Supplementary Information for

Linking Land-Cover Change with Landscape Pattern Dynamics Induced by Damming in a Small Watershed

Content of this file

Text S1 Three levels of intensity analysis

The first level is the time interval level, which addresses the question, "In which time intervals is the overall annual rate of change relatively slow or fast?" There are two equations at this level. Equation (S1) defines the annual percentage of change in the spatial extent for each time interval. Thus, Equation (S1) gives $T-1$ rates, that is, one rate per time interval. Equation (S2) defines the annual uniform rate of change when we distribute the overall change that occurred uniformly during all intervals from the first to the last time point. If $A_t < U$, then A_t is slow, meaning the time interval [Y_t, Y_{t+1}] experiences change more slowly than if the changes during all time intervals are distributed uniformly during the temporal extent [Y_1, Y_T]. If $A_t > U$, then A_t is fast, meaning the time interval [Y_t, Y_{t+1}] changes faster than if the changes during all time intervals are distributed uniformly during the temporal extent [Y_1,Y_T].

$$A_t = \frac{\left\{\sum_{j-1}^{J}\left[\left(\sum_{i=1}^{J} C_{tij}\right) - C_{tij}\right]\right\}100\%}{(Y_{t+1}-Y_t)\sum_{j-1}^{J}\left(\sum_{i=1}^{J} C_{tij}\right)} \quad \text{(S1)}$$

$$\mathrm{U} = \frac{\left\{\sum_{t=1}^{T-1}\left\{\sum_{j-1}^{J}\left[\left(\sum_{i=1}^{J} C_{tij}\right) - C_{tij}\right]\right\}\right\}100\%}{(Y_T-Y_1)\sum_{j-1}^{J}\left(\sum_{i=1}^{J} C_{tij}\right)} \quad \text{(S2)}$$

The second level is the category level, which examines how the loss intensity L_{ti} from category i and the gain intensity G_{tj} to category j compares to a uniform intensity A_t during each time interval [Y_t,Y_{t+1}]. If $L_{ti} < A_t$, then L_{ti} is dormant, meaning category i loses less than if the change during the time interval [Y_t,Y_{t+1}] were distributed uniformly across the spatial extent. If $L_{ti} > A_t$, then L_{ti} is active, meaning category i loses more than if the changes during time interval [Y_t,Y_{t+1}] were distributed uniformly across the spatial extent. Similarly, if $G_{tj} < A_t$, then G_{tj} is dormant, and if $G_{tj} > A_t$, then G_{tj} is active. Equation (S3) gives L_{ti} and Equation (S4) gives G_{tj}.

$$L_{ti} = \frac{\left[\left(\sum_{j=1}^{J} C_{tij}\right) - C_{tij}\right]100\%}{(Y_{t+1}-Y_t)\sum_{j=1}^{J} C_{tij}} \quad \text{(S3)}$$

$$G_{tj} = \frac{\left[\left(\sum_{i=1}^{J} C_{tij}\right) - C_{tij}\right]100\%}{(Y_{t+1}-Y_t)\sum_{i=1}^{J} C_{tij}} \quad \text{(S4)}$$

The third level is the transition level, which examines how the transition intensity R_{tij} from category i to category j is compared to a uniform transition intensity W_{tj} given the gain of category j during the time interval [Y_t,Y_{t+1}]. If $R_{tij} < W_{tj}$, then the gain of j avoids i, meaning the gain of j transitions from i less intensively during the time interval [Y_t,Y_{t+1}] than if the gain of j is to have transitioned uniformly from the space that is not j at time Y_t. If $R_{tij} > W_{tj}$, then the gain of j targets i, meaning the gain of j transitions from i more intensively during the time interval [Y_t,Y_{t+1}] than if the gain of j is to have transitioned uniformly from the space that is not j at time Y_t. Equation (S5) gives R_{tij}, and Equation (S6) gives W_{tj}. The order of subscripts j and i in C_{tji} in the denominator of Equation (S6) is intentional, so that the summation over i subtracts category j at the initial time Y_t.

$$R_{tij} = \frac{C_{tij}\,100\%}{(Y_{t+1}-Y_t)\sum_{j=1}^{J} C_{tij}} \quad \text{(S5)}$$

$$W_{tj} = \frac{\left[\left(\sum_{i=1}^{J} C_{tij}\right) - C_{tjj}\right]100\%}{(Y_{t+1}-Y_t)\sum_{i=1}^{J}\left[\left(\sum_{j=1}^{J} C_{tij}\right) - C_{tji}\right]} \quad \text{(S6)}$$

Table S1 The image information used for the land use classification

Image Source	Data	Spatial Resolution (m)
SPOT	2004/02/01	2.5
Landsat7 ETM+	2001/11/22	30
	2002/12/08	
Landsat5 TM	2003/12/06	30
	2004/11/30	

Table S2 error matrix of the land cover classification accuracy assessment in 2004

		Validation points					
	Class	Water	Woodland	Bareland	Cropland	Builtup	Total
Reference points	Water	258	0	0	0	0	258
	Woodland	1	168	3	7	11	190
	Bareland	3	1	274	0	88	366
	Cropland	0	0	0	96	5	102
	Builtup	3	0	0	1	329	334
	Total	265	169	278	105	433	1250
	Accuracy	97.4%	99.4%	98.6%	91.4%	76.0%	90.0%

Table S3 land use classification system

Land use type	Definition
Water	Including lake, pond, river, and others
Woodland	Including trees, bamboo, shrubs, and other forest trees
Bareland	Including saline-alkali, sand, gravel, bare-cropland, and others
Cropland	Including rice, greenhouse, and others
Builtup	Including the developed land for urban residents, industrial and mining land,

	commercial gathering areas, national defense, places of interest, and other constructive land

Table S4 mathematical notation

Notation	Meaning
T	number of time points
Y_t	year at time point t
t	index for a time point
J	number of categories
i	index for a category
j	index for a category
C_{tij}	number of pixels that are category i at time point t and category j at time point t+1
C_{tji}	number of pixels that are category j at time point t and category i at time point t+1
A_t	annual change percentage during time interval $[Y_t, Y_{t+1}]$
U	uniform intensity of annual change percentage during the temporal extent $[Y_1, Y_T]$
G_{tj}	intensity of annual gain of category j during time interval $[Y_t, Y_{t+1}]$ relative to size of category j at time point t+1
L_{ti}	intensity of annual loss of category i during time interval $[Y_t, Y_{t+1}]$ relative to size of category i at time point t
R_{tij}	intensity of annual transition from category i to category j during time interval $[Y_t, Y_{t+1}]$ relative to size of category i at time point t
W_{tj}	uniform intensity of annual transition from all non-j categories to category j during time interval $[Y_t, Y_{t+1}]$ relative to size of all non-j categories at time point t

Table S5 Equations and descriptions of landscape metrics

	Equations	Description
AREA_MN	$AREA\_MN = \frac{\sum_{i=1}^{m} \sum_{j=1}^{n} x_{ij}}{N}$ x_{ij}= the area of j patch at class i N = total number of patches	Patch Area Mean (AREA_MN) is a crucial index reflecting landscape heterogeneity. The distribution interval of its value restricts the scope of the image or map and the selection of the minimum patch size in the landscape, and it can also represent the degree of landscape fragmentation.
SHDI	$SHDI = -\sum_{i=1}^{m} (p_i * ln\, p_i)$ p_i = proportion of the landscape occupied by patch type (class) i.	Shannon's Diversity Index (SHDI) can reflect landscape heterogeneity and is sensitive to the unbalanced distribution of various patch types in the landscape, emphasizing the contribution of rare patch types to information. The higher the values of SHDI, the more heterogeneity in the landscape pattern.
CONTAG	$CONTAG = \left[1 + \frac{\sum_{i=1}^{m} \sum_{k=1}^{m} \left[p_i \frac{g_{ik}}{\sum_{k=1}^{m} g_{ik}}\right]\left[ln\left(p_i \frac{g_{ik}}{\sum_{k=1}^{m} g_{ik}}\right)\right]}{2\, ln(m)}\right](100)$ p_i= proportion of the landscape occupied by patch type (class) i g_{ik}= number of adjacencies (joins) between pixels of patch types (classes) i and k based on the double-count method m = number of patch types (classes) present in the landscape, including the landscape border if present	Contagion Index (CONTAG) can reflect the connectivity of dominant patches in landscape patterns. The higher the value is, the higher the integrity of the landscape pattern is. A high CONTAG is conducive in preventing the infiltration and diffusion of agricultural non-point source pollution. The lower the sprawl index is, the higher the risk of diffusion of external disturbance in landscape patterns.

ED	$$ED = \frac{1}{A}\sum_{i=1}^{M}\sum_{j=1}^{M}P_{ij}$$ $$ED_i = \frac{1}{A}\sum_{j=1}^{M}P_{ij}$$ P_{ij} = the boundary length between category i landscape element patches and adjacent category j landscape element patches in landscape. ED = the edge length between patches of heterogeneous landscape elements per unit area within the landscape scope. ED_i = the edge length between a certain landscape element patch and its adjacent heterogeneous patches on the unit area of the research object.	ED refers to the edge length between patches of heterogeneous landscape elements per unit area within the landscape scope. ED is an important indicator used to analyze patch shape, indicating the degree of segmentation of landscape types. It can reflect the greater the boundary density of landscape fragmentation, indicating that the higher degree of segmentation of a landscape type, and the more scattered the layout.
LSI	$$LSI = \frac{0.25E}{\sqrt{A}}$$ E = the total length of all patch boundaries in the landscape A = the total area of the landscape	LSI is the total landscape boundary and all edges within the boundary divided by the square root of the total landscape area (square meters) and adjusted by a constant (circular standard for vector layers, square standard for rasters). The LSI positively correlates with landscape shape irregularity or amounts of edge within the landscape. LSI can reflect the complexity of plaque shapes.
LPI	$$LPI = \frac{A_{max}}{\sum A}$$ A_{max} = the area of the largest patch in a patch type $\sum A$= the total area of the patch type	LPI is equal to the proportion of the total landscape area occupied by the largest patch in a patch type. This metric is helpful in determining the ecological characteristics of a landscape, such as the pattern of land or dominant type, and determines the abundance of dominant species within the landscape. The value of this index can help determine the dominant patch types in the landscape and indirectly reflect the direction and magnitude of human disturbance.

IJI	$$IJI = \frac{-\sum_{i=1}^{m}\sum_{k=i+1}^{m}\left[\left(\frac{e_{ik}}{E}\right)\ln\left(\frac{e_{ik}}{E}\right)\right]}{\ln\frac{1}{2}m(m-1)}(100)$$ i and k = patch type from 1 to m j = patch number from 1 to n	IJI is one of the most important indicators in describing landscape spatial patterns. IJI has a significant effect on the distribution characteristics of ecosystems severely restricted by certain natural conditions. Various ecosystems in mountain areas are seriously affected by vertical zonality, as their distribution is mostly circular, and IJI value is generally low. However, many transitional vegetation types in arid areas are subject to the distribution and abundance of water, and are adjacent to each other, with higher IJI values.

Table S6 land use area during 2001–2004

Year	Land use area (m^2)					Total
	Water	Woodland	Bareland	Cropland	Builtup	
2001	377,100	9,124,425	10,800	4,644,675	10,449,225	24,606,225
2002	655,875	9,100,125	0	3,852,675	10,997,550	
2003	327,825	8,304,075	0	1,855,125	14,119,200	
2004	510,750	7,356,375	180,450	1,975,500	14,583,150	

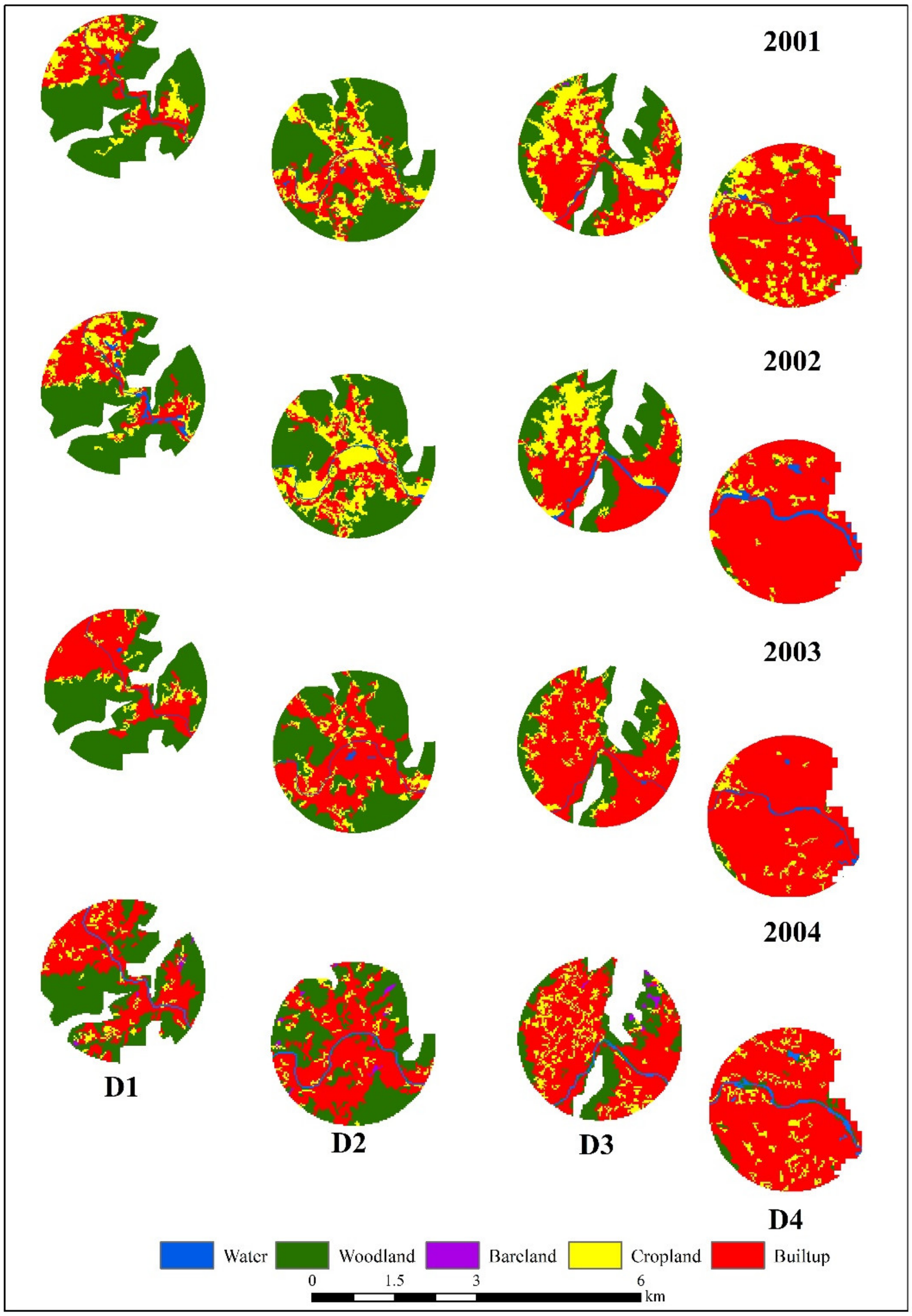

Figure S1 land use/land cover in the impacted area