A multiscale soil loss evaluation index

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Abstract Exploring the relationships between land use and soil erosion at different scales is a frontier research field and a hot spot topic in contemporary physical geography. Based on the scale-pattern-process theory in landscape ecology and with consideration of such influential factors as land use, topography, soil and rainfall, this paper applies the scale transition method to establishing a soil loss evaluation index at different scales and puts forward a research path and methodology for multiscale soil loss evaluation indices. The multiscale soil loss evaluation index is applied to the evaluation of relationships between land use and soil erosion and the research of soil erosion evaluation at multiple scales. It provides a new method for optimizing the design of regional land use patterns and integrated multiscale research.

Keywords: soil loss evaluation index, scale, land use, soil erosion.

Improper land use by mankind is one of the main causes of soil erosion^[1]. Through changing vegetative cover, soil property and runoff velocity, land use affects the occurrence and development of soil erosion^[2–5]. As scale changes, notable changes will occur in the interactive mechanisms between land use and soil erosion. Currently, research on land use and soil erosion is changing from the slope scale to the small watershed, watershed, regional and global scales^[6–9]. Examining the influence of land use on soil erosion at different scales has become a frontier field and a hot spot research topic in contemporary research in physical geography.

In examining the relationships between land use and soil erosion, experimental observations and field surveys can be used to analyze the influence of land use changes on soil erosion. Empirical soil erosion models and physical models established at different scales are important means to evaluate soil erosion. However, empirical soil erosion models cannot often reveal the impact of the spatial pattern of land use distribution on soil erosion, particularly soil loss processes. Physical models can reflect soil loss processes and simulate soil erosion changes under different land use scenarios. But in actual applications, many factors limit the accuracy of their simulation results due to the complexity of soil erosion processes, thus restricting the use of soil erosion models^[10–13]. These factors include accumulated errors, increased uncertainties and that the data obtained from field surveys and experiments are often hard to meet the parameter requirements of the models. There is a need to look for a certain kind of approach that can qualitatively or semi-quantitatively evaluate the influence of land use on soil erosion and reflect soil erosion processes but can also avoid the use of too many model parameters and reduce the influence of model accuracy on model applications.

Against the research background above, this paper sets out to apply the relevant thought and theories in landscape ecology, use for reference the calculative methods of some erosive factors in the Revised Universal Soil Loss Equation (RUSLE) and put forward a soil loss evaluation index (expressed as SL) for different scales. This index can reflect to a certain extent the soil erosion process, avoid the common problems in physical models and provide a research path and methodology for the problem of multiscale in land use and soil erosion research. It can also be used to optimize multiscale land use pattern designs and make integrated decisions for regional soil erosion control.

1 Basis for establishing a multiscale soil loss evaluation index

The scale-pattern-process theory is a fundamental principle in landscape ecology. It is also an important idea widely used in physical geography. Landscape pattern is considered as the result of comprehensive interactions between different ecological processes and the natural environment. Its spatial distribution can influence ecological processes from many aspects. Research on landscape patterns, ecological processes and their interactive relationships is inseparable from the

scale under research. When the scale is different, landscape patterns, ecological processes and the relationships of their interaction will also be different. Through analyzing the relationship between land use and soil erosion based on such a thinking, it is possible to achieve some basic understandings on the establishment of a multiscale soil loss evaluation index: (1) The spatial distribution pattern of land use can exert an important influence on soil loss processes. When the scale is different, there will be significant variations in the interrelationship between land use and soil erosion. The multiscale soil loss evaluation index to be established should reflect such variations. (2) When the scale is different, the characteristics exhibited by such soil erosion factors as land use and topography are also different. The multiscale soil loss evaluation index to be established should select corresponding evaluation factors for different scales. It also needs to ensure good coordination between the evaluation factors at different scales. (3) Because pattern can affect ecological processes from many aspects, the different spatial distribution patterns of different soil erosion factors will also have very different effects on soil loss processes. The philosophy for establishing landscape pattern indices can be used to develop a soil loss evaluation index based on the soil loss effect of the spatial distribution of different soil erosion factors. The index not only includes information on the spatial distribution pattern of soil erosion factors but can also reflect soil loss processes at different scales.

Based on the relationships between land use and other erosion factors and soil loss processes^[14], the following understandings can be gained: (1) At the slope scale, land use structure, slope gradient changes and distance from the slope base all affect soil losses. For a given type of land use, the steeper its corresponding slope is and the nearer it is to the slope base, the more contributions it will make to soil erosion and the sediments that flow out of the slope. Otherwise, the contributions will be smaller. The slope-scale soil loss evaluation index should take comprehensive account of the factors of land use structure, slope gradient and distance from slope base. (2) At the small watershed scale, because rivers in different regions have different sediment delivery ratios, landscape units' "distance" from and "relative height" over the watershed outlet may be expressed by different landscape units' "horizontal distance" and "vertical distance" from the river. Correspondingly, when a certain type of land use has a

steeper slope and is closer to the drainage network, it will make more contributions to the sediment output of the small watershed. Otherwise, its contributions will be smaller. The small watershed-scale soil loss evaluation index should give comprehensive consideration to such factors as slope, horizontal distance from river and vertical distance from river. (3) At the watershed scale, large research areas reduce the data accuracy of digital elevation models (DEM) which are used to extract such data as slope gradient, drainage network and distance from river. However, DEM accuracy will have a notable effect on the research results^[15, 16]. Consequently, it is not suitable to use factors such as slope gradient, vertical distance from river and horizontal distance from river as the topographic factor in the soil loss evaluation index at the watershed scale. Other evaluation factors corresponding to this scale have to be considered and selected.

The soil loss evaluation index needs to be designed to reflect the effect of the spatial pattern of land use on soil loss and take account of the main factors of soil erosion. The multiscale soil loss evaluation index in the current research uses for reference the research findings on the factors of rainfall erosivity, soil erodibility, cover/management and slope in RUSLE. Meanwhile as different research scales are crossed, the thinking of scale transition needs to be adopted to ensure the coordination among the soil loss evaluation indices at different scales.

2 Slope-scale soil loss evaluation index

2.1 Basic assumptions

Assuming that there are 5 types of land use at the slope scale which are respectively Land Use A, Land Use B, Land Use C, Land Use D and Land Use E from upslope to downslope (Fig. 1), the corresponding cover/management factors (*C* value) of these land use types are 1, 0.8, 0.6, 0.4 and 0.2, respectively (Table 1). The total length of the slope is 20m, and the distances (*d*) of the land use types from the slope base are 18m, 14m, 10m, 6m, and 2m, respectively (Table 1). The patch width of the different land use types is the same (4m for all). Slope gradient and soil type are both uniform. There is no spatial variation in rainfall or soil at the slope scale.

2.2 Soil loss distance index

According to the relationship between land use and

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Fig. 1. Schematic diagram of slope 1.

Table 1 The basic information of slope 1

		C value	Distance from slope base (m)
Upslope	Land Use A	1	18
	Land Use B	0.8	14
	Land Use C	0.6	10
Downslope	Land Use D	0.4	6
	Land Use E	0.2	2

slope erosion processes, the farther the land use type is away from the slope base, the smaller the contribution of its soil loss to the sediment yield of the whole slope will be. Given this, a parameter called “the soil loss distance index” (D) may be set up to express the differences in the contribution of different land use types to the total soil loss of the slope. Its corresponding formula is

$$D = \frac{L-d}{L}, \quad (1)$$

where d is the distance from the slope base, L is the total length of the slope and D is the soil loss distance index. The bigger the D is, the closer to the slope base the said land use type will be and the more it will contribute to the soil loss. In addition, the soil loss distance index can indirectly reflect the influence of the runoff factor on soil erosion. This is because when surface runoff occurs at the slope scale, the runoff volume is often bigger in positions closer to the slope base and correspondingly the soil loss will also be bigger. The soil loss distance index will then also be higher.

2.3 Soil loss evaluation index

Taking into account of the combined effect of the soil loss distance and the C value on soil loss, the formula for the slope-scale soil loss evaluation index can be expressed as

$$SL_s = \frac{\sum_{i=1}^n (D_i \cdot C_i)}{\sum_{i=1}^n D_i}, \quad (2)$$

where SL_s is the slope-scale soil loss evaluation index, D_i is the soil loss distance index, C_i is the cover/management factor and n is the number of land use patches. As a dimensionless index, SL_s is between 0 and 1. Bigger SL_s shows that the land use pattern is more inductive to soil loss, while smaller SL_s indicates that the land use pattern is more capable of helping to control soil loss.

To verify the above formula, the positions of Land Use A and Land Use B in Fig.1 can be exchanged (Fig. 2, Table 2) to respectively calculate the values of SL_s under these two land use scenarios. It can be obtained that: $SL_{s \text{ Slope 1}} = 0.44$ and $SL_{s \text{ Slope 2}} = 0.456$.

This shows that the land use pattern at Slope 2 is more prone to cause soil loss than the land use pattern at Slope 1. This is because Land Use A prone to cause more soil erosion has changed its position with Land Use B and is closer to the slope base. SL_s can reflect the influence of changes in the spatial distribution of land use on soil loss at the slope scale.

Fig. 2. Schematic diagram of slope 2.

Table 2 The basic information of slope 2

		C value	Distance from slope base (m)
Upslope	Land Use B	0.8	18
	Land Use A	1	14
	Land Use C	0.6	10
Downslope	Land Use D	0.4	6
	Land Use E	0.2	2

If different land use types cover different areas on the slope, namely their patch widths along the soil loss direction are different, the slope-scale soil loss evaluation index should then consider the influence of different land patch widths on soil loss. When the widths of Land Use A and Land Use B in Fig. 1 are changed, the width of Land Use A increases to 6m, and Land Use B decreases to 2m (Fig. 3, Table 3), their distances from the slope base will also change accordingly.

Then, the soil loss evaluation index formula should

Fig. 3. Schematic diagram of slope 3.

Table 3 The basic information of slope 3

		C value	Distance from slope base (m)	Patch width (m)
Upslope	Land Use A	1	17	6
	Land Use B	0.8	13	2
	Land Use C	0.6	10	4
Downslope	Land Use D	0.4	6	4
	Land Use E	0.2	2	4

be modified as

$$SL_s = \frac{\sum_{i=1}^n (D_i \cdot W_i \cdot C_i)}{\sum_{i=1}^n (D_i \cdot W_i)}, \quad (3)$$

where W_i is the width of different land use types along the soil loss direction, while the other parameters are the same as in Formula (2).

Formula (3) can be used to calculate the SL_s value of Slope 3. It is obtained that $SL_{s\text{Slope } 3} = 0.45$. $SL_{s\text{Slope } 3}$ is greater than $SL_{s\text{Slope } 1}$, indicating that Formula (3) can reflect the influence on soil loss of changes in land use patch width (along the soil loss direction).

Normally, slope gradient is not uniform over a slope and may have certain changes from the slope top to the slope base. Therefore, the slope-scale soil loss evaluation index should also consider the influence of slope gradient. A new slope (Fig. 4, Table 4) can be obtained by changing the gradient of different land uses in Fig. 1. Correspondingly, the calculation formula for the slope-scale soil loss evaluation index should be modified as

$$SL_s = \frac{\sum_{i=1}^n (D_i \cdot W_i \cdot S_i \cdot C_i)}{\sum_{i=1}^n (D_i \cdot W_i \cdot S_i)}, \quad (4)$$

where S_i is the slope steepness factor of different land use types, while the other parameters are the same as in

Fig. 4. Schematic diagram of slope 4.

Table 4 The basic information of slope 4

		C value	Distance from slope base (m)	Patch width (m)	Slope gradient
Upslope	Land Use A	1	18	4	20°
	Land Use B	0.8	14	4	30°
	Land Use C	0.6	10	4	15°
Downslope	Land Use D	0.4	6	4	25°
	Land Use E	0.2	2	4	18°

Formula (3). S_i can be calculated with reference to the slope steepness factor calculation method in RUSLE.

The formula ($S = 21.91 \sin \theta - 0.96$), θ is slope gradient) established by Liu *et al.*^[17] using runoff data from small plots in the Loess Plateau is adopted to calculate the slope steepness factor. Formula (4) is used to calculate the SL_s value of Slope 4, obtaining $SL_{s\text{Slope } 4} = 0.45964$. Comparison of $SL_{s\text{Slope } 1}$ with $SL_{s\text{Slope } 4}$ shows that when changes in the slope factor for different land use types are considered, certain changes also occur to SL_s .

The slope-scale soil loss evaluation index above has mainly considered the factors of land use, slope gradient, patch width and soil loss distance. Due to their rather small spatial changes at the slope scale, rainfall and soil type may be left out of the considerations. Then, Formula (4) will be the final formula for calculating the slope-scale soil loss evaluation index.

3 Small watershed-scale soil loss evaluation index

At the small watershed scale, a soil loss evaluation index is to be established by treating the whole small watershed as a whole and analyzing the level of contributions to soil loss made by the spatial distribution of land use. In terms of form, the soil loss evaluation index at this scale is considered to be similar to that of the slope-scale soil loss evaluation index. However, due to the expansion of research area, the main factors affecting soil loss may need to be presented in a form of map layer. In such a case, map layer operations will be

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needed. Correspondingly, there will be notable changes in the way to get the soil loss evaluation index. The process of the soil loss evaluation index changing from the slope scale to the small watershed scale is essentially a process of upscaling.

3.1 Soil loss evaluation index with consideration of soil loss distance

In Formula (2) of the slope-scale soil loss evaluation index, the influence of soil loss distance on SLs is taken into account. At the small watershed scale, the various factors of Formula (2) should be presented in the form of map layer. The corresponding formula may be modified as

$$SL_{sw} = \frac{\sum (D_m \cdot C_m)}{\sum D_m}, \quad (5)$$

where SL_{sw} is the small watershed-scale soil loss evaluation index, D_m and C_m are respectively the soil loss distance index map and the spatial distribution map of the C value, $D_m \cdot C_m$ refers to the product of the two map layers and can be calculated using GIS' raster calculator, $\sum (D_m \cdot C_m)$ is the spatial sum of the map layers after the multiplication, while $\sum D_m$ is the spatial sum of the soil loss distance map. It is relatively simple to get C_m of Formula (5). D_m may be obtained through calculating the straight line distance index for soil loss based on GIS.

The soil loss distance index is used to reflect differences in the level of contributions to river sediment yielded by a corresponding land use type due to different distances from the drainage network. The straight line distance index for soil loss takes the straight line distance of different land use patches relative to a river as its analysis object.

Fig. 5 is a schematic diagram of the small watershed topography. The straight line distance of the i th point in the watershed from the drainage network includes two parts, namely the horizontal distance d_i and the vertical distance h_i . When the soil loss horizontal distance index and the soil loss vertical distance index are calculated, their formulae should be adjusted on the basis of Formula (1) to

$$D_i = \frac{D_{\max} - d_i}{D_{\max}}, \quad (6)$$

$$H_i = \frac{H_{\max} - h_i}{H_{\max}}. \quad (7)$$

Fig. 5. Schematic diagram of small watershed topography.

In formula (6), D_i is the soil loss horizontal distance index of a certain point in the small watershed, $D_{\max}$ is the maximum soil loss horizontal distance in the small watershed and d_i is the soil loss horizontal distance of a certain point in the small watershed. In Formula (7), H_i is the soil loss vertical distance index of a certain point in the small watershed, $H_{\max}$ is the maximum soil loss vertical distance in the small watershed and h_i is the soil loss vertical distance of a certain point in the small watershed.

According to Formulae (6) and (7) and based on GIS, the distribution map of the small watershed soil loss horizontal distance index (D_m) and the distribution map of the small watershed soil loss vertical distance index (H_m) can be obtained. Then, Formula (5) may be modified as

$$SL_{sw} = \frac{\sum (D_m \cdot H_m \cdot C_m)}{\sum (D_m \cdot H_m)}. \quad (8)$$

3.2 Soil loss evaluation index with consideration of other factors

At the small watershed scale, when the influence of the slope steepness factor on soil loss is considered, Formula (8) may be modified as

$$SL_{sw} = \frac{\sum (D_m \cdot H_m \cdot S_m \cdot C_m)}{\sum (D_m \cdot H_m \cdot S_m)}, \quad (9)$$

where S_m is the distribution map of the slope steepness factor, while the meanings and calculation formula of the other factors are the same as in Formula (8). Among them, the distribution map of the slope steepness factor can be prepared in GIS' spatial analysis module using RUSLE's slope steepness factor calculation formula and based on the slope gradient data extracted from DEM.

At the small watershed scale, there are spatial variations in rainfall and soil type. Therefore, the small watershed-scale soil loss evaluation index should also

consider the influence of rainfall erosivity and soil erodibility. Then, Formula (9) may be further modified as

$$SL_{sw} = \frac{\sum (D_m \cdot H_m \cdot S_m \cdot R_m \cdot K_m \cdot C_m)}{\sum (D_m \cdot H_m \cdot S_m \cdot R_m \cdot K_m)}, \quad (10)$$

where R_m and K_m are respectively the rainfall erosivity distribution map and the soil erodibility distribution map, while the meanings and calculation formula of the other factors are the same as in Formula (9). Among them, the rainfall erosivity distribution map can be obtained by spatial extrapolation of the rainfall erosivity values for the various rain gauge stations calculated using RUSLE's rainfall erosivity formula. The soil erodibility distribution map can be obtained based on RUSLE's K factor calculation formula and in combination with the soil map. Formula (10) is the final calculation formula for the small watershed-scale soil loss evaluation index.

4 Watershed-scale soil loss evaluation index

As the research scale expands from the small watershed to the watershed, some factors of the small watershed-scale soil loss evaluation index need to be adjusted in the actual calculation process, because the data adopted at different scales have different levels of accuracy.

Among the main factors of the small watershed-scale soil loss evaluation index, rainfall erosivity, soil erodibility and the cover/management factor can be calculated using the method for these factors at the small watershed scale. As for the soil loss horizontal distance index, the soil loss vertical distance index and the slope steepness factor, the calculation methods at the small watershed scale can also be directly used to extract the relevant indices from high-accuracy DEM data, if no cost consideration needs to be made. The value of the corresponding indices at the watershed scale can be obtained by adopting an integrated mapping method. But in actual work, the areas involved at the watershed scale are rather big and the DEM data adopted are often of low accuracy. In this case, it is not proper to adopt the research methods at the small watershed scale to extract the relevant indices. The reason is that it is very difficult to use low accuracy DEM data to extract drainage networks of a high resolution or slope gradients of high accuracy. Consequently, calculations of the soil loss horizontal distance, the soil loss vertical distance and the slope steepness factor will be significantly

affected. Therefore, other corresponding factors for the watershed scale need to be selected to replace the soil loss horizontal distance, the soil loss vertical distance and the slope steepness factor. This may be seen as a scale transition process for the topographic factor. As for specific realization, the idea of "soil erosion surface" may be used as reference^[18,19]. Based on an analysis of the corresponding relationship between the topographic characteristics at the watershed scale and the topographic characteristics at the small watershed scale, the corresponding topographic factor at the watershed scale can be established.

4.1 The soil loss horizontal distance index

At the small watershed scale, the soil loss horizontal distance index reflects the horizontal distance of the various points in a small watershed from the drainage network. At the watershed scale, when the watershed area is fixed, the shorter the average horizontal distance from the drainage network, the more the drainage lines will be, the higher the gully density (total gully length per unit area, which represents the level of surface dissection^[20]) will be. When the gully density is higher and the average distance of land uses in the watershed from the drainage network is shorter, and the soil loss horizontal distance index of the watershed will also be higher. Therefore, gully density will be used to reflect the horizontal distance of soil loss at the watershed scale. To ensure the comparability of the factors between the watershed level and the regional level, the maximum and minimum gully density values of the different watersheds at the regional scale may be used as the reference criteria. The gully density index may be calculated to reflect the soil loss horizontal distance index at the watershed scale. Its formula is

$$G_i = \frac{g_i - g_{\min}}{g_{\max} - g_{\min}}, \quad (11)$$

where G_i is the gully density index of the i th watershed at the regional scale, g_i is the gully density of the i th watershed at the regional scale, while $g_{\max}$ and $g_{\min}$ are respectively the maximum value and the minimum value of gully density of the various watersheds at the regional scale.

4.2 The soil loss vertical distance index and slope steepness factor

The mountain body at the watershed scale may be abstracted as a cone (Fig. 6). When the watershed area is fixed, the steeper the mountain slope is, the bigger its

Fig. 6. Schematic diagram of watershed mountain body.

relative height and the larger its corresponding surface area will be. Its topography surface roughness (ratio between the surface area of the ground and its projected area^[21], has the similar meaning with tortuosity index in 3D^[22]) will also be higher. Therefore, topography surface roughness may be considered to comprehensively reflect the soil loss vertical distance and the slope steepness factor.

To ensure comparability of the factors between the watershed scale and the regional scale, the maximum and minimum topography surface roughness values in different watersheds at the regional scale also need to be used as the reference criteria in actual applications. The topography surface roughness index is calculated to express the soil loss vertical distance index and the slope steepness factor. Its formula is

$$R_i = \frac{r_i - r_{\min}}{r_{\max} - r_{\min}}, \quad (12)$$

where R_i is the topography surface roughness index of the i th watershed at the regional scale, r_i the topography surface roughness of the i th watershed at the regional scale, while $r_{\max}$ and $r_{\min}$ are respectively the maximum value and the minimum value of the modified topography surface roughness of the various watersheds at the regional scale.

A further analysis of the topography surface roughness index reveals that topography surface roughness is calculated as the ratio between the surface area of the ground and its projected area. At the watershed scale, there are elevation changes from the upstream to the downstream of the drainage network. The surface where the drainage network lies is in fact a curve changing with elevation (Fig. 7). Though use of the topography surface roughness index can directly reflect the influence of slope gradient in the soil loss process, it nevertheless cannot well show the characteristics of the horizontal distance from the drainage network. Modification of topography surface roughness may be considered to use the ratio between the surface area of

Fig. 7. Schematic diagram of drainage surface.

the topography and the area of the curve where the drainages network lies as the modified topography surface roughness.

Correspondingly, the modified topography surface roughness index is

$$R'_i = \frac{r'_i - r'_{\min}}{r'_{\max} - r'_{\min}}, \quad (13)$$

where R'_i is the modified topography surface roughness index of the i th watershed at the regional scale, r'_i is the modified topography surface roughness of the i th watershed at the regional scale, while $r'_{\max}$ and $r'_{\min}$ are respectively the maximum value and the minimum value of the modified topography surface roughness of the various watersheds at the regional scale.

4.3 Calculation formula for the watershed-scale soil loss evaluation index

Based on an analysis of the soil loss horizontal distance index, the soil loss vertical distance index and the slope steepness factor in the calculation formula for the small watershed scale soil loss evaluation index, a corresponding topographic index at the watershed scale is established. The calculation formula for the watershed-scale soil loss evaluation index is

$$SL_w = \frac{\sum (R_m \cdot K_m \cdot C_m)}{\sum (R_m \cdot K_m)} \cdot G \cdot R', \quad (14)$$

where SL_w is the watershed-scale soil loss evaluation index, G and R' are respectively the gully density index and the modified topography surface roughness index, while the meanings of the other factors are the same as in Formula (10).

In the actual calculation process, R_m , K_m and the C_m factor can be obtained using GIS technology, watershed

scale rain gauge data, soil maps and land use maps. The G and R' factors need to be calculated based on a comprehensive analysis of the gully density and modified topography surface roughness of the various watersheds at the regional scale.

5 Multiscale soil loss evaluation index

Summing up the soil loss evaluation calculation formulae at the slope, small watershed and watershed scales, the conceptual formula for a multiscale soil loss evaluation index can be obtained

$$SL = \frac{f(R, K, T, C)}{f(R, K, T)}, \quad (15)$$

where SL is the soil loss evaluation index, R is the rainfall erosivity factor, K is the soil erodibility factor, T is the topographic factor, C is the cover/management factor and f is the calculation function for soil loss evaluation index at different scales. Among them, the topographic factor will have different forms of expression at different scales.

Based on Formula (15) and in combination with Formulae (4), (10) and (14), research can be conducted

on soil loss evaluations at different scales and land use pattern optimization. Comprehensive research on multiscale soil loss evaluation is a process of downscaling. Its basic paths are as follows (in Fig. 8, those parts in gray base color show a rather high soil loss evaluation index and require land use pattern optimization):

(1) Divide a region into x watersheds and calculate the soil loss evaluation index for each watershed and based on the calculation results, specify the watersheds that require land use pattern optimization and a further analysis of soil loss evaluation index.

(2) Further divide the watersheds with a rather high soil loss evaluation index into y small watersheds, analyze the soil loss evaluation index for each small watershed and specify those small watersheds that require land use pattern optimization.

(3) Further divide the small watersheds with a rather high soil loss evaluation index into z slopes, analyze the soil loss evaluation index for each slope, specify those slopes that require land use pattern optimization and adjust the land use structure at the slope scale.

Fig. 8. Basis path for multiscale soil loss evaluation.

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In this process, multiscale comprehensive research can be done on land use and soil erosion through a level-by-level breakdown of the regional scale to the watershed, small watershed and slope scales. It is also possible to provide specific guidance plans for the optimization of land use patterns.

6 Conclusions

Based on the relevant theories of landscape ecology and the main processes of soil loss, soil loss evaluation indices are established for the small watershed and watershed scales through level-by-level upscaling the developed slope-scale soil loss evaluation index. The downscaling method is also used to formulate a research path for a multiscale soil loss evaluation index. The soil loss evaluation index put forward in the current research can preliminarily reflect the characteristics of soil loss processes and avoid the restriction of too many parameters in the physically-based soil erosion models. It can also be used to study the relationship between land use and soil erosion at mutiscales and provide technical support for optimizing land use pattern designs and comprehensive control of regional soil losses. Currently, the index is still a conceptual model. Further research may be conducted to develop built-in GIS models for multiscale soil loss evaluation. This will allow the index to be better used in the relevant research on land use and soil erosion.

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