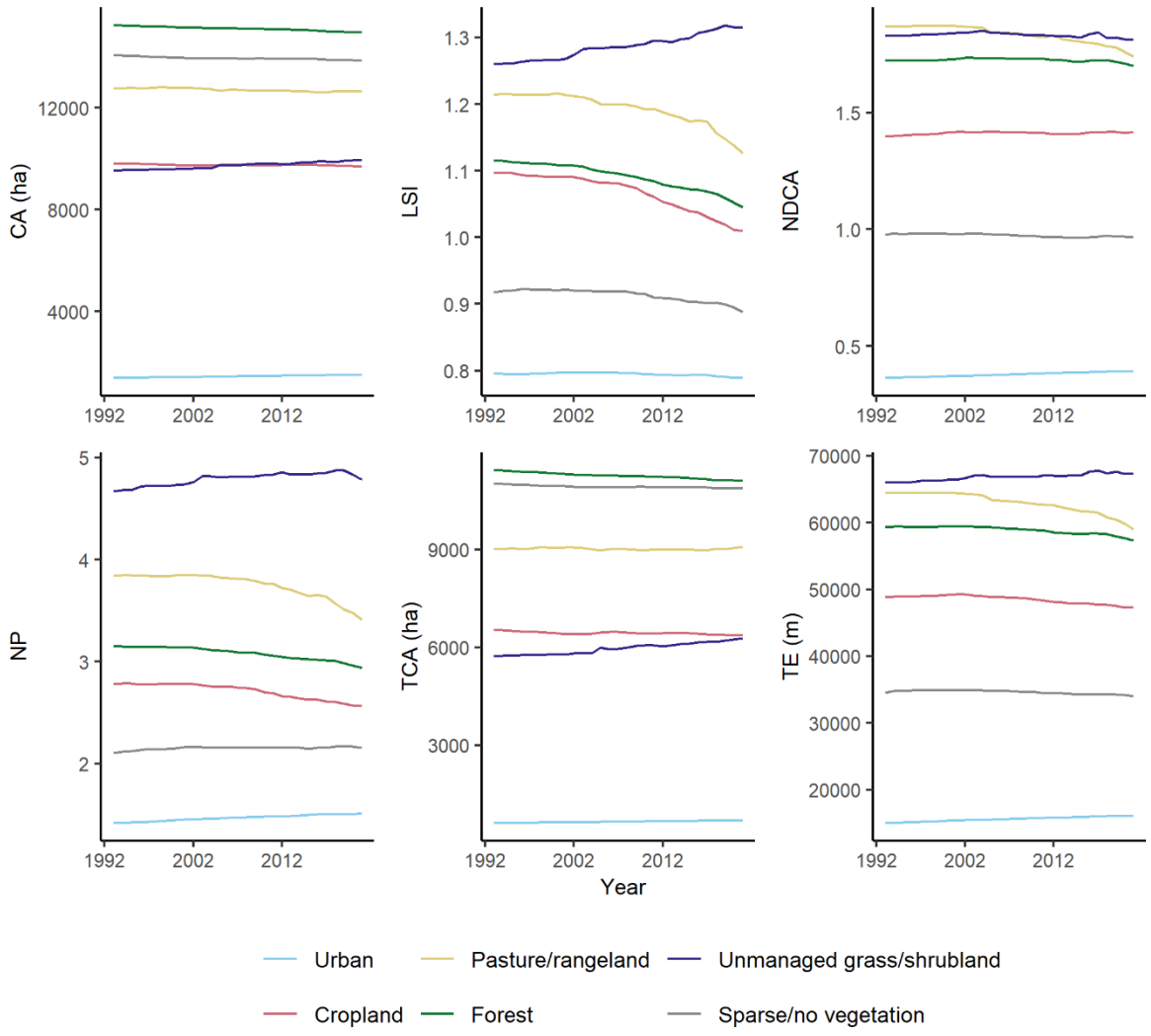


Fig. S 7 *Global-scale standard deviations in landscape metrics in 400 km² extent landscapes from 1992 to 2020. Lines give the standard deviation of one landscape metric for one land use and land cover class across landscapes of 400 km² extent in every year from 1992 to 2020. See Fig. 2 for landscape metric definitions and units*

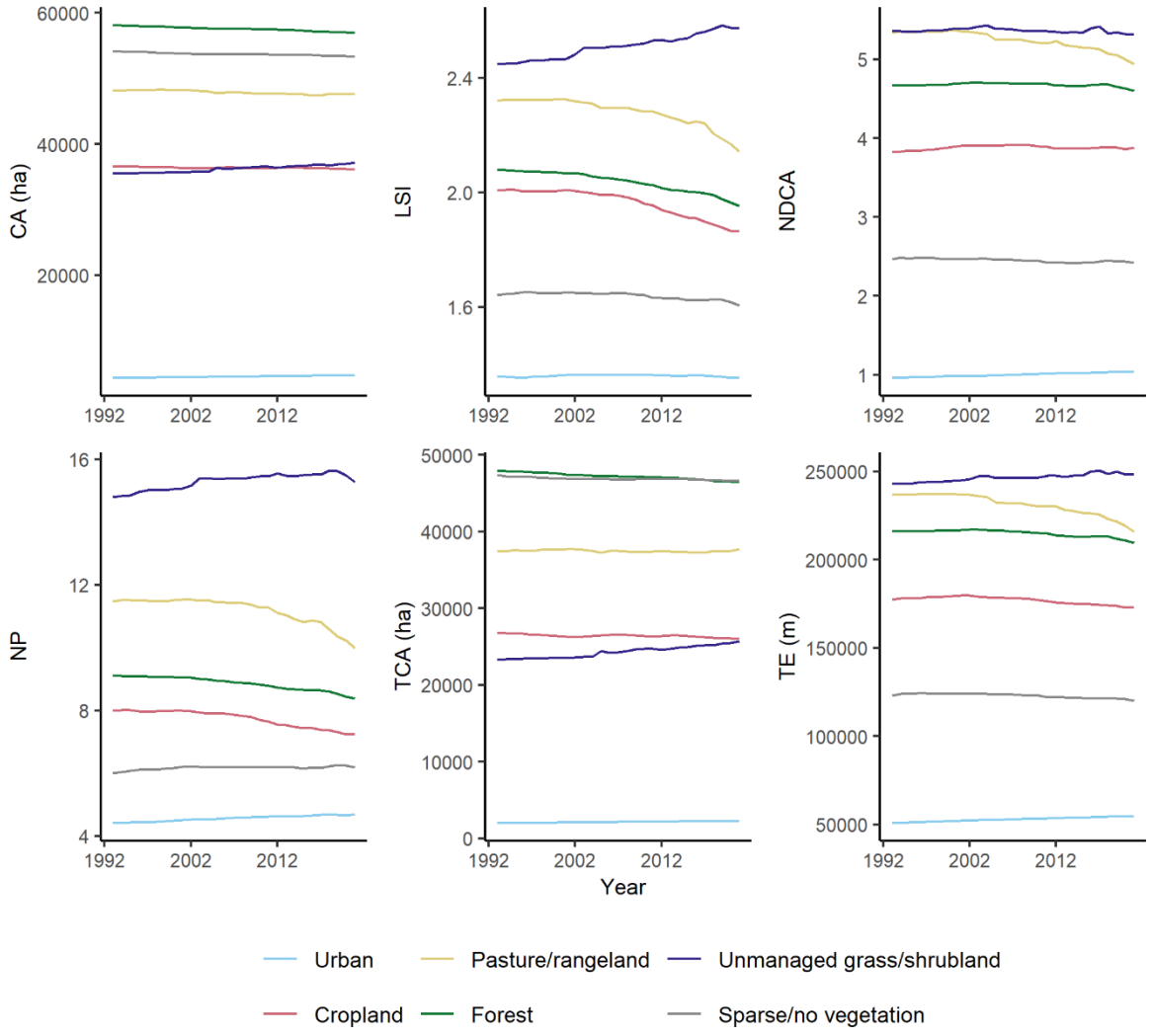


Fig. S 8 *Global-scale standard deviations in landscape metrics in 1600 km² extent landscapes from 1992 to 2020. Lines give the standard deviation of one landscape metric for one land use and land cover class across landscapes of 1600 km² extent in every year from 1992 to 2020. See Fig. 2 for landscape metric definitions and units*

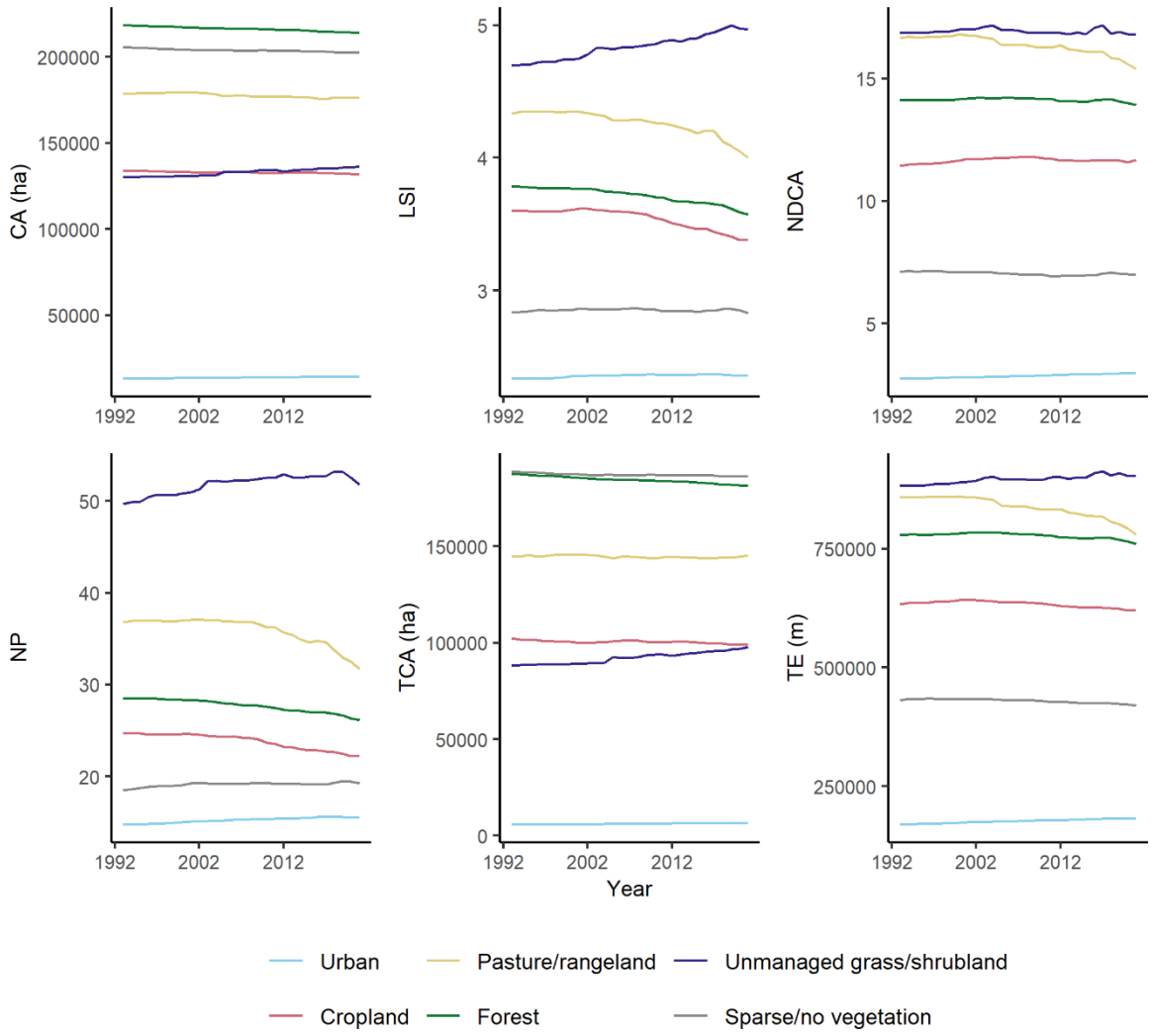


Fig. S 9 *Global-scale standard deviations in landscape metrics in 6400 km² extent landscapes from 1992 to 2020. Lines give the standard deviation of one landscape metric for one land use and land cover class across landscapes of 6400 km² extent in every year from 1992 to 2020. See Fig. 2 for landscape metric definitions and units*

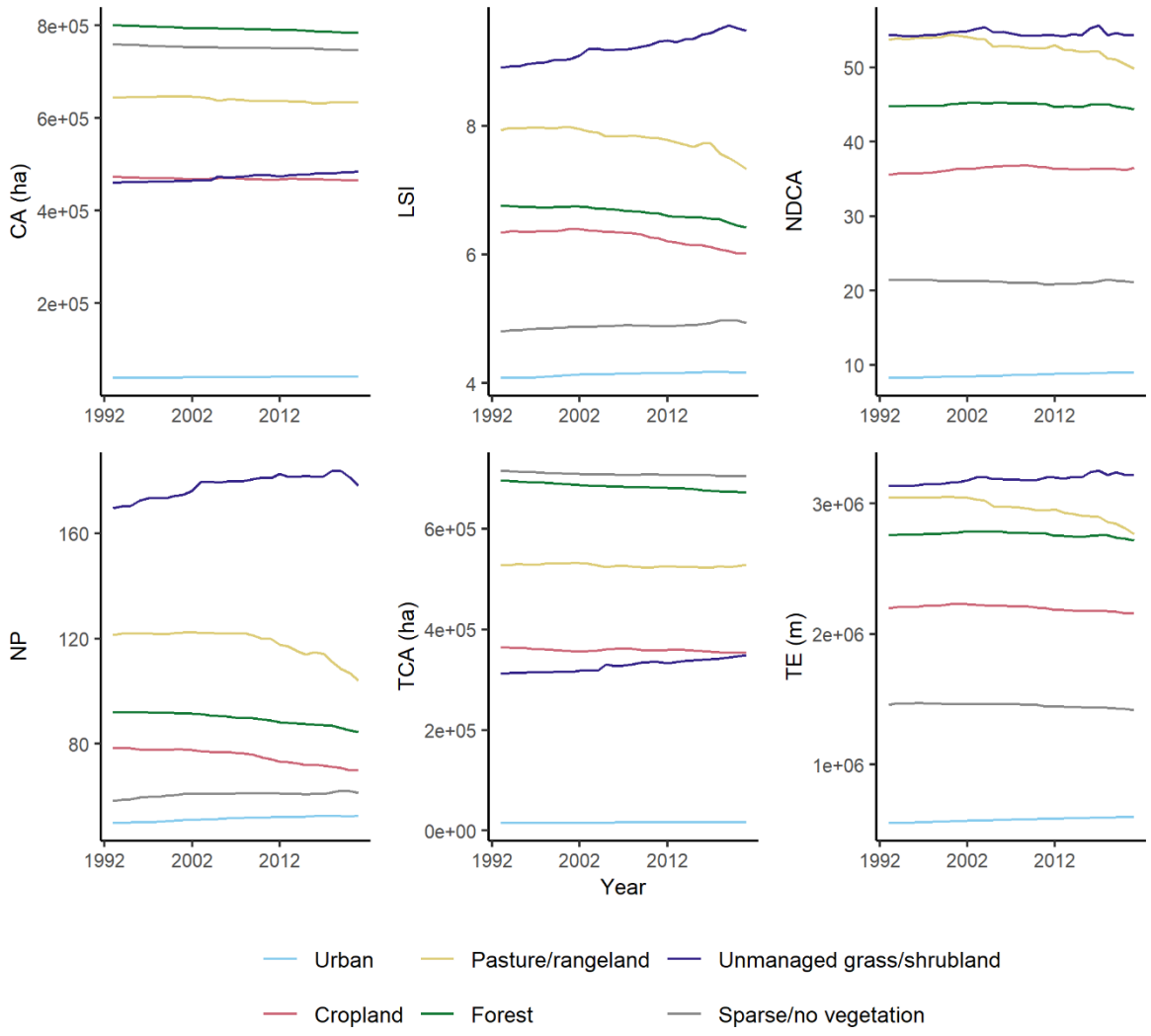


Fig. S 10 *Global-scale standard deviations in landscape metrics in 25600 km² extent landscapes from 1992 to 2020. Lines give the standard deviation of one landscape metric for one land use and land cover class across landscapes of 25600 km² extent in every year from 1992 to 2020. See Fig. 2 for landscape metric definitions and units*

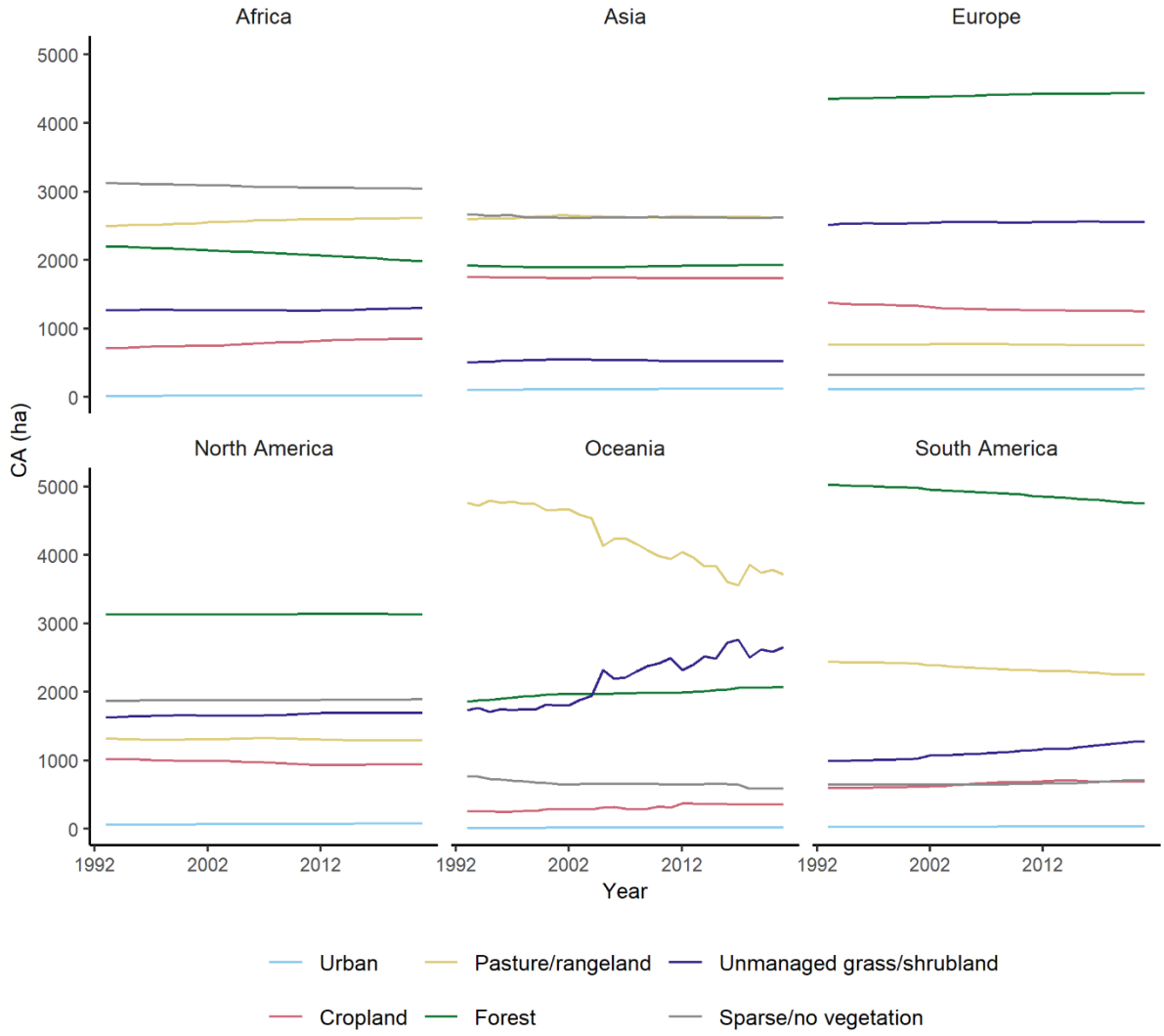


Fig. S 11 *Average class area (CA) at continental-scale from 1992 to 2020 in landscapes of 100 km² extent. Lines give the mean of CA for one land use and land cover class. Units for CA are hectares (ha). Standard deviations are plotted separately in Fig. S 17*

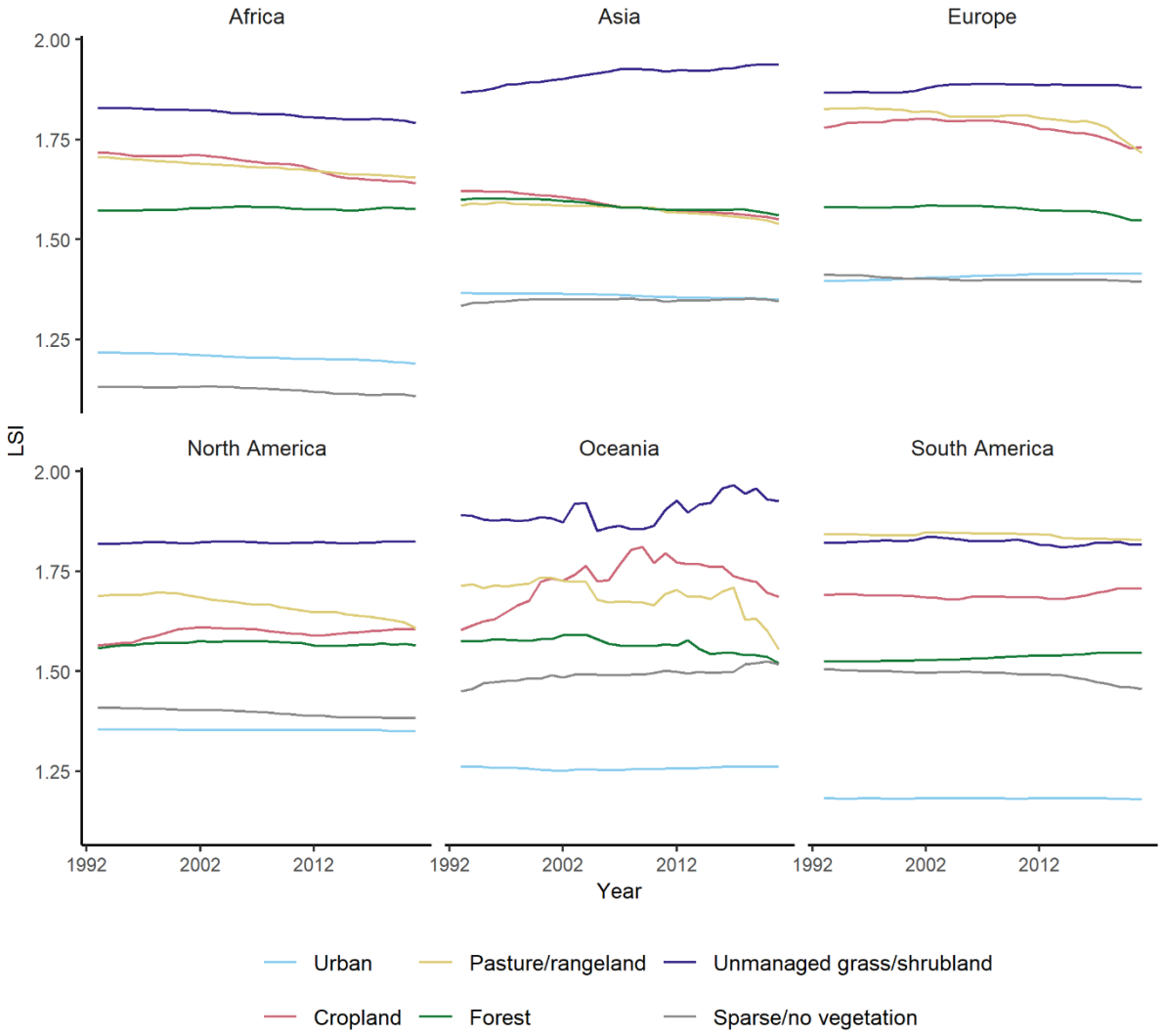


Fig. S 12 *Average Landscape Shape Index (LSI) at continental-scale from 1992 to 2020 in landscapes of 100 km² extent. Lines give the mean of LSI for one land use and land cover class. LSI is a unitless measure. Standard deviations are plotted separately in Fig. S 18*

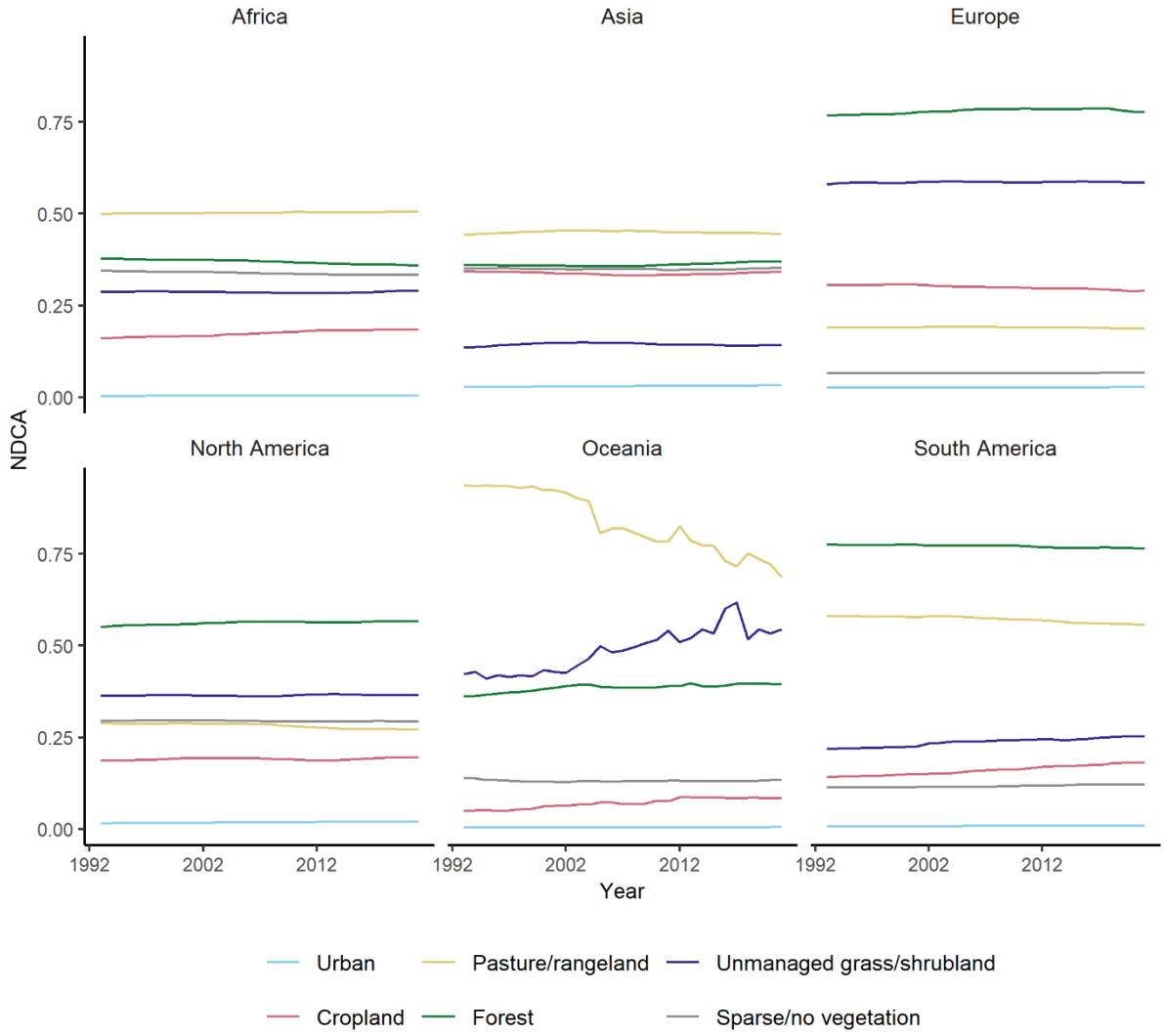
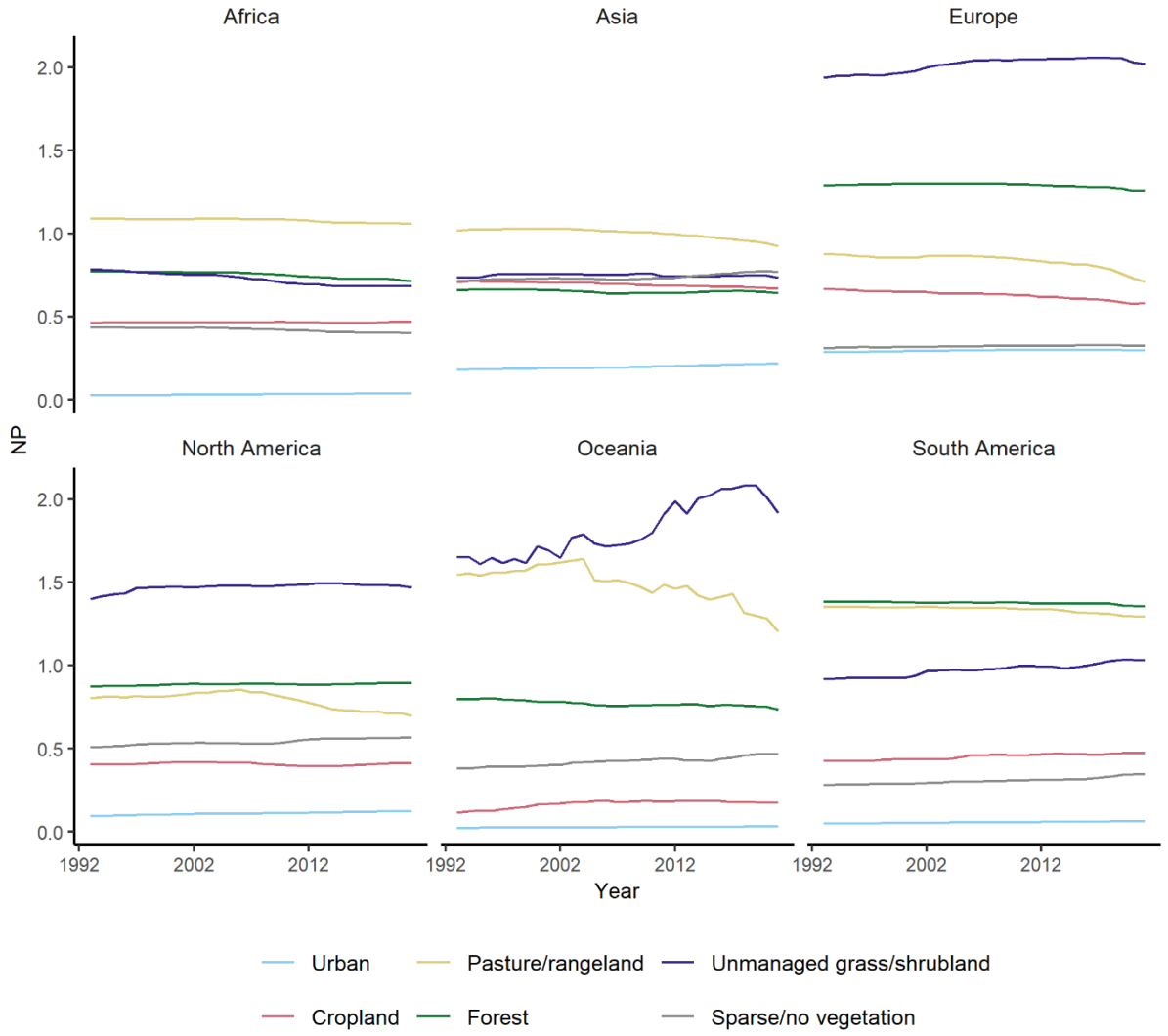
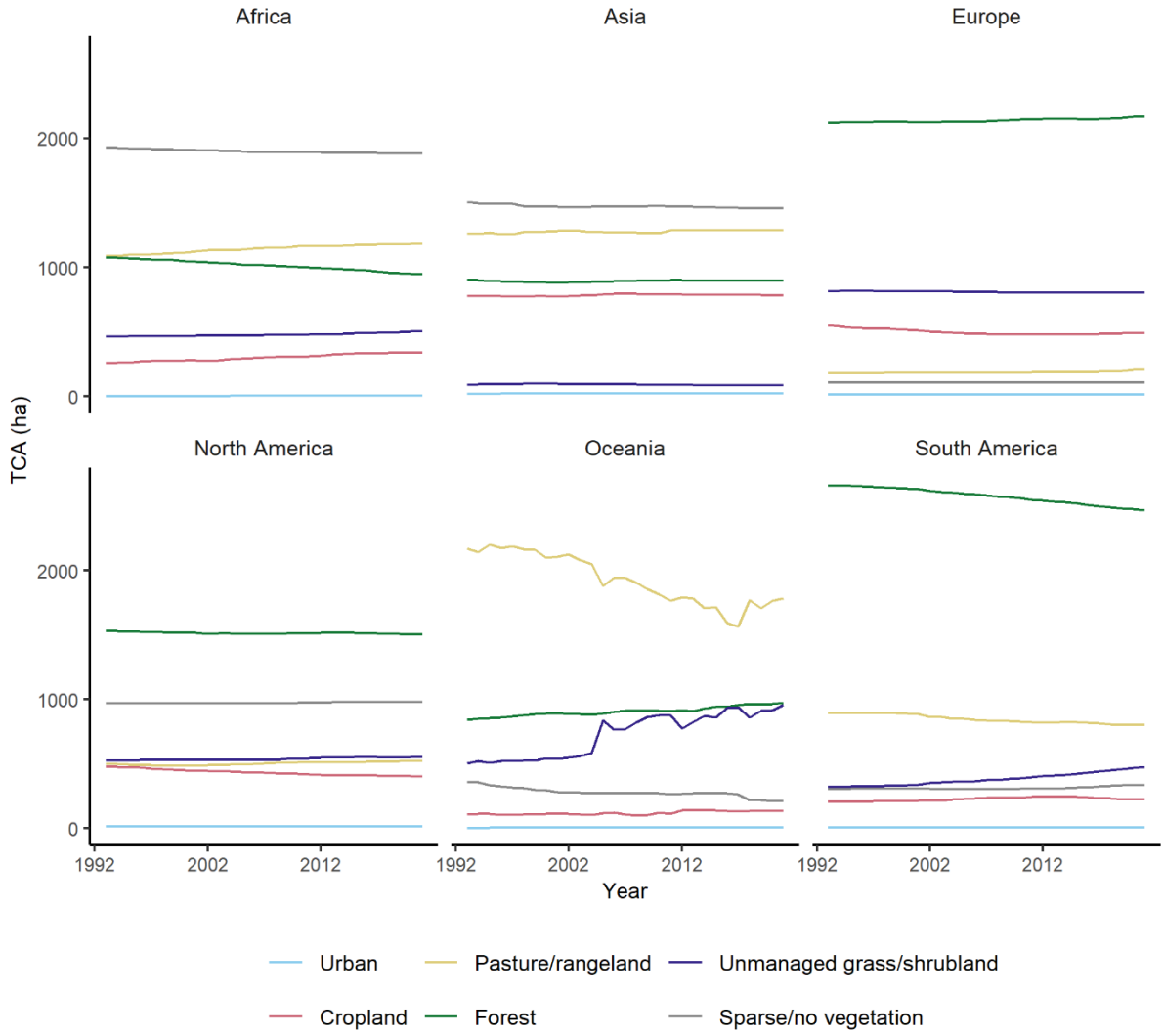


Fig. S 13 *Average number of disjunct core area patches (NDCA) at continental-scale from 1992 to 2020 in landscapes of 100 km² extent. Lines give the mean of NDCA for one land use and land cover class. NDCA is a unitless measure. Standard deviations are plotted separately in Fig. S 19*



88

89 ***Fig. S 14*** *Average number of patches (NP) at continental-scale from 1992 to 2020 in landscapes of 100*
90 *km² extent. Lines give the mean of NP for one land use and land cover class. NP is a unitless measure.*
91 *Standard deviations are plotted separately in Fig. S 20*



92

93 ***Fig. S 15*** *Average total core area (TCA) at continental-scale from 1992 to 2020 in landscapes of 100*
94 *km² extent. Lines give the mean of TCA for one land use and land cover class. Units for TCA are*
95 *hectares (ha). Standard deviations are plotted separately in Fig. S 21*

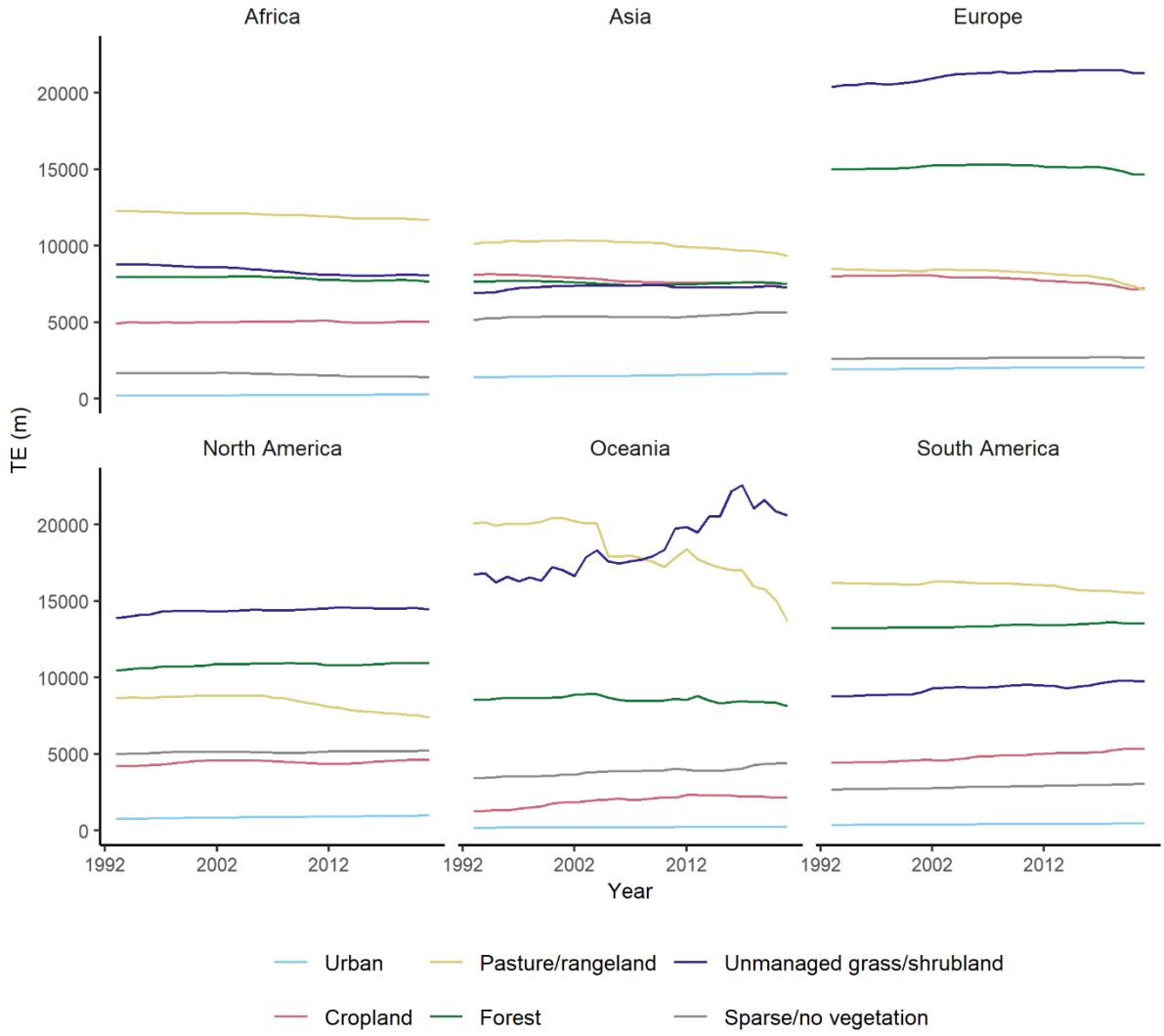


Fig. S 16 *Average total edge length (TE) at continental-scale from 1992 to 2020 in landscapes of 100 km² extent. Lines give the mean of TE for one land use and land cover class. Units for TE are metres (m). Standard deviations are plotted separately in Fig. S 22*

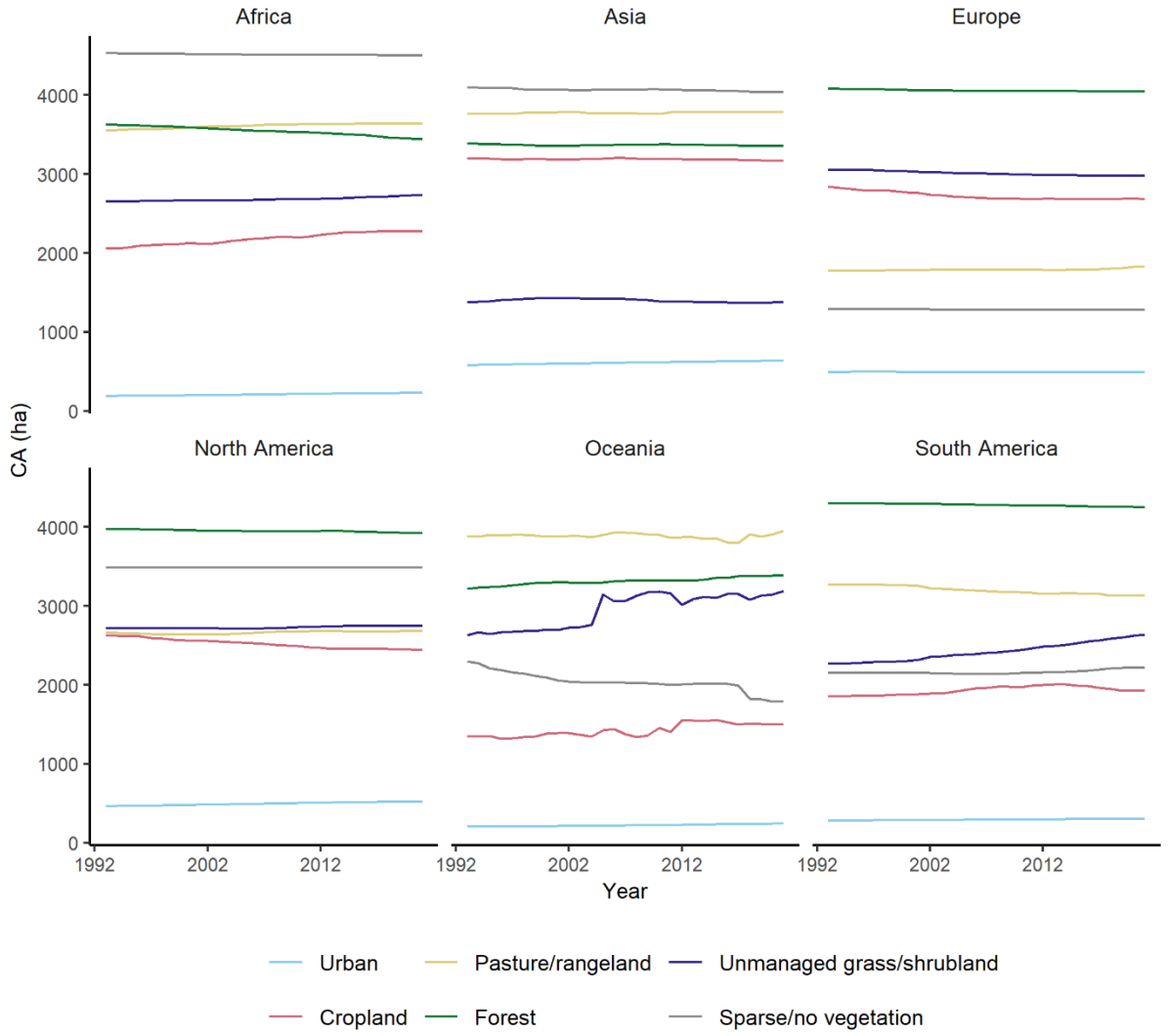


Fig. S 17 *Standard deviation of class area (CA) from 1992 to 2020 in landscapes of 100 km² extent. Lines give the standard deviation of CA for one land use and land cover class. Units of CA are hectares (ha)*

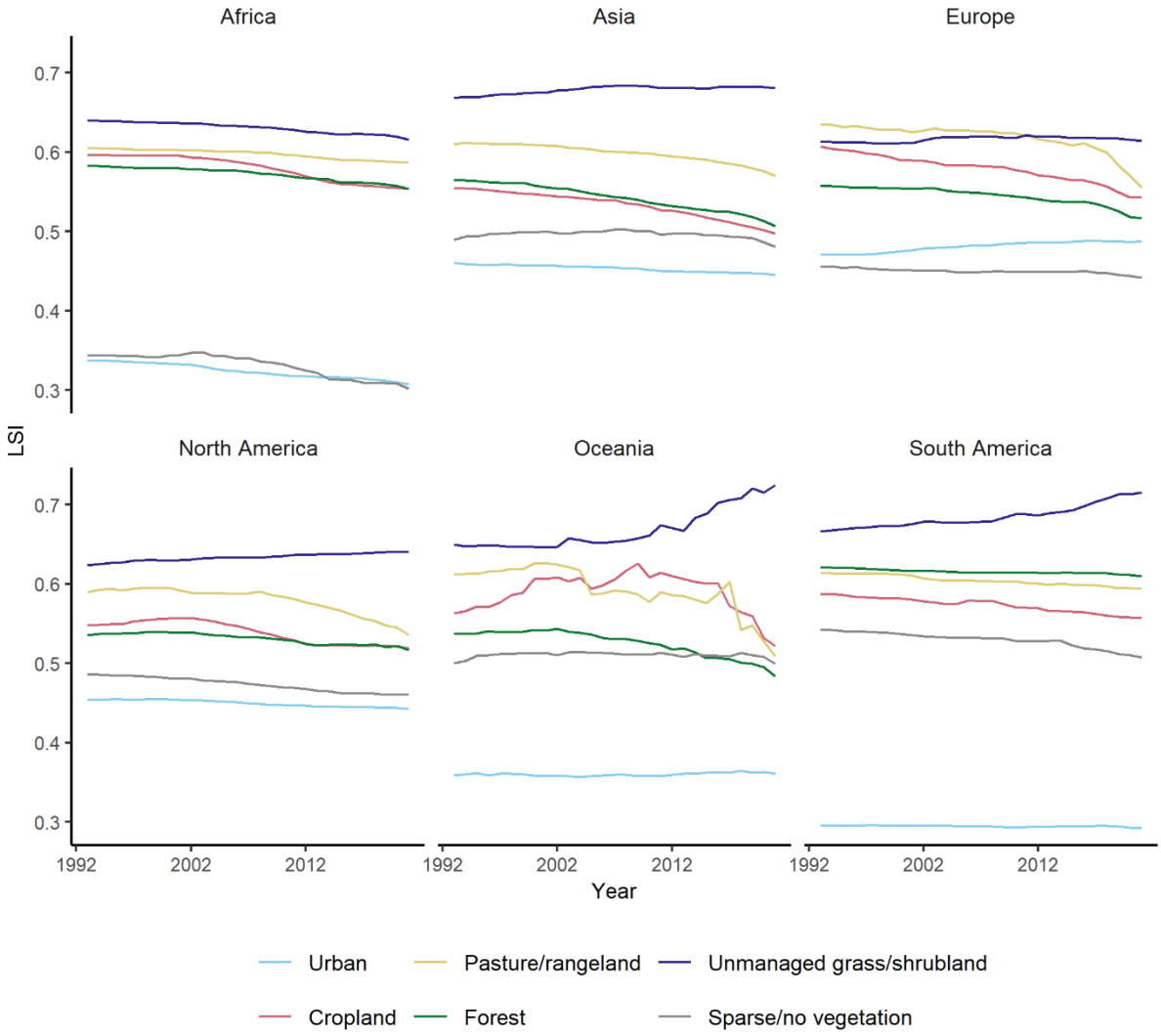


Fig. S 18 *Standard deviation of Landscape Shape Index (LSI) from 1992 to 2020 in landscapes of 100 km² extent. Lines give the standard deviation of LSI for one land use and land cover class. LSI is a unitless measure*

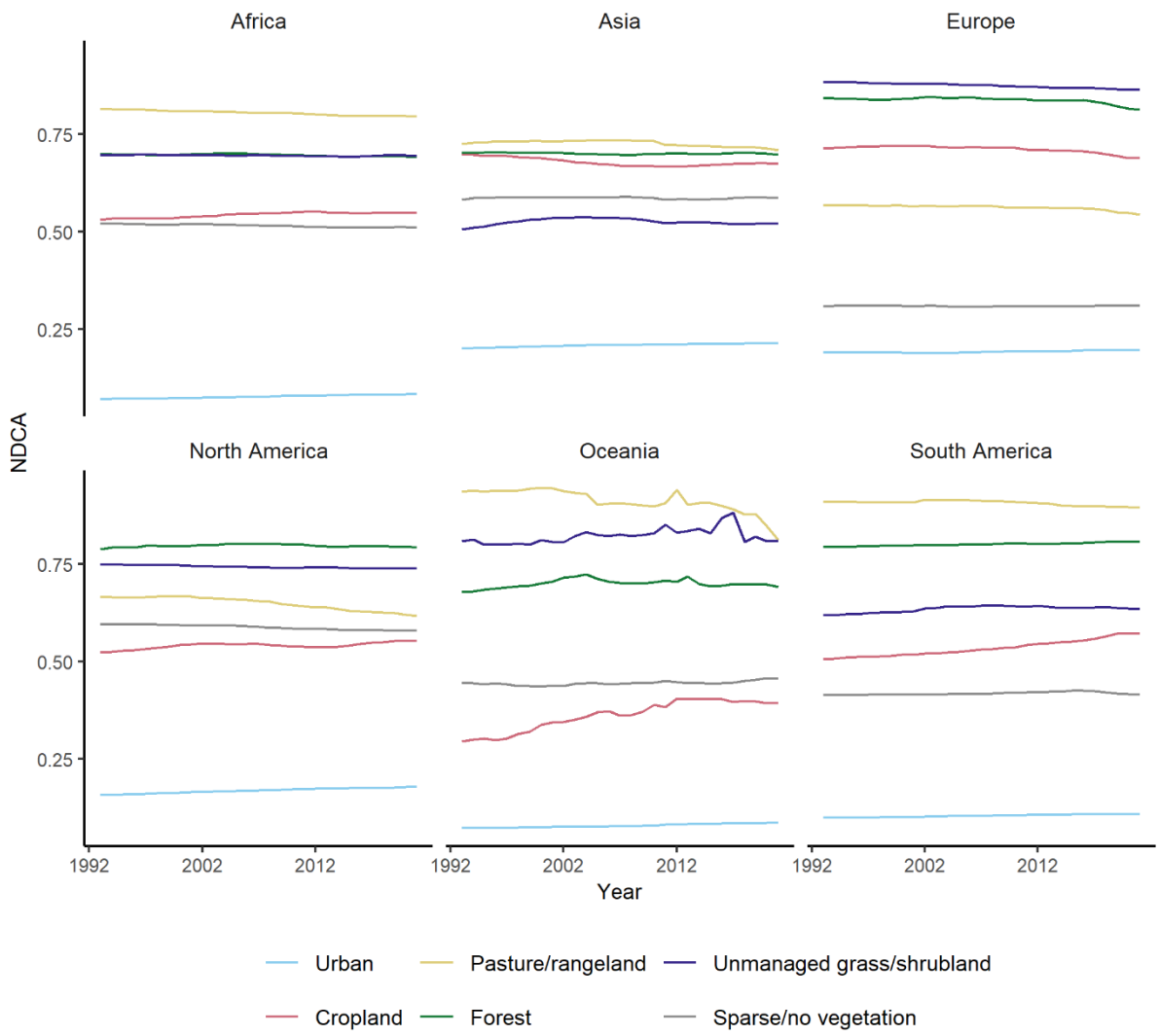


Fig. S 19 *Standard deviation of number of disjunct core area patches (NDCA) from 1992 to 2020 in landscapes of 100 km² extent. Lines give the standard deviation of NDCA for one land use and land cover class. NDCA is a unitless measure*

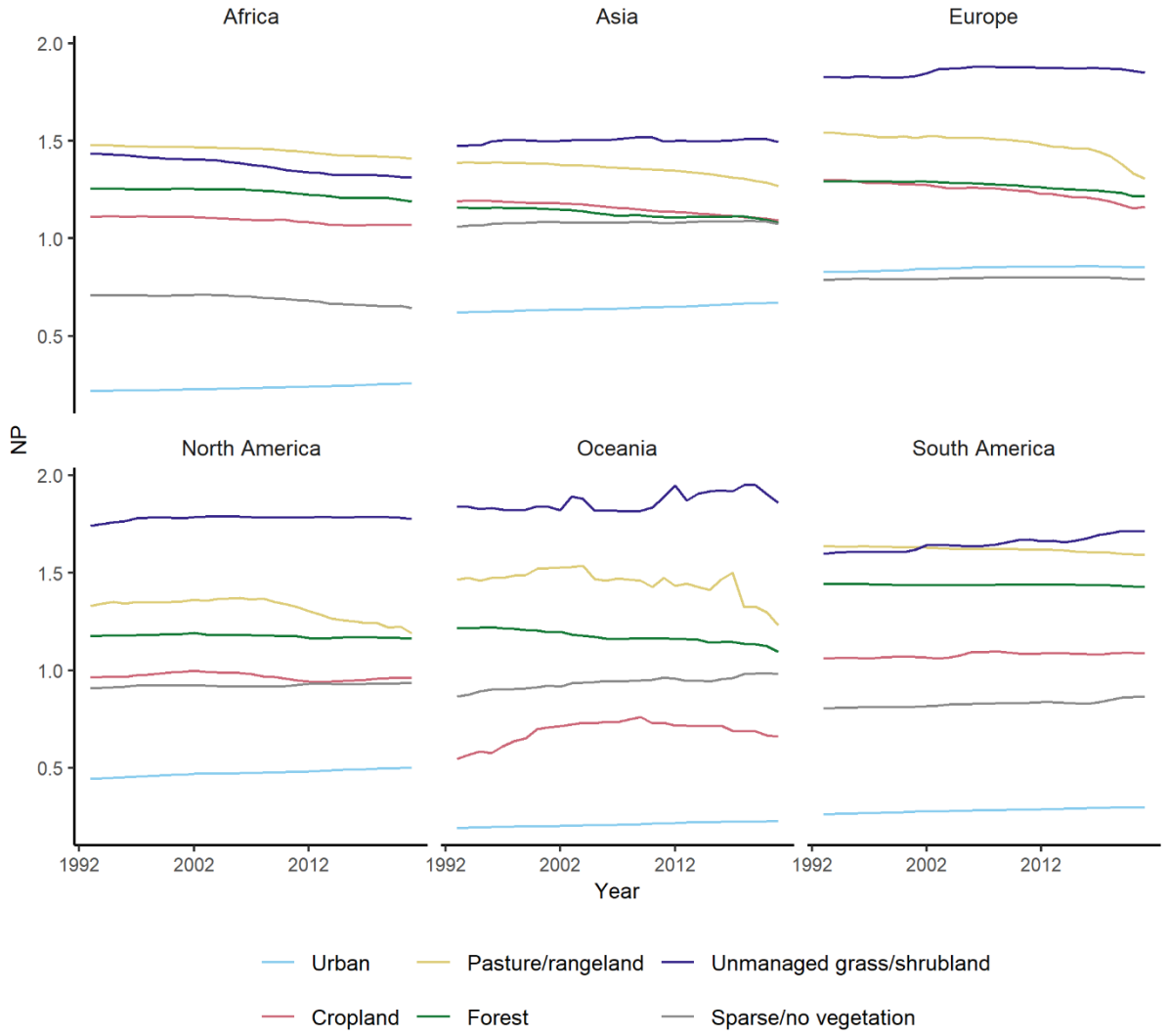
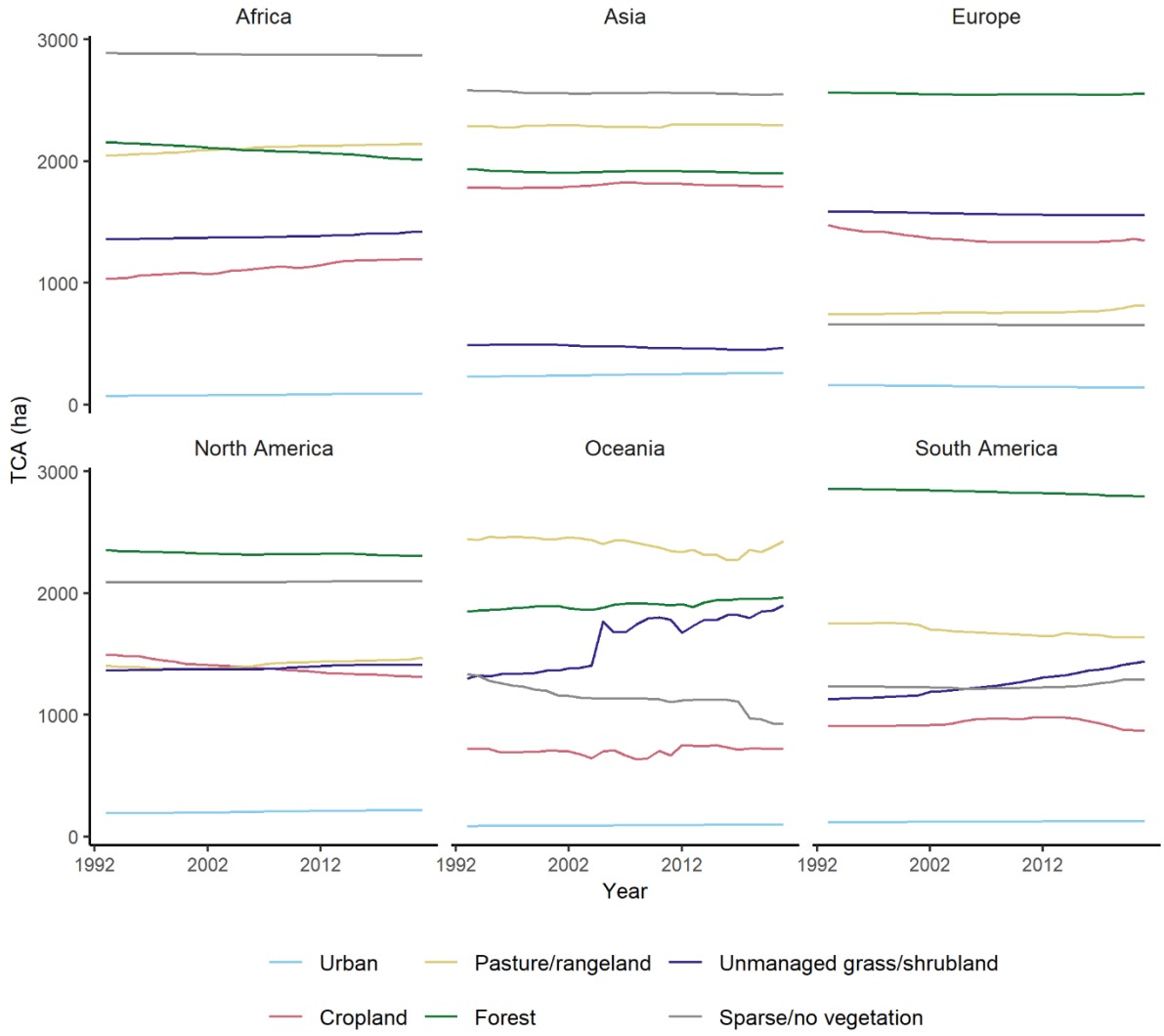
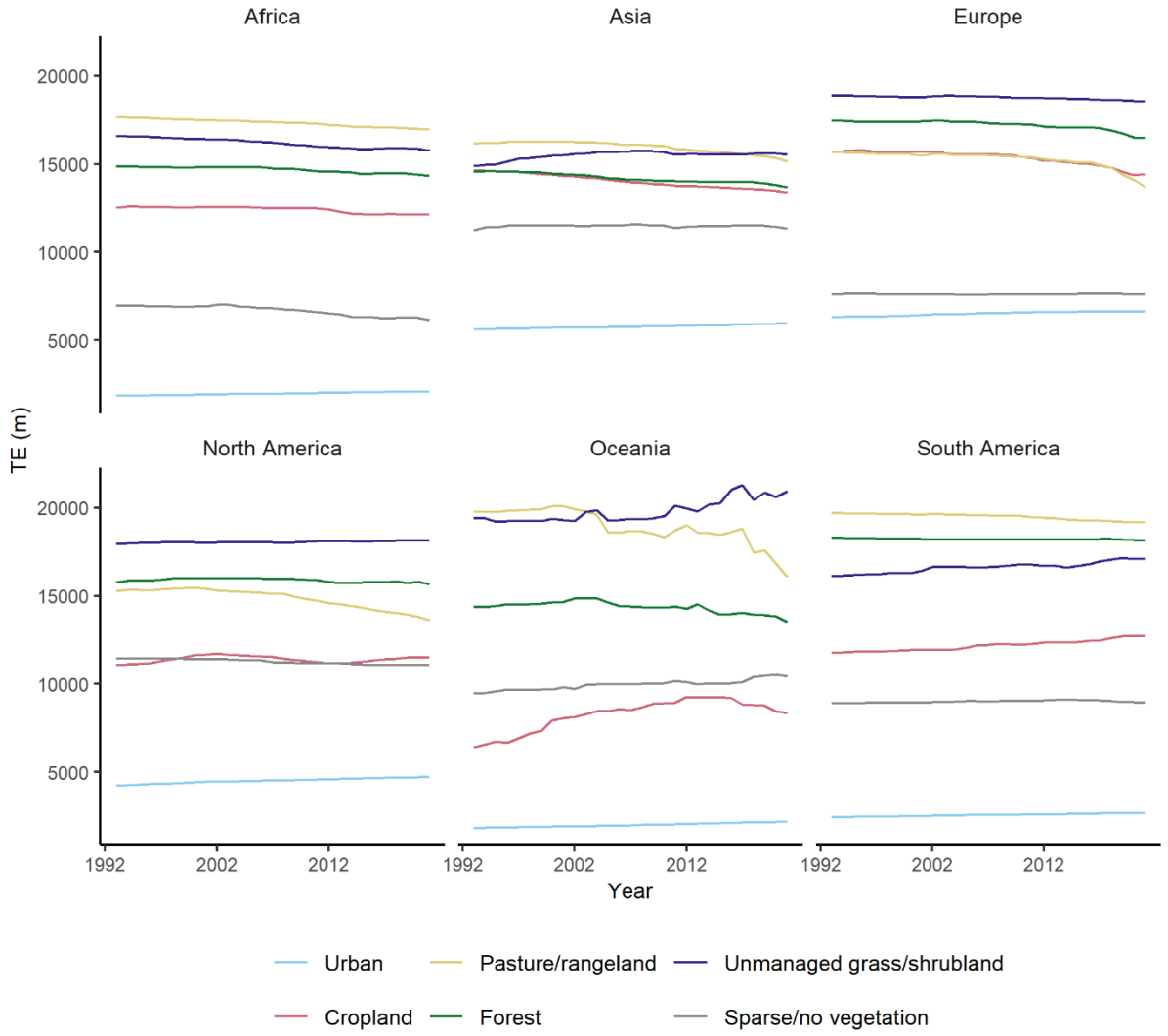


Fig. S 20 *Standard deviation of number of patches (NP) from 1992 to 2020 in landscapes of 100 km² extent. Lines give the standard deviation of NP for one land use and land cover class. NP is a unitless measure*



116

117 ***Fig. S 21*** *Standard deviation of total core area (TCA) from 1992 to 2020 in landscapes of 100 km²*
118 *extent. Lines give the standard deviation of TCA for one land use and land cover class. Units of TCA*
119 *are hectares (ha)*



120

121 ***Fig. S 22*** *Standard deviation of total edge length (TE) from 1992 to 2020 in landscapes of 100 km²*
122 *extent. Lines give the standard deviation of TE for one land use and land cover class. Units of TE are*
123 *metres (m)*

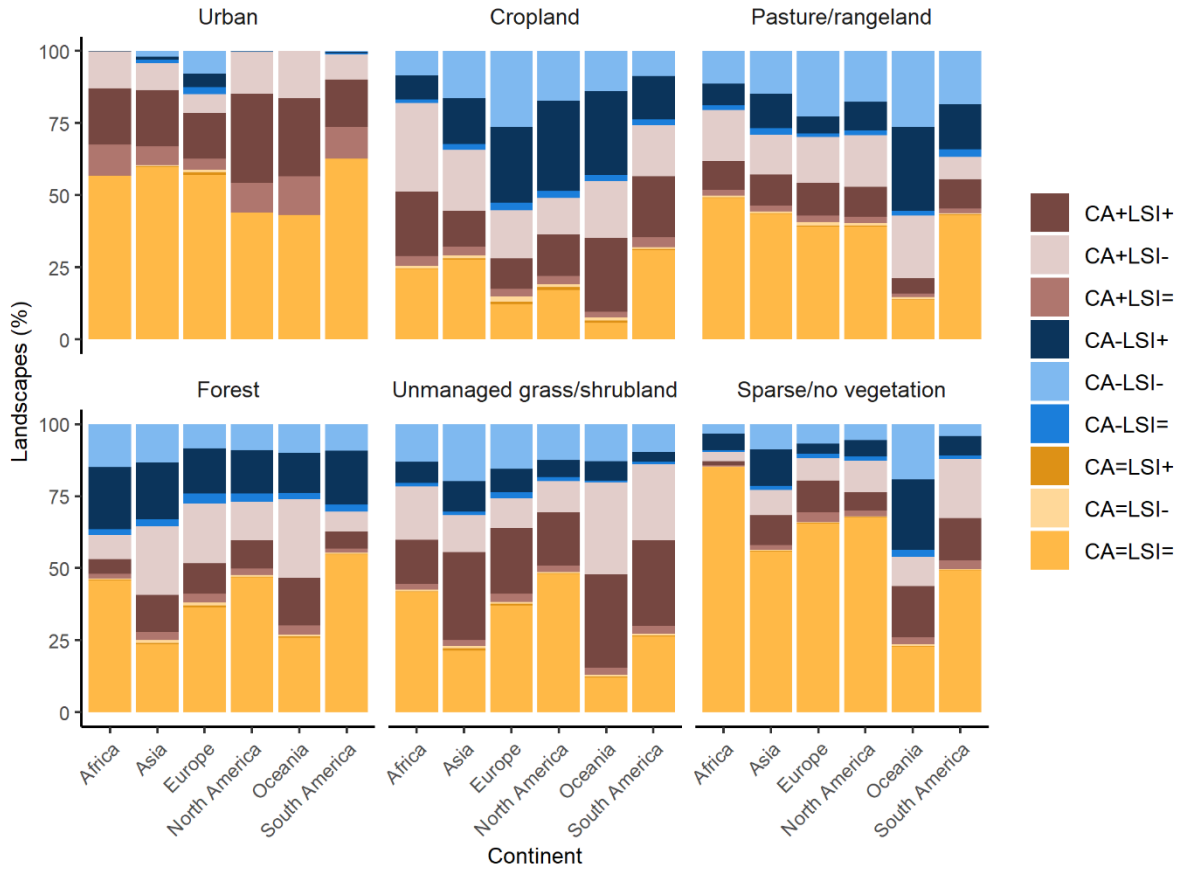


Fig. S 23 *Direction of net change in area and aggregation within 100 km² landscapes from 1992 to 2020 at continental scale. Bars give the percentage of landscapes which contained the specific land use and land cover (LULC) class in both 1992 and 2020*

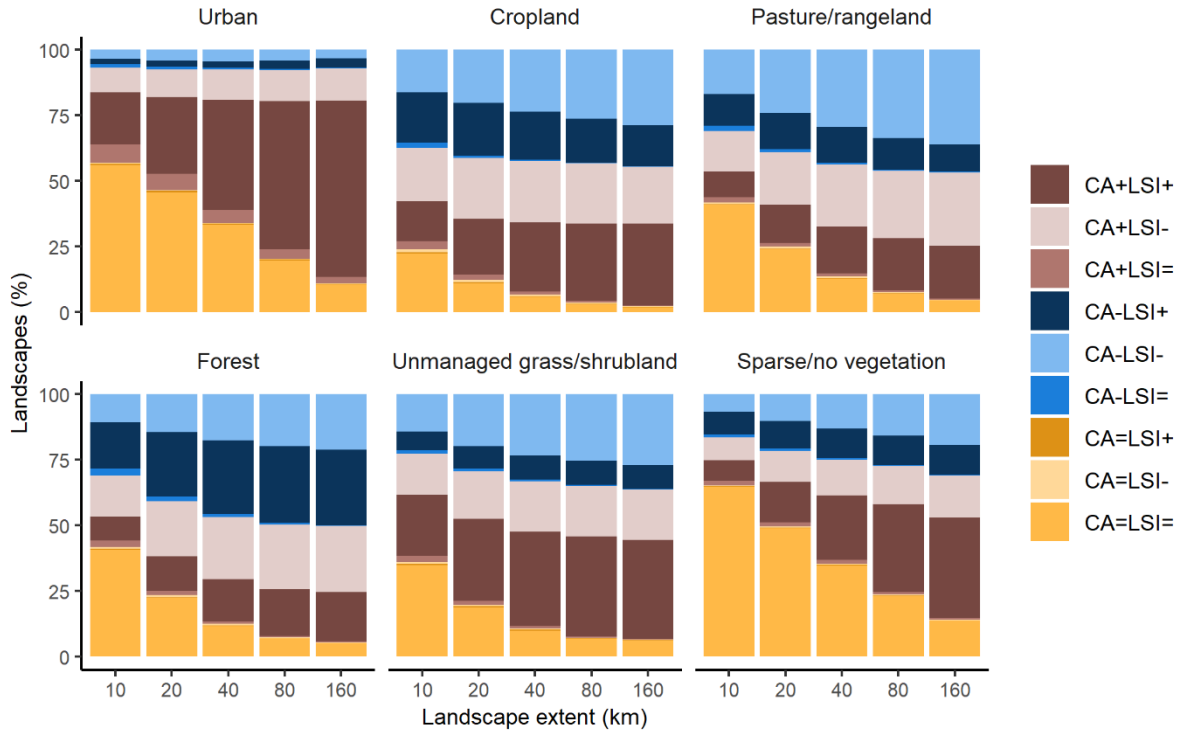


Fig. S 24 *Direction of net change in area and aggregation within landscapes of increasing extent from 1992 to 2020. Landscape extent is the length of each side of a landscape in kilometres. Bars give the percentage of landscapes which contained the specific land use and land cover (LULC) class in both 1992 and 2020*

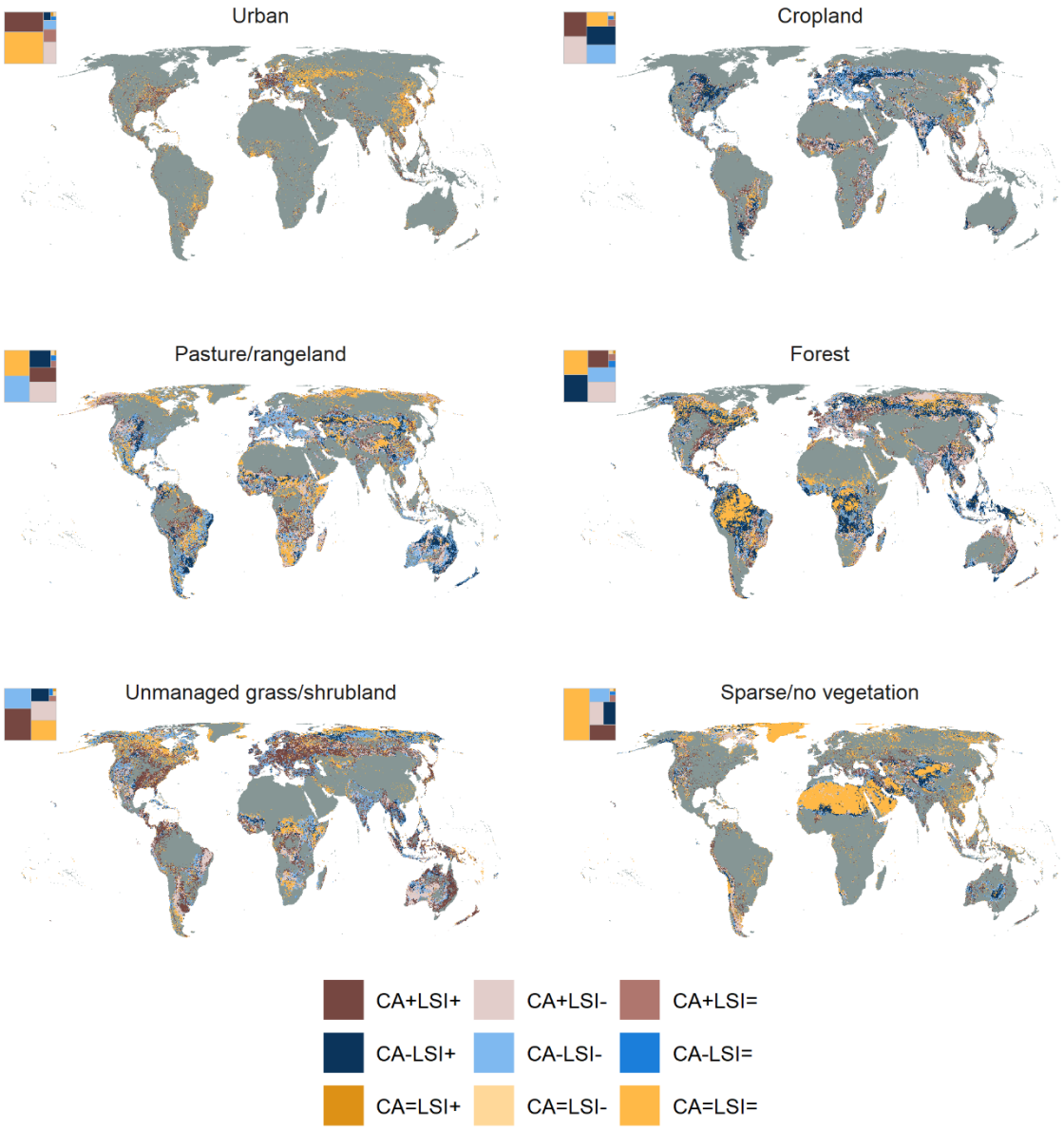


Fig. S 25 *Direction of net change in area and fragmentation in 400 km² landscapes from 1992 to 2020. Direction of net change is shown for landscapes which contained the land use and land cover (LULC) class of interest in both 1992 and 2020. CA = class area, LSI = Landscape Shape Index. The square inset in each panel shows the relative proportion of landscapes assigned to each of the nine categories of CA and LSI change for that LULC class. Grey shading indicates the absence of a LULC class in a landscape in both 1992 and 2020. Note that LSI+ indicates increased fragmentation of a LULC class and LSI- represents decreased fragmentation*

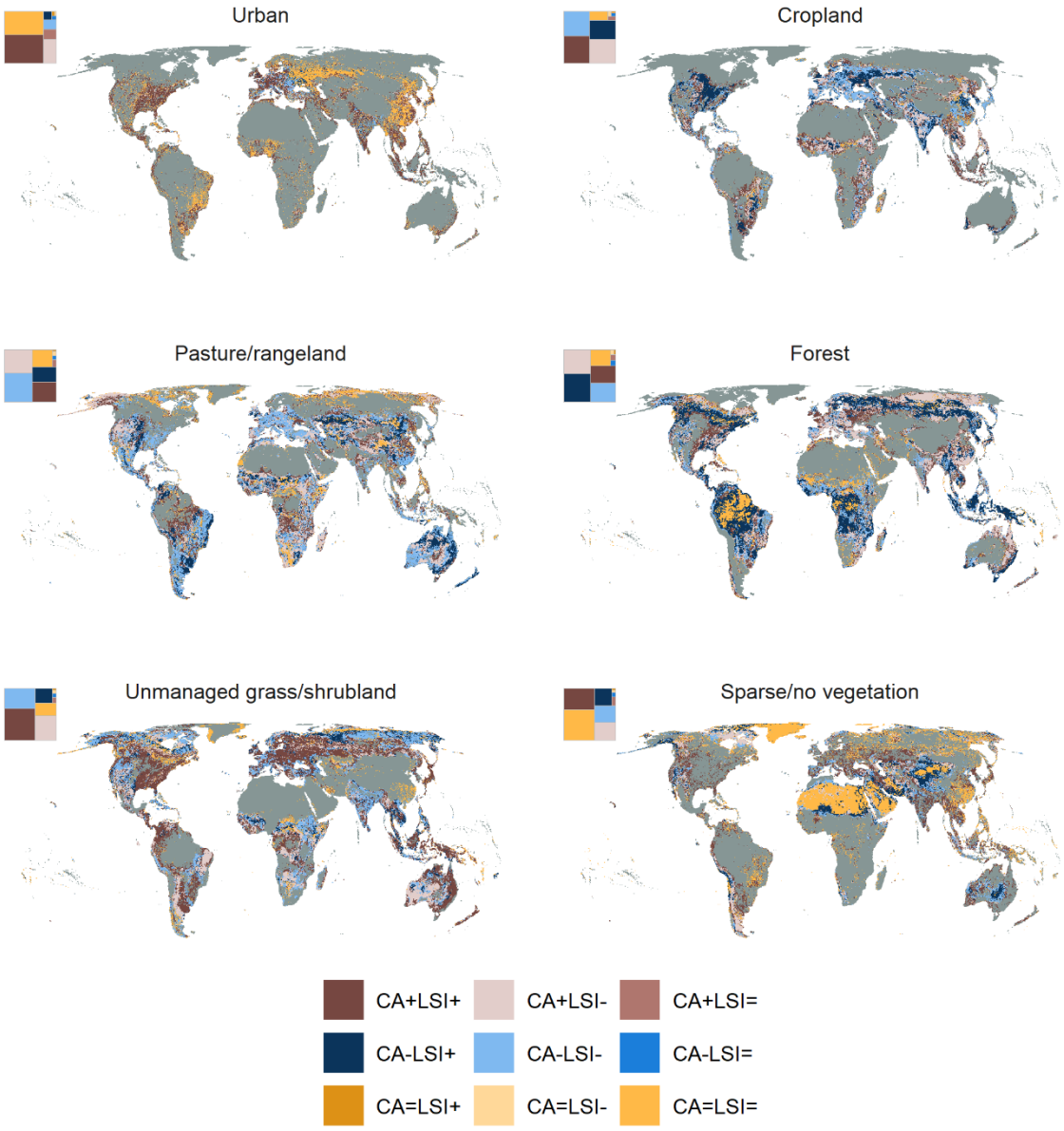


Fig. S 26 *Direction of net change in area and fragmentation in 1600 km² landscapes from 1992 to 2020. Direction of net change is shown for landscapes which contained the land use and land cover (LULC) class of interest in both 1992 and 2020. CA = class area, LSI = Landscape Shape Index. The square inset in each panel shows the relative proportion of landscapes assigned to each of the nine categories of CA and LSI change for that LULC class. Grey shading indicates the absence of a LULC class in a landscape in both 1992 and 2020. Note that LSI+ indicates increased fragmentation of a LULC class and LSI- represents decreased fragmentation*

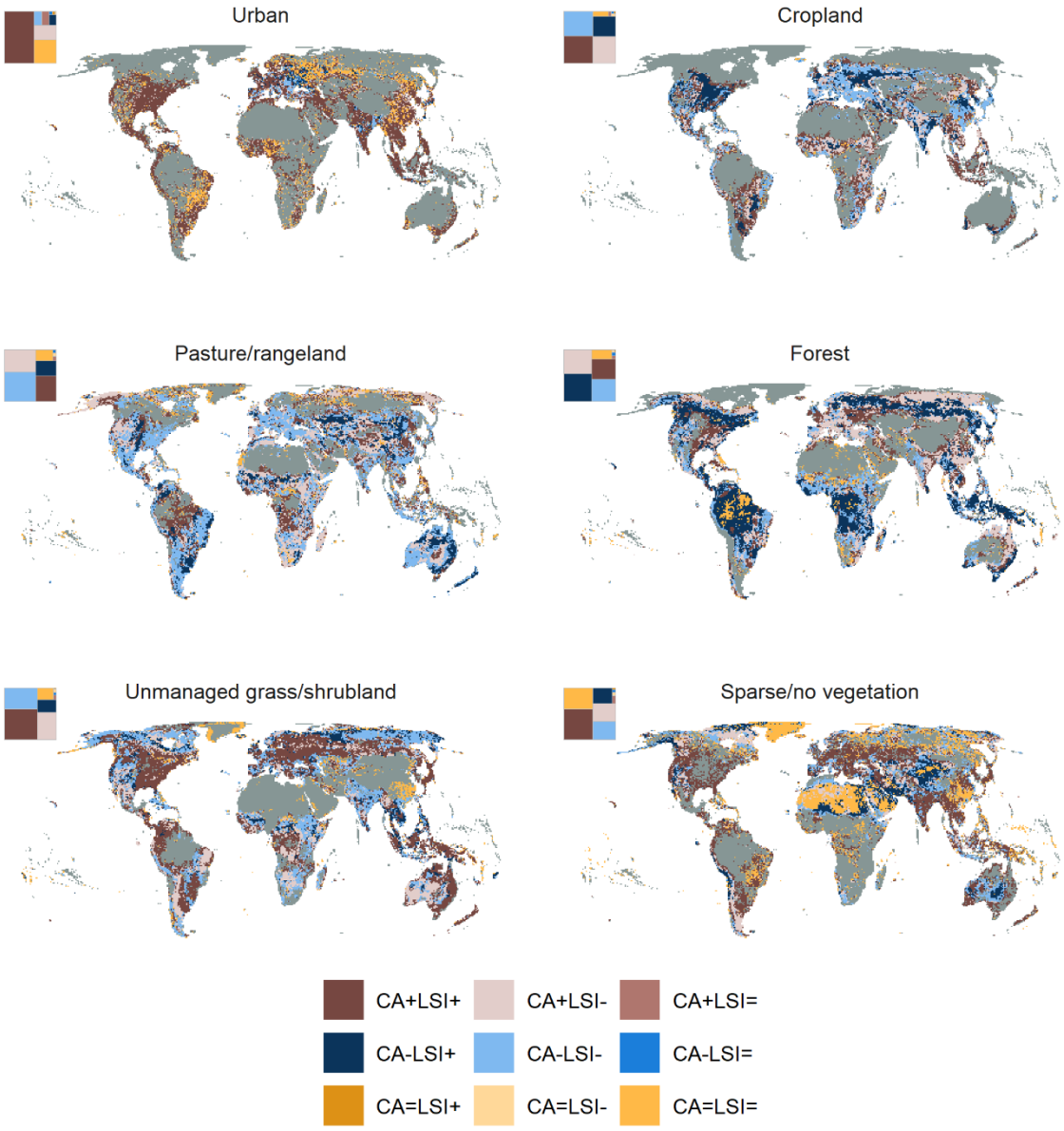


Fig. S 27 *Direction of net change in area and fragmentation in 6400 km² landscapes from 1992 to 2020. Direction of net change is shown for landscapes which contained the land use and land cover (LULC) class of interest in both 1992 and 2020. CA = class area, LSI = Landscape Shape Index. The square inset in each panel shows the relative proportion of landscapes assigned to each of the nine categories of CA and LSI change for that LULC class. Grey shading indicates the absence of a LULC class in a landscape in both 1992 and 2020. Note that LSI+ indicates increased fragmentation of a LULC class and LSI- represents decreased fragmentation*

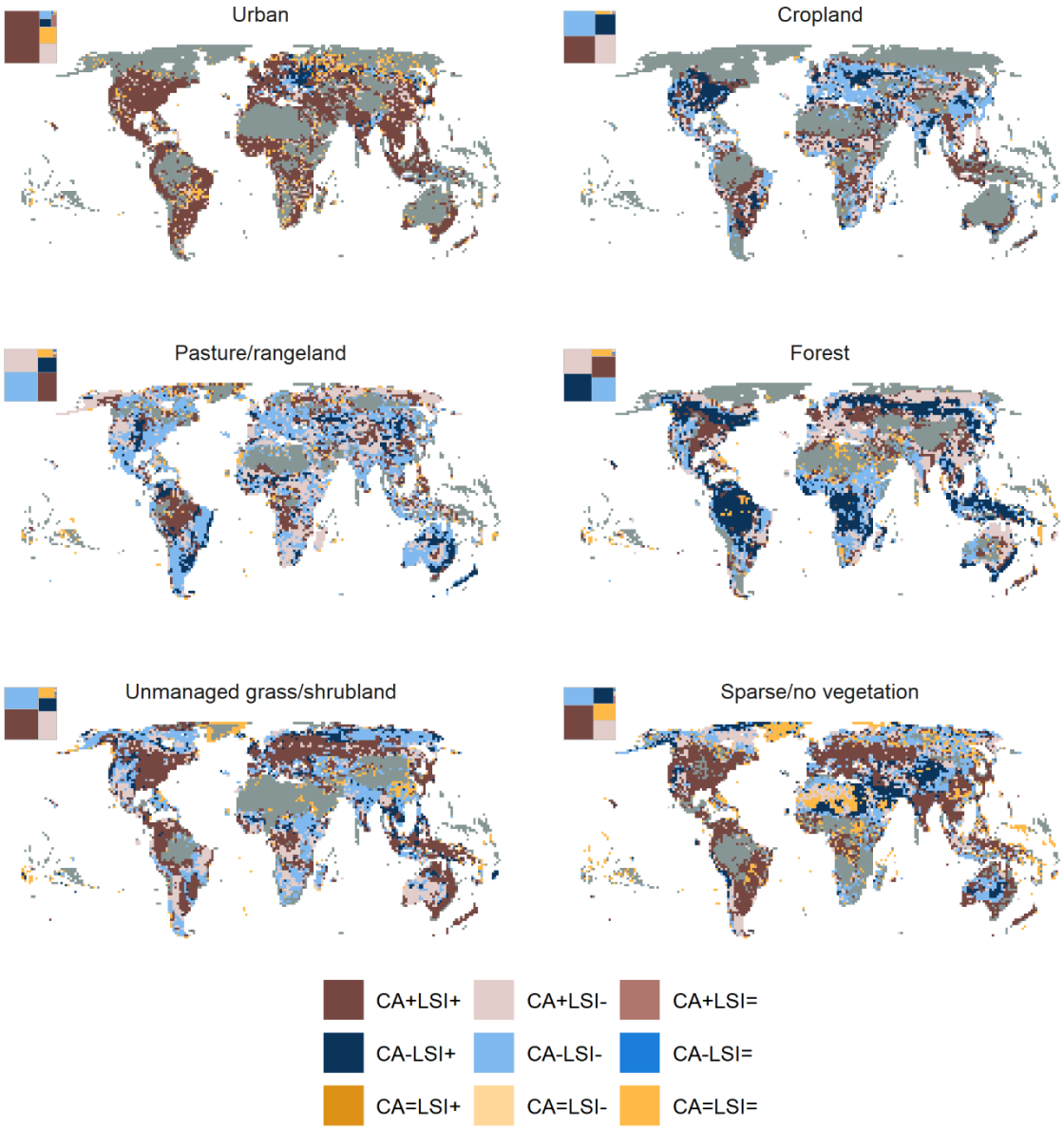


Fig. S 28 *Direction of net change in area and fragmentation in 25600 km² landscapes from 1992 to 2020. Direction of net change is shown for landscapes which contained the land use and land cover (LULC) class of interest in both 1992 and 2020. CA = class area, LSI = Landscape Shape Index. The square inset in each panel shows the relative proportion of landscapes assigned to each of the nine categories of CA and LSI change for that LULC class. Grey shading indicates the absence of a LULC class in a landscape in both 1992 and 2020. Note that LSI+ indicates increased fragmentation of a LULC class and LSI- represents decreased fragmentation*

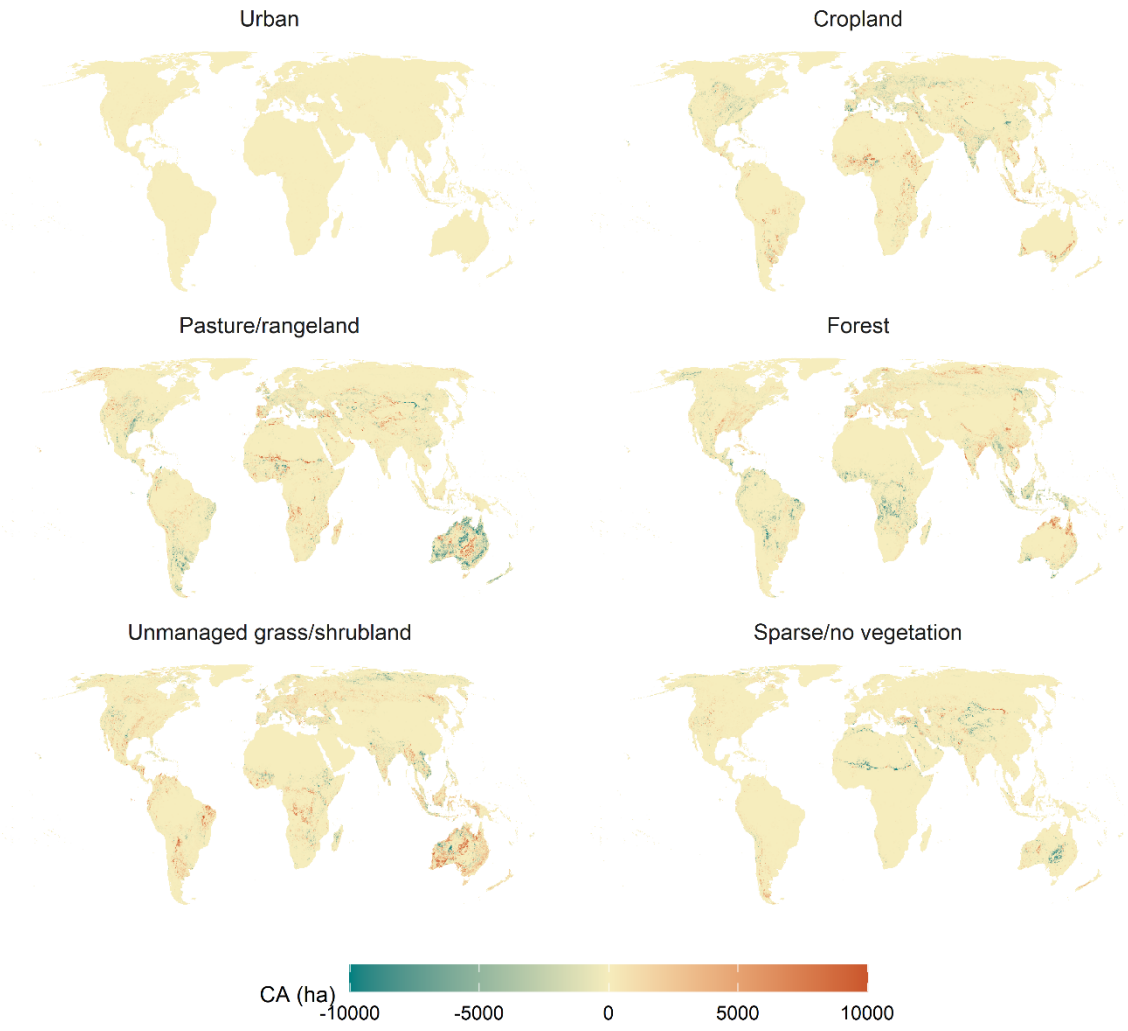


Fig. S 29 *Net change in class area (CA) from 1992 to 2020. Net change is shown in 100 km² extent landscapes at global scale for six land use and land cover classes. Positive values (red) indicate a net increase in CA by 2020, whereas negative values (teal) indicate a net decrease. Units for CA are hectares*

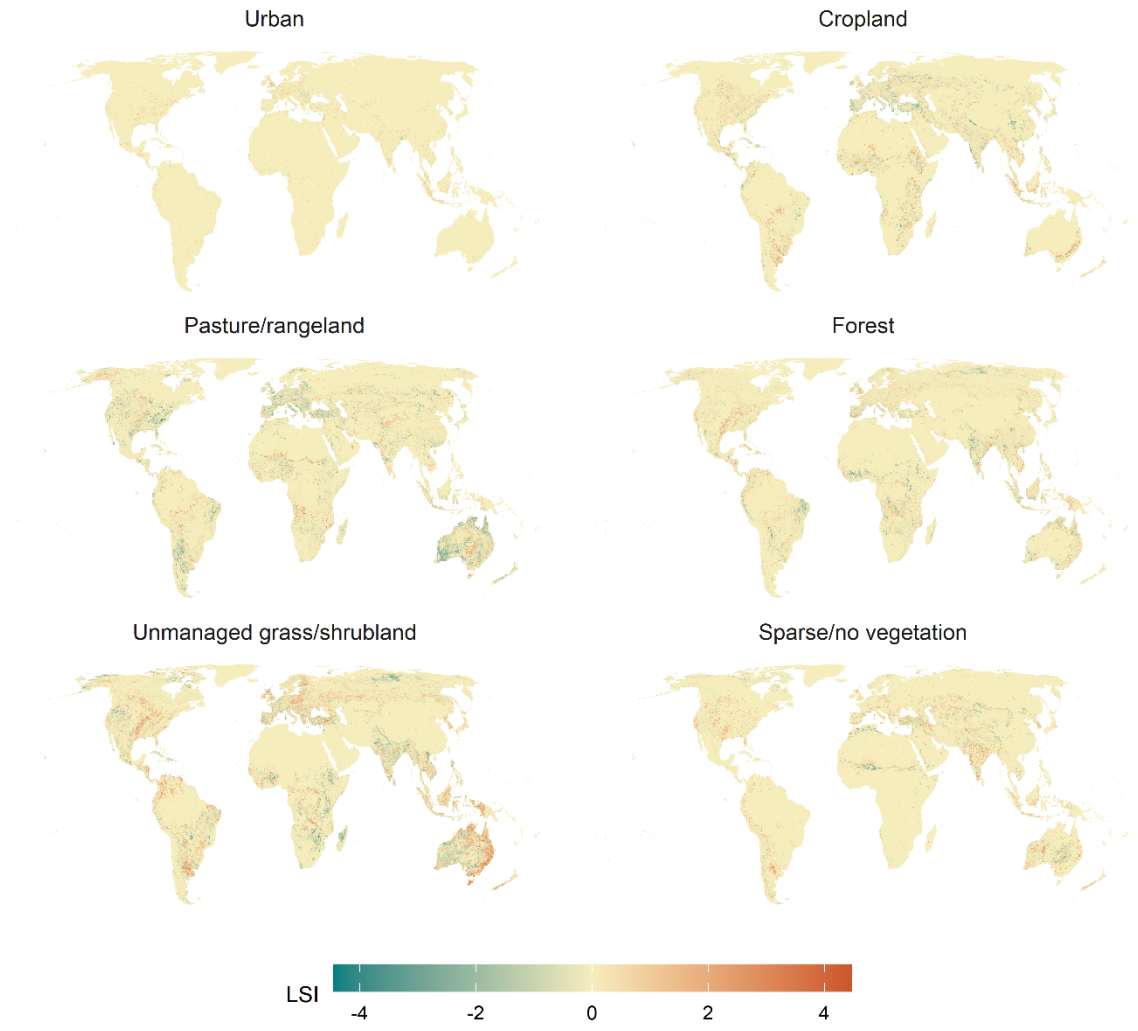


Fig. S 30 *Net change in Landscape Shape Index (LSI) from 1992 to 2020. See Fig. 1.12 for further information. LSI is a unitless measure*

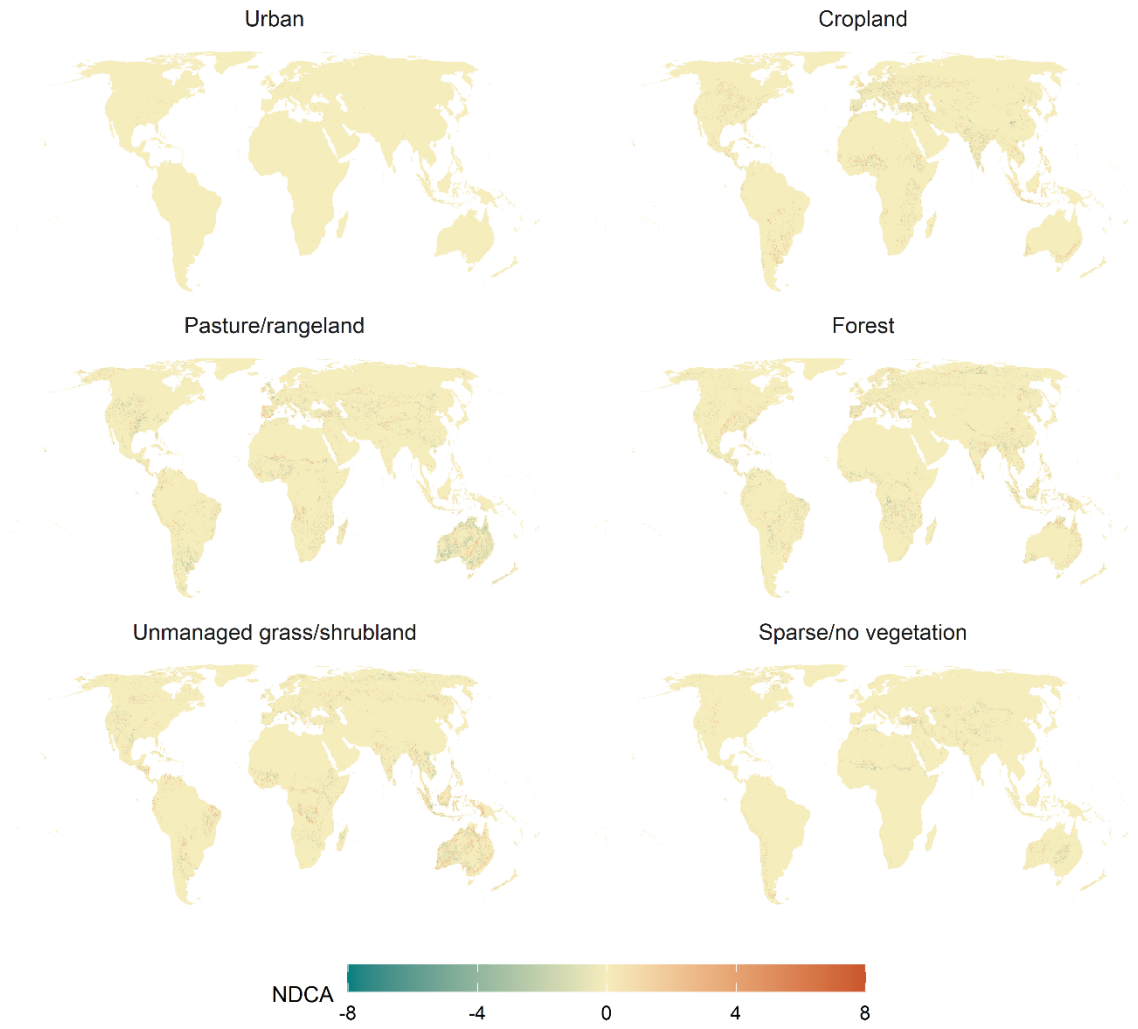
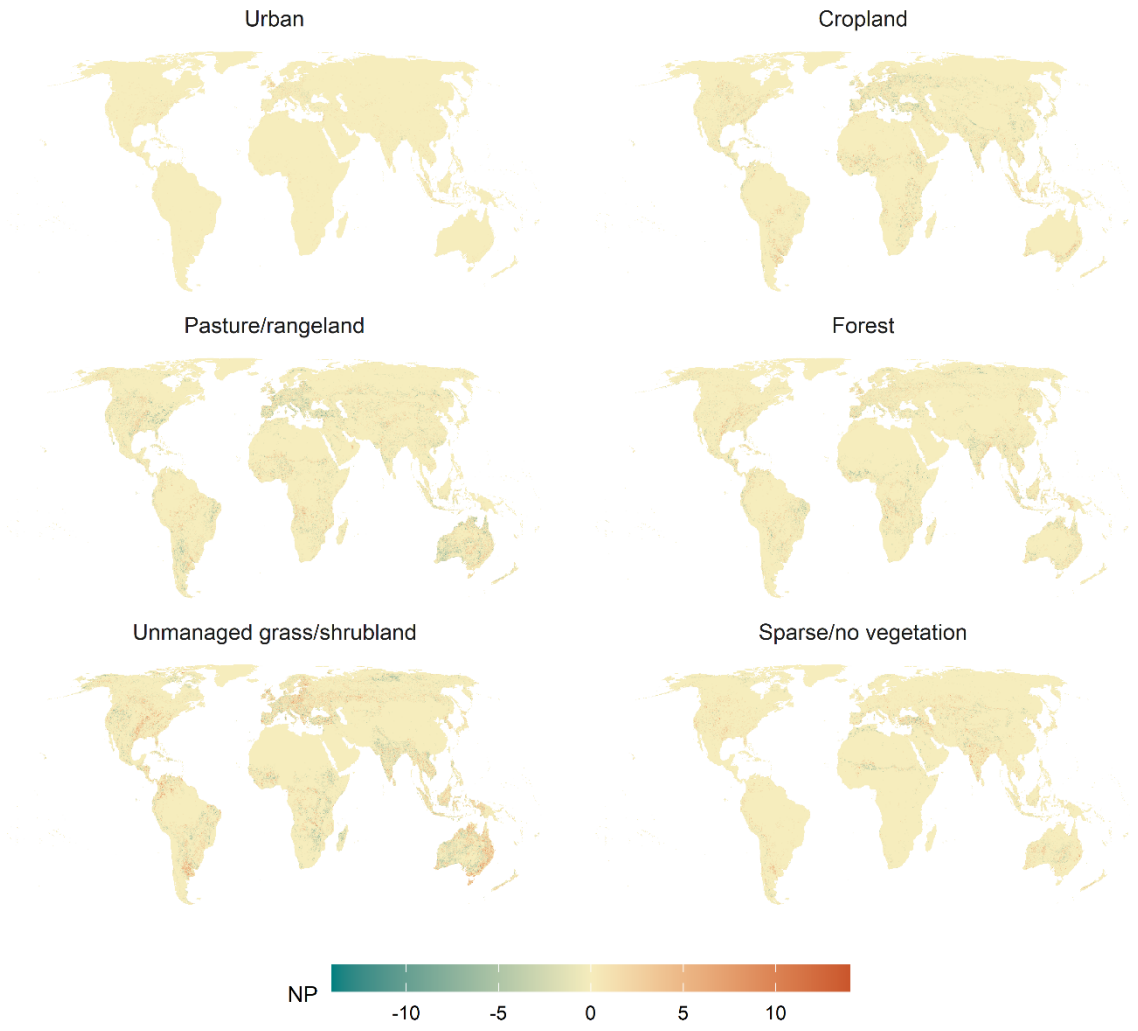
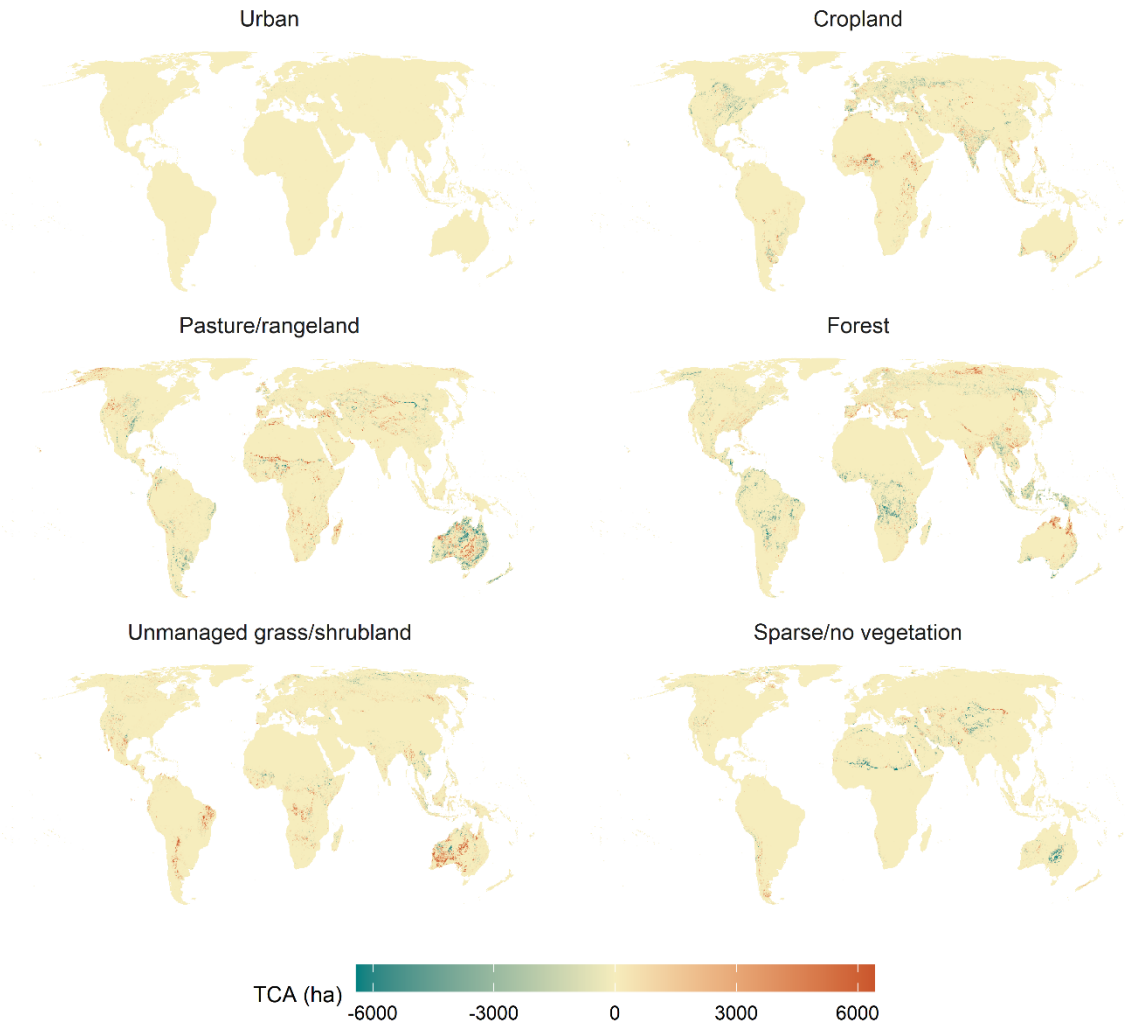


Fig. S 31 *Net change in number of disjunct core area patches (NDCA) from 1992 to 2020. See Fig. 1.12 for further information. NDCA is a unitless measure*



176

177 ***Fig. S 32*** *Net change in number of patches (NP) from 1992 to 2020. See Fig. 1.12 for further*
178 *information. NP is a unitless measure*



179

180 ***Fig. S 33*** *Net change in total core area (TCA) from 1992 to 2020. See Fig. 1.12 for further information.*
181 *TCA is in units of hectares*

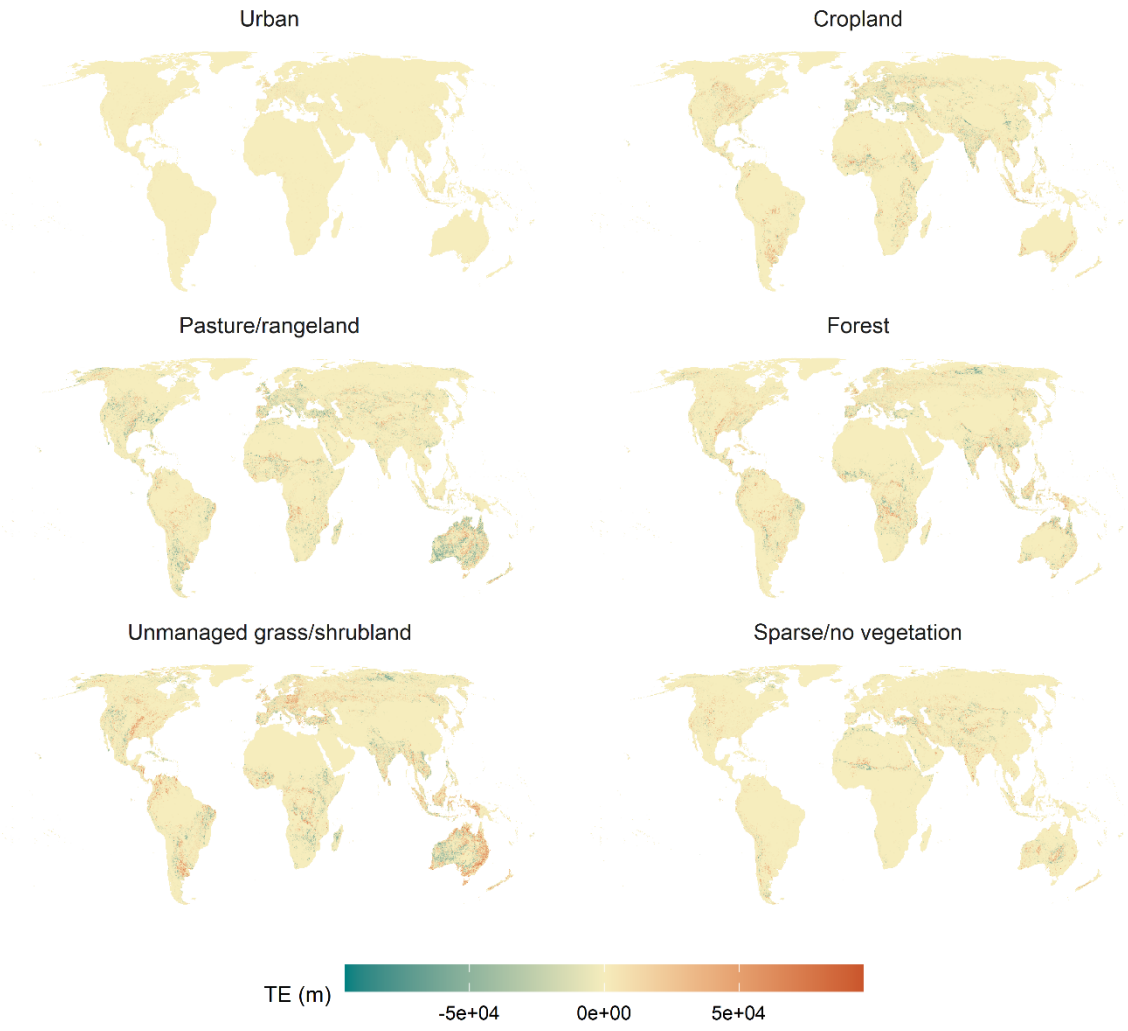


Fig. S 34 *Net change in total edge length (TE) from 1992 to 2020. See Fig. 1.12 for further information. TE is displayed in units of metres*

References

Hesselbarth MHK, Sciaini M, With KA, et al (2019) landscapemetrics: an open-source R tool to calculate landscape metrics. Ecography 42:1648–1657. https://doi.org/10.1111/ecog.04617