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Research article

Landscape planning for a rural ecosystem: case study of a resettlement area for residents from land submerged by the Three Gorges Reservoir, China

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Abstract

The goals of landscape planning are multiple for rural ecosystems of the resettlement area in the Hubei Province of China. They relate to the types, diversity and patterns of the ecosystems, and to the conservation of ecosystem functions and biodiversity. We were interested in the improvement of socio-economic conditions, and the promotion of the development of farmland ecosystems and natural forest ecosystems. The landscape planning took into account the conservation and the restoration of forestlands, and the reconstructions of farmlands, towns and villages. The areas of towns and villages were assigned by trade-off analysis balancing ecological, economic and social benefits. The spatial pattern of used lands was designed by a multi-criteria optimal spatial planning, resulting in the strengthening of some primary ecosystem functions. In the resettlement area forests will expand to a matrix, and cropland patches together with tree fences will form patch-corridor systems. Significant ecological, economic and social benefits can be derived from this landscape pattern.

Introduction

Human beings show a tendency to modify ecosystems. As human populations have grown and the power of technology has expanded, the scope and nature of this modification has changed drastically. Many ecosystems are dominated directly by humanity, and no ecosystem on the earth's surface is free of pervasive human influence (Vitousek et al. 1997). Humans have often shaped landscapes to socio-economic needs, and rural landscapes are the result of the exploitation of natural resources. Constant reconstruction ecosystems has resulted in an expansion of single-function artificial ecosystems and a reduction of natural ecosystems that provide multiple services for human society. Recently, scientists have understood that the true impact of human activity on natural environments could crowd out other species with specific habitat requirements, causing the entire ecosystem to collapse (Sample 1994).

Ecosystem management can be regarded as a land management philosophy designed to protect broad natural habitats while leaving room for development (Slocombe 1993; Cushman 1995). In addition landscape planning has been considered a basic part of ecosystem management (Kondoh 1993; Henry and Amoros 1995). The close interaction between landscape and land use leads to a need to include landscape planning in land use planning policy. Landscape planning is not a simple, linear activity. It is based on large areas that are diverse in terms of ecology, economy and society, and that are complexly connected and interacting (Slocombe 1993; Grumbine 1994; Kay and Schneider 1994). Landscape planning can influence the ecological, economic and social values of the countryside, and thus refers to broad goals to be identified within the ecosystem such as jobs, environmental protection, or self-reliance. In addition, more specific targets for the ecosystem, e.g. levels of wildlife populations, harvest level, etc., must be identified (Slocombe 1998). These goals need to link land use changes that affect landscape pattern and in turn affect species and populations and dynamic feedbacks, and alter land use pattern (Lee et al 1992; Franklin (1993)). The benefits of landscape functioning derived from an interconnected system of patches and corridors have been well-documented (Harris and Gallagher 1989; Zanaboni and Lorenzoni 1989; Bennett 1990; Burel and Baudry 1990; Forman 1995). This type of landscape configuration can help the landscape sustain itself, and thus should be given attention in the landscape planning for rural ecosystems.

In the Hubei Province of China, to resettle the people from land submerged by the Three Gorges Reservoir, some resettlement areas are being established in several counties, one of which is in Xingshan County. In these resettlement areas, many natural ecosystems will be converted into human-dominated ecosystems and the landscape pattern of ecosystems will experience great changes. In this study, we shaped the landscape planning to the situation of the resettlement area in question, which relates to the conservation and the restoration of forestland, the rehabilitation of farmland, the reconstruction of towns and villages, etc. The planning gives special attention to the requirements of lands for the conservation of ecological function and biodiversity, the development of economy and the maintenance of social stability. An interconnected system of patches and corridors will be established in the resettlement area.

Study area and ecological questions

Xingshan County is situated in the west part (31° 3′ – 3°1 34′ N, 110° 25′ – 111° 6′ E) of Hubei Province, China, which has an area of about 2316 km^2 (Figure 1). The county is about 100 km away from the Three Gorges Dam that is being built, and lies to the south of the Shennongjia natural protection area. Xingshan has a subtropical continental monsoon climate, where annual precipitation is about 1100 mm on the average. A resettlement area is being established in the county, which will resettle the people from the submerged areas of the county. The resettlement area has an area of about 60027 ha and an elevation between 200–2200 m. Several streams flow into the Xiangxi River, which flows through the area from north to south, forming a corridor, and then into the Yangtze River, which transports 1299 million m^3 water annually. Riverbed and mountain shape influence the landscape of the area intensively. The resettlement area is situated in the socio-economical central zone of the county. Its original population is about 93700, and its outputs of agriculture and industry were 30.46% and 67.65% of the totals of the county in 1997. Being mountainous, infrastructures are poorly-developed in the resettlement area, e.g., communication, electric power supply, educational and medical facilities, etc.

An official survey (BLMXC 1997) describes land use in the resettlement area. The total area of forests is 21000 ha. Evergreen broadleaf forests are distributed at elevations below 500 m, evergreen and deciduous broadleaf mixed forests at elevations between 500–1300 m, and deciduous broadleaf forests and conifer forests at elevations above 1300 m. However, in low mountain and river valley areas ($\leqslant$ 800 m elevation) lands have been cultivated excessively. Vegetation has been destroyed repeatedly and residual forests have been reduced further. In middle and high mountains (> 800 m elevation) dense forests have been converted into sparse forests, and in turn barren mountain. These aggravate the runoff of water and soil. In the resettlement area there is an erosion area of 15811.6 ha, where 0.65 million ton of soil were lost annually. Orchards (tangerines, etc.) and crop agricultural fields (maize, potato, etc.) are distributed at elevations between 200–1000 m. Farmlands, residential areas, dense forests and grasslands form patches and are spread in a matrix composed of sparse forest and shrub. Water conservation and erosion control are two main ecosystem factors in the resettlement area. The Xiangxi River transfers both ecosystem factors which make an impact on the Yangtze River. The capacities of both ecosystem factors are closely related to forest condition. Thus forest ecosystems play an important role in the resettlement area.

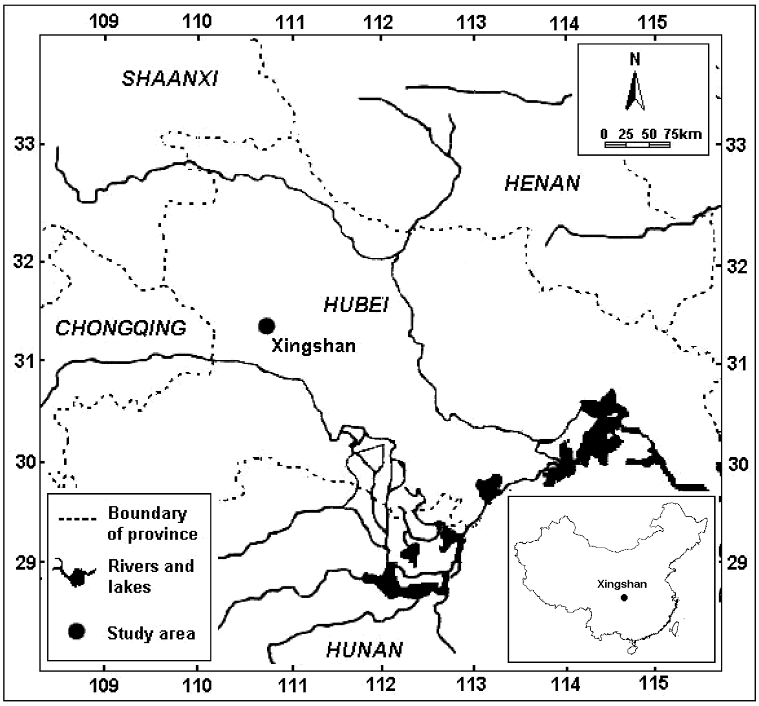

Figure 1. The location of the study area (Xingshan County). Insert shows the location within China

When the Three Gorges Area stores water, the backwater will enter Xingshan County along the Xiangxi River, and submerge about 9700 ha land. This will result in losses of 187.26 ha farmland, 24.64 ha forestland and 122.4 ha residential area. Moreover the reconstruction of towns and villages will decrease the area of vegetation by about 394 ha (CYR 1992). The loss of forest weakens the capacities of water conservation and erosion control, and results in decreased habitats. The construction of the resettlement area also disturbs to wildlife. Consequently, the species and amount of wildlife will decreass with a loss in biodiversity.

The goals of landscape planning for the resettlement area relate to the types, diversity and patterns of the ecosystem, and to description of its structure, moreover, to the maintenance of connectedness and complex organization of the system (Slocombe 1998). In the resettlement area, many biophysical functions, e.g., water retention, wildlife shelter, climate regulation, etc, are closely related to the situation of forest ecosystems. Since recently serious flood and soil loss has occurred repeatedly in the Yangtze River, we have paid special attention to water conservation and erosion control. When water retention capacity that produces the two ecosystem factors (Costanza et al. 1997) is improved by conserving forests, other related biophysical functions will also be improved. Thus, water retention capacity can be used as an indicator of the situation of biophysical functions. We considered the increase of water retention capacity as the goal for improving biophysical functions. In the context of community and society, we were interested in the improvement of socio-economic conditions, e.g., the increase of agriculture output and the improvement of infrastructures, moreover the ecosystem level characteristics, such as overall biodiversity and landscape mosaic, would be relevant. Patchiness is the degree to which landscape elements differ from the matrix, and contrast is the degree of difference between the elements' appearance and function (Forman and Godron 1986; Fedorowick 1993). A medium degree of patchiness and a moderate contrast between landscape elements will be formed. In addition, we promoted the developments of farmland ecosystem and natural forest ecosystem coordinately.

Methods

We adopted the following methods to make out the landscape planning: 1) creating spatially-explicit data layers within a GIS; 2) characterizing the resettlement area; 3) relating the resettlement area to ecological resources of interest; and 4) producing land use planning maps referring to landscape configuration.

Landscape level characterization

In this study we classified the landscape elements of the resettlement area based on the types of vegetation, soil, slope and elevation. According to the results of both natural evolution and man-made affects, the resettlement area was divided into “used land”, “forestland” and “uncultivated land”. The used lands include towns, villages and farmlands. The forestlands hold forest and sparse forest, while the uncultivated lands hold shrub and grass.

An integrated spatial database embodied within a GIS (ARC/INFO system (ESRI 1994)) was developed as the foundation of the landscape planning (Brown (1994) and Soller (1994); Peccol et al. 1996). The vegetation data were derived from the visual interpretation of Landsat TM image on September 15, 1995, together with an extensive field survey in Xingshan County in 1997. Six vegetation types were used in this study. We digitized the resettlement area’s soil map (drawn by the Bureau of Land Management of Xingshan County) and topographical map (drawn by the Bureau of Survey and Drawing of PRC) at the scale of 1:50,000, and derived relevant data from these maps. In the resettlement area there are five types of soils. We divided the slope angle into three categories and the altitude into two types. Thus, in the resettlement area vegetation includes six types, soil five types, slope angle three categories, and altitude two types (see Table 1). The spatial database includes four data layers, that is, vegetation, soil, slope and altitude. The four data layers were overlaid to divide the study area into 180 types of vegetation-soil-slope-altitude complexes. The overlaid ecological factor map shows these complexes’ biophysical characteristics and spatial patterns in the resettlement area. The polygon map was converted into a grid map, and a grid cell represents a land area of 4ha. We used these cells to divide ecoregions and design towns and villages.

Division of ecoregions

To describe the characteristic of the resettlement area and relate it to ecological resources of interest, we regionalized this area by spatial classification to form ecoregions (Bryce and Clarke 1996). An ecoregion boundary was drawn around an area that is relatively homogeneous in landscape characteristics, that is by vegetation, soil, slope and altitude. In the resettlement area, water retention, biodiversity conservation and agricultural production are critical ecosystem functions. Therefore, the division of ecoregions was based on the situations of these ecosystem functions in a complex. Here, the resettlement area was divided into four ecoregions: 1) the function conservation region, where forests or farmlands will be conserved (or restored) to maintain water retention capacity or agriculture output; 2) the function rehabilitation region, where forests or farmlands will be rehabilitated to strengthen relevant ecosystem functions; 3) the vegetation conservation region, where vegetation will be restored (or conserved) to form some special landscape elements (e.g., tree fences); and 4) the vegetation maintenance region, where the current situation of vegetation will be maintained.

Table 1. Types of vegetation, soil, slope and altitude in the resettlement area

Name	Type	Code
Vegetation	Forest (canopy > 0.3)	FRT
	Sparse forest (canopy ⩽ 0.3)	SFT
	Shrubs	SHR
	Grasses	GRA
	Orchard	OCH
	Crop	CRP
Soil:	Yellow brown soil	YBS
	Yellow soil	YLS
	Lime soil	LMS
	Purple soil	PPS
	Rice soil	RCS
Slope Angle:	Less than 15	SA < 15°
	Between 15 and 25	SA=15° ~ 25°
	More than 25	SA > 25°
Altitude:	Lower than and equating to 1000m	⩽1000 m
	Higher than 1000 m	>1000 m

Trade-off analysis

In this study, we assigned the areas of used lands using trade-off analysis. The benefits derived from the economic and social objectives, e.g., increasing economic outputs and job availability, were put against benefits from the ecological objectives, e.g., water conservation, erosion control, etc. We balanced the three kinds of benefits by their economic values. In

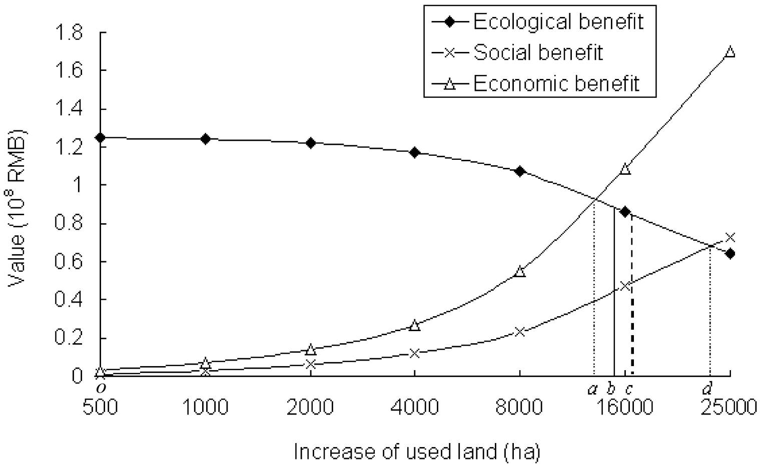

Figure 2. The trade-off analyses for the areas of used land based upon the relationships between the benefit curves and the limitations of the area of available land. *oa* is the minimum suitable area of the used land; *od* is the maximum suitable area of the used land; *oc* is the total area of available land cells; *ob* is the area of the used lands that was used for the reconstruction of towns and villages.

the resettlement area the average economic value of ecological services is 2516 RMB ha $^{-1}$ (RMB: Chinese Currency, 8.3 RMB = 1 US$) (Guo et al. 2001). When the area of used land increases, ecological benefits will decrease due to decrease in forests. According to official statistics (BSXC 1999), Xingshan County's average economic output in 1998 was about 6808 RMB ha $^{-1}$. Economic benefit will increase with the increase in area of used land. In addition, we are of the opinion that resettling more people in the local resettlement area could avoid social instability and the loss of local traditional culture caused by migration, and thus provide greater social benefit. Here we used the economic compensation that the migrants obtain as an indicator for social benefit. The compensation is about 5000 RMB person^{-1}. Because used land is 1.71 ha person^{-1} in Xingshan County, the expenditure can be converted into 2923 RMB ha $^{-1}$. Social benefit will increase with increase in area of used land. Trade-off analyses were carried out based upon the relationships between these benefit curves and the limitations of the area of available land (Figure 2). The suitable area of used land was assigned in accordance with the balance principle for ecological, economic and social benefits.

Multi-criteria optimal spatial planning

Clearly the constructions of towns and villages can result in a change in the spatial pattern of land use. In this study, we developed a multi-criteria optimal spatial planning to design the patterns of used lands in the resettlement area. The 'multi-criteria' relates to ecological, economic and social factors. This method can make the spatial patterns of used lands produce maximal integrated ecological, economic and social benefits.

According to the discussions above, we used water retention capacity as the criterion of ecological benefit. And the criterion of economic benefit was the cost of construction. As infrastructures that provide remarkable social benefits are poorly-developed in the resettlement area, we considered that if the spatial patterns of towns and villages are more advantageous to the improvement of infrastructures, greater social benefit could be obtained. Surely the concentric patterns of towns and villages, especially in mountainous areas, are more advantageous than scattered patterns, because of less investment and workload. Moreover, concentric patterns also allow inhabitants to utilize infrastructures conveniently. Thus greater social benefit can be obtained from the concentric patterns than the scattered. Here we used the degree of concentration for the spatial patterns of towns and villages as the criterion of social benefit.

According to the types of vegetation, soil, slope and altitude, the lands used for the constructions of towns and villages were divided into eight types of available land cell by grid map and illustrated by the "Classes" (see Table 2). We used these available land cells to carry out the multi-criteria optimal spatial planning for designing towns and villages. The "availability" was used to indicate the relative available degree of a land cell by evaluating its integrated

Table 2. Definition for available land cell by using the types of vegetation, soil, slope and altitude

Type	Definition by logical expression
Class 1	(CRP) × (YBS + YLS + LMS) × (SA<15) × ($\leqslant$1000 m)
Class 2	(OCH) × (YBS + YLS + LMS) × (SA<15) × ($\leqslant$1000 m)
Class 3	(GRA) × (YBS + YLS + LMS) × (SA<15) × ($\leqslant$1000 m)
Class 4	(SHR) × (YBS + YLS + LMS) × (SA<15) × ($\leqslant$1000 m)
Class 5	(CRP) × (YBS + YLS + LMS) × (SA=15 ~ 25) × ($\leqslant$1000 m)
Class 6	(OCH) × (YBS + YLS + LMS) × (SA=15 ~ 25) × ($\leqslant$1000 m)
Class 7	(GRA) × (YBS + YLS + LMS) × (SA=15 ~ 25) × ($\leqslant$1000 m)
Class 8	(SHR) × (YBS + YLS + LMS) × (SA=15 ~ 25) × ($\leqslant$1000 m)

ecological, economic and social benefits. The reconstruction of towns and villages can change vegetation and slopes by plant clearing and cutting and land leveling. The availability of a land cell relies on the ecological, economic and social effects derived from these changes. In the resettlement area, the used land includes a county town, three towns and eleven larger villages, and each one is surrounded by farmlands. We chose fifteen spots in available areas, and drew four concentric circles, C_1, C_2, C_3 and C_4, using each spot as center. Then we evaluated the available areas in these concentric circles by the "Levels".

Ecological effect is derived from the variation of water retention capacity caused by the change of vegetation or slope in a land cell. Then the ecological effect in the *i*th Class of land cell, $E_{el}(p_i)$, can be defined as follows:

$$E_{el}(p_i) = (w(v) + Dw(v))(w(s) + Dw(s))/w(v)w(s),$$
$$i = (1, \ 1/4, \ 6) \qquad (1)$$

Where $w(v)$ and $w(s)$ are the water retention capacities of the vegetation and the slope in the *i*th Class of land cell, v = {SHR, GRA, OCH, CRP} and s = {SA<15, SA=15 ~ 25}. And $\Delta w(v)$ and $\Delta w(s)$ are their increments caused by the changes of vegetation and slope. The parameters in the Eq.(1) were obtained based upon the coefficients of water retention capacity for the vegetations SHR, GRA, OCH and CRP (0.57, 0.35, 0.11 and 0.07) and the slope angles SA<15 and SA=15 ~ 25 (1.00 and 0.57) (Guo et al. 2000) (see Table 3). Economic effect relates to the cost of construction. Different types of vegetation and slope can result in differences in the cubic meters of earth removed by plant clearing and cutting and land leveling. In addition, removing more cubic meters of earth can result in an increase in the cost of construction. Then, according to removed cubic meters of earth, the economic effect in the *i*th Class of land cell, $E_{en}(p_i)$, can be defined as follows:

$$E_{en}(p_i) = 0.01/m(v) \quad m(s) \qquad (2)$$

Where $m(v)$ and $m(s)$ are relative cubic meters of earth removed for the vegetation and the slope in the *i*th Class of land cell. In the resettlement area, for SHR, GRA, OCH and CRP the cubic meters of earth that need to remove are about 0.8, 0.3, 0.7 and $0.1m^{-2}$ respectively, and the ratio of SA <15 to SA=15 ~ 25 for the cubic meters of earth that need to remove is 0.37 approximately. The parameters in the Eq.(2) were obtained by normalizing those data (Table 3). Social effect is referred to the degrees of concentration for the spatial patterns of towns and villages. And the degrees of concentration depend on the locations of land cells, which are indicated by the "Levels". Then the social effect in the *k*th Level, $E_{sc}(l_k)$ is:

$$E_{sc}(l_k) = 0.5/\sum_{j=1}^{k} r_j, \quad k = (1, \ldots, 4) \qquad (3)$$

Where r_j is the radius of the *k*th Level concentric circle (see Table 4). Then the availability for the *i*th Class of land cell in the *j*th Level, Av_{ij}, can be appraised by the equation as follows:

$$Av_{ij} = E_{el}(p_i)E_{en}(p_i)E_{sc}(l_j),$$
$$i = (1, \ 1/4, \ 6) \text{ and } j = (1, \ 1/4, \ 4) \qquad (4)$$

In this study, the choice of available land cell is based on the principles: 1) giving priority to the land cell with higher availability; and 2) making the patterns of towns and villages as concentrated as possible.

Table 3. The description of the parameters in the evaluation models.

Parameters	CRP	OCH	GRA	SHR	SA<15	SA=15～25
$w(v)$	0.07	0.11	0.35	0.57		
$w(s)$					1	0.77
$\Delta w(v)$	0	0	−0.26	−0.48		
$\Delta w(s)$					0	0.43
m(v)	0.125	0.333	0.142	1		
m (s)					0.368	1

Table 4. Concentric circles and the Levels of available areas for the multi-criteria optimal spatial planning

Concentric circle	Radius (km)	Area
C_1,	0.5	Level 1
C_2,	1	
$C_2 - C_1$		Level 2
C_3	1.5	
$C_3 - C_2$		Level 3
C_4	2	
$C_4 - C_3$		Level 4

Results

Ecoregions

The function conservation regions comprise two kinds of land: 1) all the forestlands; and 2) the used lands that have low-level soil losses (the modulus of soil erosion <15 ton ha $^{-1}$ yr^{-1}). In this region forests or farmlands will be conserved, and sparse forests will be restored into forests. The function rehabilitation regions also have two kinds of land: 1) holding high-level soil loss (the modulus of soil erosion > 35 ton ha $^{-1}$ yr^{-1}); and 2) the uncultivated lands that are suitable for culturing (soil type is YBS, YLS or LMS; slope angle is SA< 15 or SA=15～25; and elevation is ≤1000 m). In this region forests will be rehabilitated to increase water retention capacity, and farmlands will be constructed to increase agricultural output. The vegetation conservation regions are located at some boundaries between different landscapes, e.g., between the used lands and the forestlands, etc. The vegetation maintenance regions are the uncultivated lands that hold a low-level soil loss, where current situations will be maintained. Figure 3 gives the distributions of four ecoregions in the resettlement area.

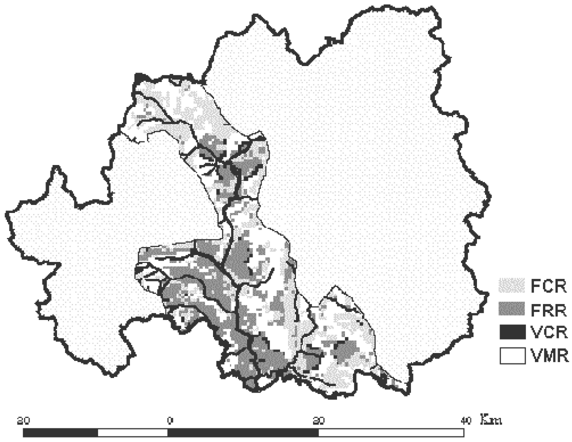

Figure 3. ??Ecoregions in the resettlement area. FCR: function conservation region; FRR: function rehabilitation region; VCR: vegetation conservation region; VMR: vegetation maintenance region.

As a result, in the resettlement area all forests will be conserved and all sparse forests will be restored to forests. According to the characteristics of vegetation zone, forests at elevations below 500 m will be restored to evergreen broadleaf forest, e.g., Camphor tree (*Cinnamonum camphora* (Linn.) Presl), at elevations between 500～1300 m to evergreen and deciduous broadleaf mixed forest or warm-temperate aciculisilvae, e.g., Masson pine (*Pinus massoniana* Lamb.), China fir (*Cunninghamia lanceolata* (Lamb.) Hook), Sawtooth oak (*Quercus acutissima* Carrath.) and Cork oak (*Quercus variabilis* Blume), and at elevations above 1300 m to deciduous broadleaf forest or temperate aciculisilvae, e.g., Huashan pine (*Pinus armandii* Franch) and Brightleaf beech (*Fagus lucida* Rehc. et Wils.). In the function conservation regions some large areas of forests will be formed. In part of the function rehabilitation regions, which have purple soil and rice soil, forests will be rehabilitated to control soil erosion. In the vegetation conservation regions vegetation will form some tree fences to more or less surround towns and villages, or along the banks of the Xiangxi River. Some farmland patches will be formed in the function conservation regions and the function rehabilitation regions.

Reconstruction of towns and villages

In the resettlement area the current area of the used land is 13045 ha. Based on the trade-off analyses with the principle of multiple benefits balance, the suitable area of the used land ranges between 14000 and

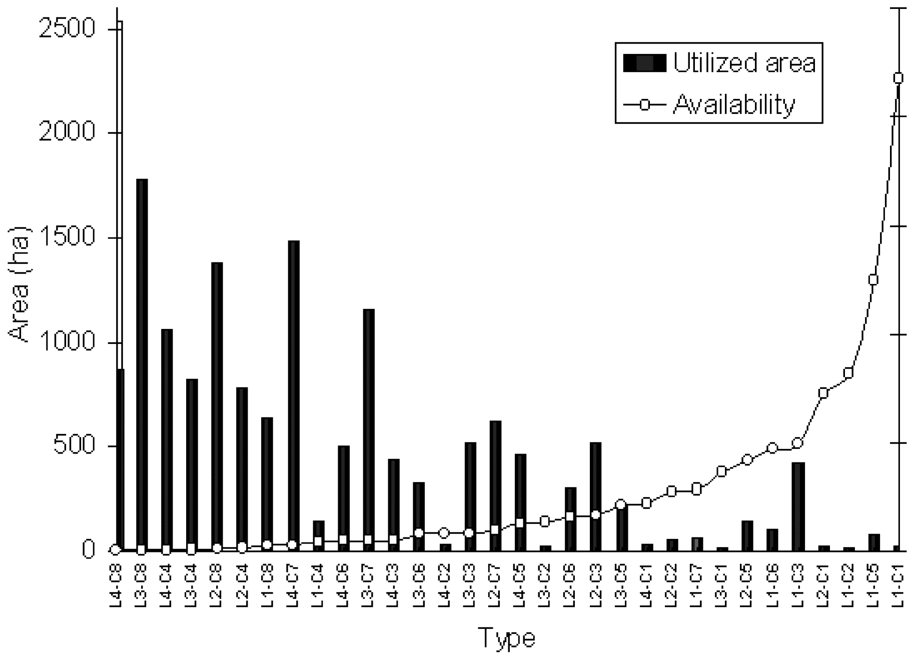

Figure 4. The availability and the utilized areas of available land cells for constructing a county town, towns and villages

23500 ha (see section *ad* in Figure 2). The spatial patterns of the used lands were designed by multi-criteria optimal spatial planning. Based on Equation (1)-(3) with parameters in Tables 3 and 4, the ecological effects of available land cells follow such order as: Class 5 > Class 6 > Class 1 > Class 2 > Class 7 > Class 3 > Class 8 > Class 4; the economic effects: Class 2 > Class 7 > Class 6 > Class 4 > Class 1 > Class 3 > Class 5 > Class 8; and the social effects: Level 1 > Level 2 > Level 3 > Level 4. Using Equation (4) we evaluated the availability of every available land cell (see Figure 4), and formed the three 'waiting lists' of the land cells for constructing a county town, towns and villages according to the availability. In the resettlement area the total area of available land cells is 16730 ha (point *c* in Figure 2). Then the scale of suitable area should be between point *a* and *c* in Figure 2. Here the area of the used lands that was used for the reconstruction of towns and villages is 15170 ha (point *b* in Figure 2), including 13470 ha farmlands and 1700 ha residential areas. The areas of county town, towns and villages are respectively 1020, 3190 and 10980 ha. According to the availability from large to small, a land cell was chosen from a 'waiting list' until the areas of towns or villages added up to the expected area. As a result, we obtained the optimal spatial patterns of county town, towns and villages in the resettlement area. Moreover, as the uncultivated lands hold a low level of soil loss, the vegetation maintenance regions provide room for the expansion of towns and villages, and for the further development of socio-economy.

New landscape pattern of the resettlement area

By reconstructing, in the resettlement area the area of forest will attain 32240 ha, occupying 53.7% of the total. Thus forest will become a matrix, and used lands and uncultivated lands will spread in forest as patches. Tree fences, which surround used lands or line the banks of the Xiangxi River, together with cropland patches, will form patch-corridor systems. Figure 5 shows the spatial pattern of land use in the resettlement area after reconstruction.

Here we used the patchiness and the contrast to appraise the landscape pattern in the resettlement area. Patchiness was derived by measuring the percentage area occupied by each landscape element per grid square, and contrast was derived by measuring the degree of similarity between groups of landscape elements (other than the matrix) in each grid square (Fedorowick 1993). In this area there are three landscape types: forest, used land and uncultivated land. Since forest matrix occupies a medium percentage 53.7%, the patchiness of landscape elements reaches a medium degree in the area. In addition, the water

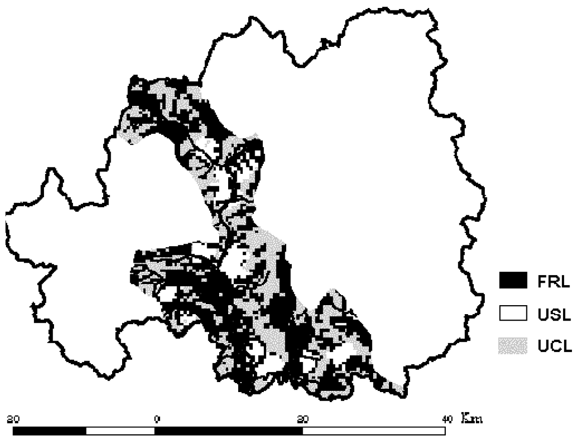

Figure 5. The spatial pattern of land use in the resettlement area. FRL: forestland; USL: used land; UCL: uncultivated land.

retention capacity of used land is 62% of that of uncultivated land. This indicates that the contrast in ecological function between the two, to which we pay close attention, is also in a moderate degree in the resettlement area.

Discussion

Standing in the catchments of the Xiangxi River, forests in the resettlement area play an important role in conserving water and linking up water systems. We estimated that in the resettlement area water retention capacity, via conserving and restoring, would attain 1325.75 million m^3 yr^{-1}, increased by about 39.7% (Guo et al. 1998, 2000). Moreover, the forests that abut on the Shennongjia natural protection area can provide habitats and shelters for some animals that need large habitats. Some internal species can also be conserved in those regions. Smaller forests distributed throughout the resettlement area can decrease the losses of water and soil, and provide ‘stepping stones’ for moving wildlife.

In the resettlement area, corridors (tree fences) can produce significant ecological benefits in terms of inhibiting runoff and erosion, increasing nutrient cycling, and providing microclimatic benefits (including reduced wind velocity, higher atmospheric and soil moisture), as well as significant agricultural benefits (Forman and Godron 1986). Tree fences also provide habitats for species that prey on farming pests. Such an arrangement of interconnected landscape elements is also beneficial to wildlife by providing movement corridors, habitat and resting sites (Morrison (1994) and Henry and Amoros (1995); Wyant et al 1995). The relationship between landscape form (e.g., fences, rivers and streams) and function (farming and conservation) affects the associated ecological processes (gene exchanges and infiltration rates) that are prevalent. Therefore, introducing a patch-corridor network into the fragmented rural landscape can enhance both the human-induced (agricultural) activities and the landscape functioning (wildlife) of the ecosystem (Hobbs and Saunders 1991).

Moreover, restoring a medium patchiness to the landscape of the resettlement area will provide for adequate species-land interactions as well as maintaining the opportunity for different habitats and agricultural opportunities. Likewise, a moderate contrast between elements would encourage habitat diversity, species-land exchanges and erosion reduction without the high level of conflict associated with a highly contrasting landscape (Fedorowick 1993).

Landscape planning not only needs some clearly defined goals, but also an overall systemic analysis to the problems, as well as reliable and exact ways of operation and (some) controllable landscape system(s). Our work has produced scene trial approaches to landscape planning. In this study, the division of ecoregions, trade-off analysis and multi-criteria optimal spatial planning are effective methods for analysis and design. In addition, we adopted a grid map supported by GIS as an effective way of operation, and a patch-corridor system as a controllable landscape system.

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