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Landscape change and sustainable development in Yangtze River Basin, China

Landscape and stand structures in a hilly agricultural area in Fenghua City, Zhejiang Province, China: impact of fuelwood collection

Michiro Fujihara · Keitarou Hara · Liangjun Da · Yongchuan Yang · Xiangkun Qin · Noritoshi Kamagata · Yi Zhao

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Abstract Paddy fields surrounded by forests are characteristic of the rural landscapes in East Asia. These characteristic landscapes are maintained by agricultural activities; recently, however, local and regional changes in economic and social systems have resulted in their deterioration. In order to conserve these landscapes, the diversity of land-use systems should be documented, and the human impact on landscape structure should be analyzed. In this study, landscape structure, stand structure, and influence of human activity on the landscape were examined for a hilly agricultural area in Fenghua City, Zhejiang Province, China. Eleven types of landscape elements were recognized that include evergreen broad-leaved forests, evergreen coniferous (*Pinus massoniana*) forests, tall bamboo (*Phyllostachys pubescens*) forests, small bamboo (*Phyllostachys praecox* f. *prevernalis*) plantations, tea gardens, grasslands, dry arable fields, paddy fields, residential areas, bare ground, and open water. In the study plots, which were established in the main forest types, the species name, cover abundance, and sociability of vascular plants were recorded, and tree height and diameter at breast height were measured. In addition, the amount of fuelwood collected from the forests was determined. There were many component species common to both secondary and natural forests, but the stand structure for these forests was considerably different. *Cyclobalanopsis* (*Quercus*) *glauca*, which had adapted to being frequently cut, was found to be the preferred species for fuelwood.

Keywords Secondary forest · Human impact · Species composition · Sprout · *Cyclobalanopsis* (*Quercus*) *glauca* · Evergreen broad-leaved forest

M. Fujihara (✉)
Graduate School of Landscape Design and Management, University of Hyogo/Awaji Landscape Planning and Horticulture Academy, 954-2 Nojimatokiwa, Awaji, Hyogo 656-1726, Japan
e-mail: fujihara@awaji.ac.jp

K. Hara
Department of Environmental Information, Tokyo University of Information Sciences, 4-1 Onaridai, Wakaba-ku, Chiba 260-8501, Japan

L. Da
Department of Environmental Science and Technology, East China Normal University, 3663 North Zhongshan Road, Shanghai 200062, China

Y. Yang
Faculty of Urban Construction and Environmental Engineering, Chongqing University, Key Lab of Three Gorges Reservoir Region's Eco-Environment, Ministry of Education, Chongqing, No. 174 Shapingba Street, Shapingba District, Chongqing 400045, China

X. Qin
Botanical Department, Shanghai Museum of Natural History, 1102 Longwu Road, Shanghai 200231, China

N. Kamagata · Y. Zhao
Graduate School of Informatics, Tokyo University of Information Sciences, 4-1 Onaridai, Wakaba-ku, Chiba 260-8501, Japan

Introduction

Modification of forests due to human impact is a major factor in global environmental change. Even areas that remain predominantly forested can be changed considerably by human alteration of historical disturbance regimes (Wimberly and Ohmann 2004). Paddy fields surrounded by forest are characteristic of the rural landscapes in East Asia, where biodiversity in rural areas is considered to be

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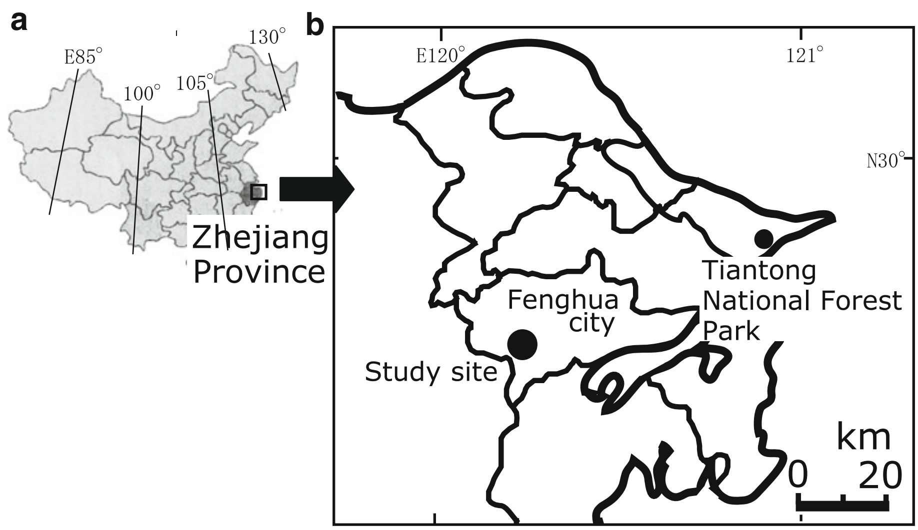


Fig. 1 Map of China showing the location of **a** Zhejiang Province and **b** the study site and Tiantong National Forest Park

high, especially in Japan. These types of landscapes have been maintained by the continued practice of agricultural activities; however, local and regional changes in economic and social systems have resulted in the deterioration of such landscapes. In Japan, abandonment of agricultural activities in rural areas has been shown to have a critical influence on its biodiversity (Iiyama et al. 1995). In China, rural areas are now undergoing severe degradation due to human influence (Ren et al. 2007). Both the underutilization (e.g., abandonment) and the overuse (e.g., deforestation) of rural areas can influence its biodiversity and landscape structure. Therefore, in order to conserve the biodiversity of the rural areas in China, it is necessary to document the diverse land-use systems and analyze the human impact on the landscape structure in these areas. Multiscale analysis is important for a comprehensive analysis of the total landscapes (Fu et al. 2005).

This study aimed to examine landscape and stand structures of secondary forests in a particular hilly rural area of China and elucidate the influence of human activity on these structures.

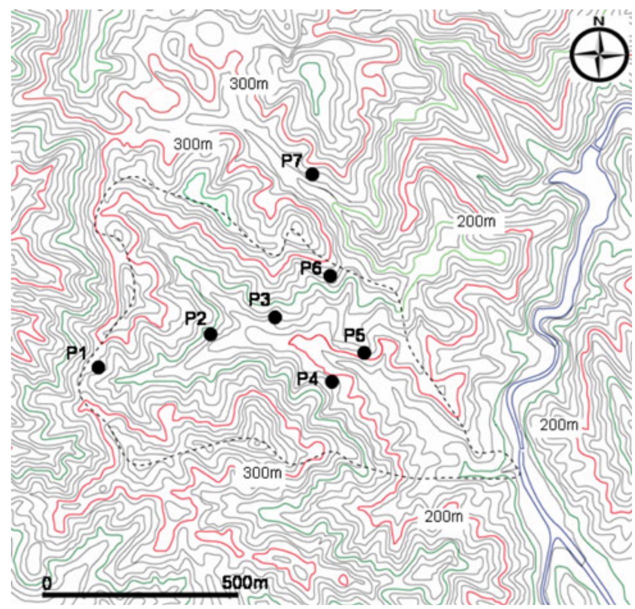


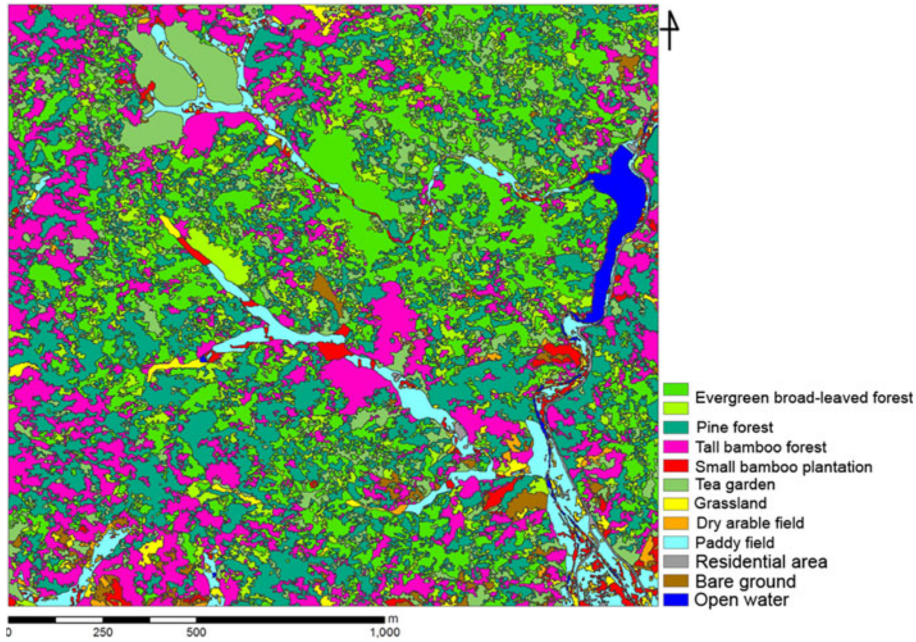
Fig. 2 Topography of the study site and location of study plots (P1–P7). *Dotted line* shows the catchment where fuelwood data were obtained

Materials and methods

The study site is located in a hilly agricultural area in Fenghua City, Zhejiang Province, eastern China, at coordinates 29°31′6″N and 121°10′45″E (Fig. 1). The altitude of the study site ranges from 130 to 370 m a.s.l. and a main river runs through the eastern part from south to north, with several branches flowing into the river from the west (Fig. 2). A road runs along the main river, and there is a village located in the southeastern part of the site. Vegetation and land use on the valley floor are quite different from those on the hillside slopes (see Figs. 2, 3). The valley floor consists of cultivated land, including paddy fields and arable fields, whereas most hillside slopes are covered by forests—evergreen broad-leaved forests, in particular. The Editorial Board of Land History of Ningbo City (1999) documents the predominant landscape feature in the Fenghua City region as being forest. The mean annual temperature and precipitation recorded at the nearest meteorological station (i.e., at Ningbo City) are 16.2°C and 1300–1400 mm, respectively (http://japanese.ningbo.gov.cn/art/2007/3/19/art_232_2946.html).

Field surveys and IKONOS satellite image data (14 April 2003) were used to produce a landscape map of the study site and to classify the distribution pattern of the

Fig. 3 Land-cover map of the study site



landscape elements. The site was initially divided into two parts—the valley floor and the hillside slopes—according to topography. Inclination of valley floor was relatively gentle, whereas hillside slope was steep and quite different. Valley floor was occupied by cultivated land; hillside was dominated by forests. The eCognition version 4 software was used to carry out our object-based classification for each of these parts. This procedure involved adjusting an object's size and shape to distinguish between paddy and forest areas. Texture and color information from the image data were used to segment each unit, and similar areas were integrated by increasing the scale parameters (Kamagata et al. 2006). Segments were classified using nearest-neighbor methods by considering spectral features. The vegetation map, created on the basis of field surveys, was used for training data to identify the different types of vegetation.

To determine species composition and stand structure, one to three plots (ca. 10 m × 10 m) were established in each type of forests and included evergreen broad-leaved: plots 2, 3, and 7; pine: plots 1, 5, and 6; and tall bamboo: plot 7 (Fig. 2). In each plot, the species name, cover abundance, and sociability (Braun-Blanquet 1964) of vascular plants were recorded for each layer, and the height (*H*) and diameter at breast height (DBH) of trees >1.3 m in height were measured. The number of stems of each tree was counted, and the ratio of the number of stems to the number of trees (sprout ratio) was calculated for all tree species. The distance in a straight line and that along a footpath from each plot to the village in the southeastern part of the study site were measured using a topographical map. In order to estimate the amount of fuelwood collected from forests, species names and diameters of the trees cut by residential people were recorded in plot 5.

It was difficult to find areas of natural forest within the vicinity of the study site, as most of this region had been disturbed by human activity. The nearest forest reserve, Tiantong National Forest Park, is located about 60 km from the study site. The composition and structure of the tree species within Tiantong National Forest Park have been documented many times previously (Cai 1994; Chen et al. 1994; Li 1994; Song 1994; Xiao 1994; Kawano et al. 1999; Murakami et al. 1999; Nakamura et al. 1999a, b; Song and Wang 1995; Yang et al. 2005, 2006). The species considered in the study site reported here were compared with those of Tiantong National Forest Park (Fig. 1).

Residents in the study site used both petroleum and wood as fuel in their homes for day-to-day activities. To collect fuelwood, the people cut stems, bind them into bundles, and leave them along a footpath to dry. The amount of fuelwood collected were determined by counting the number of bundles; additionally, the species name and the diameter and length of the cut stems and the number of stems per bundle were recorded in a catchment. Field surveys were conducted in July 2001, August 2002, and September 2004.

Results

Landscape structure

Figure 3 shows a land-cover map of the study site, an area approximately 2 km × 2 km. Eleven types of land cover were identified and consisted of forest vegetation, comprising: (1) evergreen broad-leaved forests, (2) pine (*Pinus massoniana*) forests, and (3) tall bamboo (*Phyllostachys pubescens*) forests; and cultivated land, comprising: (4) small bamboo (*Phyllostachys praecox* f. *prevernalis*) plantations, (5) tea gardens, (6) dry arable fields, and (7) paddy fields; in addition to (8) grasslands, (9) residential areas, (10) bare ground, and (11) open water. The percentage of total area covered by forests was 76.0% and that covered by cultivated land 19.4% (Table 1). Evergreen broad-leaved forest covered 31.7% of the total area and was the dominant type of cover on hillside slopes. Forests of pine and tall bamboo made up 24.9% and 19.4%, respectively, of the total area, and the percentage area covered by tea gardens was 12.1%. Valley floors were covered mainly by cultivated land, with paddy fields accounting for 4.8% of the study site's total area. The percentage of total area covered by small bamboo plantations was 1.8% and by dry, arable fields 0.7%. Relatively small portions of the total land were covered by grassland (1.6%), bare ground (1.5%), and open water (1.1%). Only 0.5% of the study site was occupied by residential areas.

Whereas patches of evergreen broad-leaved forest were widely distributed on hillside slopes throughout the entire area, tall bamboo forest patches of relatively large size were located on the lower part of slopes. Pine forests were located on small ridges or convex slopes. Small bamboo plantations were established on abandoned paddy fields, and thus restricted to the valley floor. Large patches of tea gardens were distributed on slopes surrounding paddy fields. Most grassland was located in narrow valleys near the upstream branches of the main river, but some were located on downstream hillside slopes. Dry, arable fields were also located in narrow valleys near the upstream river branches, whereas paddy fields were located on the valley floor. There was a near-continuous distribution of paddy fields between the upstream and downstream regions of the valley floor, interrupted by a scattering of small bamboo plantations and dry, arable fields. Most residential areas were located near the center of the village on the southeastern part of the study site. Several patches of bare ground, the result of tree felling, were scattered across hillside slopes. Open water consisted of reservoirs, ponds, and streams. There were several ponds in the valleys near the upstream river branches and a reservoir on the main river in the eastern part of the study site.

Table 1 Percentage of area of the study site occupied by various types of land cover

Land-cover type	Area (%)
Forest area	76.0
Evergreen broad-leaved forest	31.7
Pine forest	24.9
Bamboo forest	19.4
Cultivated area	19.4
Phyllostachys praecox plantation	1.8
Tea garden	12.1
Dry, arable field	0.7
Paddy field	4.8
Others	4.7
Grassland	1.6
Bare ground	1.5
Residential area	0.5
Open water	1.1

Stand structure and species composition

Table 2 shows species composition and location characteristics for each study plot. Of the three main forest types, plots 1, 5, and 6 represent pine. Plot 1 consisted of pine scrub located on a ridge; it contained 17 different species, less than that of other plots. There was a lack of tall trees in this plot. The subtree layer was dominated by *P. massoniana* but also consisted of *Schima superba*. *Quercus fabri* was present in the shrub and herb layers. Plot 6 was located on the upper part of a slope, with its tree layer dominated by *P. massoniana*, *S. superba*, *Cyclobalanopsis* (*Quercus*) *glauca*, and *Castanopsis sclerophylla*. Plot 5 was located on the small ridge on the middle part of a slope; its tree layer was dominated by *P. massoniana* and *S. superba*, but it also contained *C.* (*Q.*) *glauca* and *C. sclerophylla*.

Plots 2, 3, and 7 represented the evergreen broad-leaved type of forest, and the dominant tree species were *C. sclerophylla*, *S. superba*, and *C.* (*Q.*) *glauca*. Plot 3 also contained *P. massoniana* and *Liquidambar formosana*. Elements of natural forest, such as *Lithocarpus glabar* and *Castanopsis eyeri*, were found in the tree layer in plot 7, which was located on the slope of a catchment, at a location far from the village. Plot 4 was located on the lower part of a slope, and it was dominated by *P. pubescens*. The only tree species in the tree layer was *L. formosana*. *Loropetalum chinense* were widely distributed in the study site. *Schima superba* was found in tree and/or subtree layers in all plots of pine and evergreen broad-leaved forests and presented in herb layer in bamboo forest. The tree layer of natural forests in Tiantong National Forest Park harbors many species, including *S. superba*, *C.* (*Q.*) *glauca*, *C. sclerophylla*, *L. formosana*, *L. glabar*, and *Quercus fabri* (Table 2).

Table 3 shows the stand structure of each plot in this study. The mean DBH and tree height in plot 1 were smaller than those in other plots. The largest maximum DBH values were found for trees in plots 2 and 7, although all trees in the study site were fairly small. *Castanopsis*

Table 2 Species composition of each plot

Landscape element type		Pine forest			Evergreen broad-leaved f.			Bamboo
Plot No.		Plot1	Plot6	Plot5	Plot3	Plot2	Plot7	Plot4
Tree-layer Height (m)			8~12	8~12	8~16	8~12	8~14	2~12
Coverage (%)			50	50	60	90	75	70
SubT-layer Height (m)		3~7	4~8	4~8	4~8	4~8	4~8	
Coverage (%)		75	25	65	50	40	40	
Shrub-layer Height (m)		0.6~3	0.5~4	0.4~4	0.6~4	0.4~4	0.4~4	0.8~2
Coverage (%)		80	25	40	50	50	40	20
Herb-layer Height (m)		0~0.6	0~0.5	0~0.4	0~0.6	0~0.4	0~0.4	0~0.8
Coverage (%)		98	75	45	20	10	15	80
Area (m^2)		5×5m	5×10m	10×10m	10×10m	10×10m	10×10m	5×10m
Direction		S60E	S30W	S20W	S60W	S20W	S20W	N20E
Inclination (degree)		25	5	35	30	35	35	20
Distance from village in straight line		1196	965	848	978	1043	1087	826
Distance from village along path		1883	1609	1426	1587	1674	2000	1413
Topography		Ridge	US	MS	LS	LS	MS	LS
No. of Species		17	23	34	40	33	35	50
Pinus massoniana	T		2	2	1			
	ST	4	1					
*Schima superba**	T		3	2	1	4		
	ST	2	2			3	2	
	S		+			1	1	
	H			+	+	+	+	+
*Cyclobalanopsis glauca**	T		2	1	2	2	2	
	ST		1	3	2	1	2	
	S		2	2	+	2	1	
	H			1		1		+
*Castanopsis sclerophylla**	T		2	1	2	1	2	
	ST		2		2			
	S			1	1	1		
	H					+		
*Liquidambar formosana**	T				2	1		+
	S				+			+
	H							+
*Lithocarpus glaber**	T					1	3	
	ST			1		1	1	
	S	1	+			1	1	
	H	1	+			1	2	
Castanopsis eyrei	T						2	
	ST						1	
	S						1	
Phyllostachys pbescens	T			1				4
	S		1					
Loropetalum chinense	ST		+	1	2	3	1	
	S	2	2	2	2	2	1	1
	H	+	1	1	1			1
*Quercus fabri**	S	+		1		+		+
	H	+	+	1	+			+
Symplocos caudata	T					1		
	ST		+			2		
	S			1	1	1	2	
	H					1	1	
Quercus acutissima	T					+		
Rhododendron ovatum	ST					+		
	S		+	+	1	2		
	H					1	+	
Myrica rubra	ST				1			
	S				+	1		
Platycarya strobilacea	S						1	1
	H						+	

Small trees and herbaceous species are omitted in this table. The asterisks indicate main component species found in the tree layer of a natural forest in Tiantong National Forest Park. Cover-abundance is represented as 5 (>75%), 4 (50–75%), 3 (25–50%), 2 (5–25%), 1 (numerous, but <5%), and +(few trees only at most)

US upper part of slope, *MS* middle part of slope, *LS* lower part of slope

eyeri and *L. glabar*, which are the main components of a natural forest, were found in plot 7. The forest area in plot 7 was considered to be relatively well developed compared with other plots, and the crown size of its tall trees was large.

Table 4 shows the basal areas of each tree species in each plot. *P. massoniana* occupied >60% of the total basal area in plot 1, but other pine plots contained evergreen broad-leaved trees. In plot 7, *C. eyeri*, *C. schlorophylla*, and *L. glabar* comprised >60% of the total basal area. The mean basal area of evergreen broad-leaved forest plots was higher than that of pine-forest plots.

Figure 4 shows the rank abundance curves for species found in each of three types of forest. The tall bamboo

Table 3 Stand structure of each plot

Landscape element type	Plot no.	DBH (cm)			Height (m)		
		Mean ± SD	Min	Max	Mean ± SD	Min	Max
Pine forest	Plot 1	1.9 ± 2.4	0.3	14.8	2.6 ± 1.1	1.4	6.4
	Plot 6	3.1 ± 3.5	0.3	17.7	3.7 ± 2.8	1.3	11.7
	Plot 5	3.0 ± 3.3	0.3	16.4	3.9 ± 2.5	1.5	11.8
Evergreen broad-leaved forest	Plot 3	2.9 ± 2.9	0.2	14.9	4.2 ± 3.3	1.3	19.0
	Plot 2	2.3 ± 2.7	0.3	26.0	3.8 ± 2.7	1.3	15.1
	Plot 7	2.4 ± 3.7	0.1	24.8	3.4 ± 2.4	1.5	13.8
Bamboo forest	Plot 4	6.4 ± 4.1	0.2	12.0	9.4 ± 5.4	1.3	16.0

DBH diameter at breast height, *SD* standard deviation, *Min* minimum, *Max* maximum

Table 4 Basal area of each plot

Species	Pine forest						Evergreen broad-leaved forest						Bamboo forest	
	Plot 1		Plot 6		Plot 5		Plot 3		Plot 2		Plot 7		Plot 4	
	cm^2	%	cm^2	%	cm^2	%	cm^2	%	cm^2	%	cm^2	%	cm^2	%
Evergreen coniferous tree species														
Pinus massoniana	**1774.7**	**66.39**	**879.9**	**28.73**	**779.8**	**29.72**	91.6	4.30						
Cunninghamia lanceolata			**718.3**	**23.45**										
	1774.7	66.39	1598.2	52.18	779.8	29.72	91.6	4.30	0.0	0.00	0.0	0.00	0.0	0.00
Deciduous broad-leaved tree species														
Liquidambar formosana							413.9	19.42	62.2	2.63			0.1	0.00
Quercus acutissima									46.5	1.97				
	0.0	0.00	0.0	0.00	0.0	0.00	413.9	19.42	108.7	4.61	0.0	0.00	0.1	0.00
Evergreen broad-leaved tree species														
Castanopsis eyeri											341.5	12.56		
Castanopsis sclerophylla			355.7	11.61	374.5	14.27	**507.5**	**23.81**	30.6	1.30	482.8	17.76		
Cyclobalanopsis glauca			108.7	3.55	**580.4**	**22.12**	**500.5**	**23.48**	416.6	17.65	**910.6**	**33.50**		
Lithocarpus glaber					6.6	0.25	11.2	0.53	203.1	8.60	**612.0**	**22.52**		
Quercus fabri	55.0	2.06	3.5	0.12	14.1	0.54			1.8	0.07				
Schima superba	442.4	16.55	**863.5**	**28.19**	464.5	17.70	231.0	10.84	**1149.2**	**48.69**	171.6	6.31		
Myrica rubra							89.3	4.19	5.3	0.22				
Elaeocarpus japonicus									2.5	0.10				
	497.3	18.61	1331.5	43.47	1440.0	54.88	1339.5	62.84	1809.0	76.64	2518.5	92.65	0.0	0.00
Bamboo														
Phyllostachys heteroclada			5.1	0.17	60.6	2.31							**1865.4**	**99.86**
Others														
	401.1	15.01	128.3	4.19	343.6	13.09	286.6	13.45	442.7	18.76	199.8	7.35	2.6	0.14
Total	2673.2	100.00	3058.0	99.83	2563.4	97.69	2131.5	100.00	2360.4	100.00	2718.3	100.00	2.6	0.14

The bold figures show the values of dominant species more than 20% of total basal area in each plot

(*P. pubescens*) forest curve depicts one dominant species and a few companion species. The slope of the curve for pine forests is steep, indicating that there were only a few dominant species in pine forests. There were many dominant tree species in evergreen broad-leaved forests. The diversity of species in evergreen broad-leaved forests was higher than that in pine forests.

Sprout ratio

For each evergreen broad-leaved tree species, the number of stems per tree is shown in Table 5. The ratio of the total number of stems to the number of trees (sprout ratio) varied among different species. The ratio ranged from 1.0 to 5.0 for *C. sclerophylla*, and from 1.8 to 5.0 for *C.* (*Q.*) *glauca*.

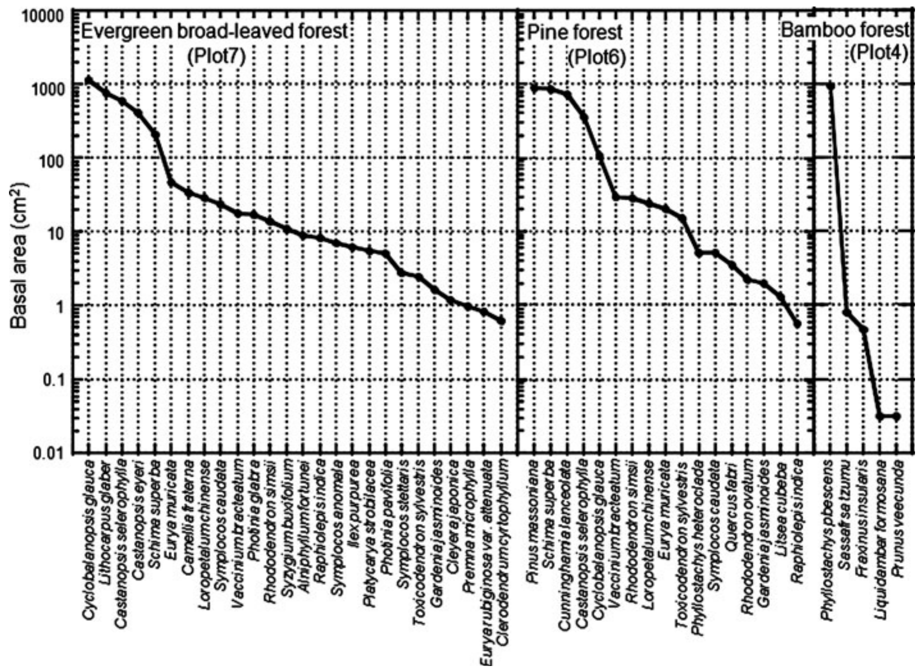


Fig. 4 Rank abundance curves for living trees in each plot

Table 5 Number of stems per tree (sprout ratio) for each species

Species	Pine forest			Evergreen broad-leaved forest		
	Plot 1	Plot 6	Plot 5	Plot 3	Plot 2	Plot 7
Castanopsis eyeri						2.7
Castanopsis sclerophylla		1.4	1.4	5.0	1.2	1.0
Cyclobalanopsis glauca		1.8	2.4	3.0	5.0	2.3
Lithocarpus glaber			1.0	1.2	1.0	2.0
Quercus fabri	1.5	1.0	1.0		1.0	
Schima superba	2.0	1.6	1.2	1.0	1.1	1.0
Myrica rubra				3.0	1.0	
Elaeocarpus japonicus					1.0	

C. eyeri was found only in plot 7, and it had a sprout ratio of 2.7. Conversely, *Q. fabri* was found in many stands, but it had a relatively low sprout ratio, ranging from 1.0 to 1.2. *S. superba* and *Myrica rubra* also had low sprout ratios, ranging from 1.0 to 3.0.

Fuelwood collection

Table 6 shows the characteristics of wood clips collected for fuel in a catchment area (see Fig. 2). Pine trees were cut down only after they had died. Of the broad-leaved trees, *C.* (*Q.*) *glauca* and *Pratycalya storobilacea* were the species that were most favored for fuelwood, and hence, the most number of stems of these species were collected. Both live and dead trees of *P. storobilacea* were distributed along the river in the study site. Among the tree species distributed in the forests, *C.* (*Q.*) *glauca* was the most preferred among all species used as fuelwood.

Table 7 shows data for plot 5 that include number of trees and stems, stems to tree ratio, and volume of live and felled trees collected for fuelwood. There was a strong preference for cutting stems of *C.* (*Q.*) *glauca*. For each species, we calculated the ratio of the total number of stems to the number of trees. The stem to tree ratio for *C.* (*Q.*) *glauca* was higher than that of all other species, indicating that it was most preferred for cutting.

C. (*Q.*) *glauca* stems that had been collected for fuelwood were stored either in the field (Fig. 5a) or in the kitchens of the residents' houses (Fig. 5b).

Discussion

Fu et al. (2005) suggested that more attention should be paid to the relationships between processes occurring on the watershed scale and those occurring on other scales. They also suggested that multiscale studies are required to clarify the total landscape. In our study, both stand- and watershed-level research was conducted. Data at the watershed level identified the various types of landscape features in the study site and their distribution throughout the study site (Fig. 2; Table 1). Relationships among the different types of landscape features were established using stand-level data, such as species composition and stand structure (Tables 2, 3, 4; Fig. 4).

Table 6 Wood collected for fuel in a catchment area

Species name	Size	Length (m)	Diameter (cm)	No. of poles per bundle	No. of bundles	Volume (cm^3)		Relative abundance (%)	
						Per bundle	Total		
Cyclobalanopsis glauca	Large	3.0	4.0	4	1	192.0	192.0		
	Small	1.9	3.0	16	7	273.6	1915.2		
	Subtotal						2107.2	53.2	12.4
Platycarya strobilacea		1.6	3.5	72		1661.3	1661.3	41.9	9.8
Other broad-leaved		1.4	2.0	30		196.0	196.0	4.9	1.2
Broad-leaved total							3964.5	100.0	23.3
Pinus massoniana	Large	3.4	10.0	14		4950.4	9900.8		
	Small	1.9	3.0	50		1021.3	1021.3		
	Subtotal						10922.1		64.3
Total							16993.8		100.0

Table 7 Live and felled (cut and collected) trees in plot 5

Species name	Live trees							Trees collected for fuelwood		Rate of yield $B/(A + B) \times 100$
	Individual		Stem		Stems to tree ratio	D^2H		D^2H		
	No.	%	No.	%		(cm^3) A	%	(cm^3) B	%	
Pinus massoniana	8.5	6.0	8.5	4.2	1.0	12178.0	35.5	0.0	0.0	0.0
Schima superba	7.3	5.2	8.5	4.2	1.2	6723.9	19.6	0.0	0.0	0.0
Cyclobalanopsis glauca	35.4	25.0	84.2	41.3	2.4	5323.3	15.5	776.0	71.8	12.7
Castanopsis sclerophylla	8.5	6.0	12.2	6.0	1.4	5227.6	15.2	305.3	28.2	5.5
Toxicodendron sylvestris	6.1	4.3	6.1	3.0	1.0	3171.5	9.2	0.0	0.0	0.0
Phyllostachys heteroclada	3.7	2.6	3.7	1.8	1.0	709.7	2.1	0.0	0.0	0.0
Albizia kalkora	1.2	0.9	1.2	0.6	1.0	348.9	1.0	0.0	0.0	0.0
Loropetalum chinense	31.7	22.4	34.2	16.8	1.1	293.4	0.9	0.0	0.0	0.0
Dalbergia hupeana	14.6	10.3	14.6	7.2	1.0	95.2	0.3	0.0	0.0	0.0
Alniphyllum fortunei	9.8	6.9	15.9	7.8	1.6	69.9	0.2	0.0	0.0	0.0
Quercus fabri	3.7	2.6	3.7	1.8	1.0	51.7	0.2	0.0	0.0	0.0
Lithocarpus glaber	1.2	0.9	1.2	0.6	1.0	46.2	0.1	0.0	0.0	0.0
Albizia julibrissin	1.2	0.9	1.2	0.6	1.0	23.2	0.1	0.0	0.0	0.0
Litsea cubeba	1.2	0.9	1.2	0.6	1.0	17.1	0.0	0.0	0.0	0.0
Ilex purpurea	1.2	0.9	1.2	0.6	1.0	14.9	0.0	0.0	0.0	0.0
Premna microphylla	3.7	2.6	3.7	1.8	1.0	3.7	0.0	0.0	0.0	0.0
Symplocos caudata	1.2	0.9	1.2	0.6	1.0	0.5	0.0	0.0	0.0	0.0
Gardenia jasminoides	1.2	0.9	1.2	0.6	1.0	0.2	0.0	0.0	0.0	0.0
Total	141.6	100.0	203.9	100.0	1.4	34298.8	100.0	1081.4	100.0	3.1

The volume of trees collected was calculated from the diameter at ground level

Many component species of secondary forests in the study site were common to those of natural forests located 60 km away (i.e., the Tiantong National Forest Park), but the structures of the stands were different. Yang et al. (2005) described the relationship between tree species distribution and topography in the Tiantong National Forest Park. Our study reveals that human influence appears to have disrupted the natural relationships between microlandform units and species distribution. Natural forest species such as *L. glabar* and *C. eyeri* were found on the slopes of a catchment that was remote from the village. Relatively developed evergreen broad-leaved forests were found only in the remote catchment area, which residents of the study site could not readily access. Nevertheless, other locations remote from residential areas were found to have been severely impacted by human activity. Both

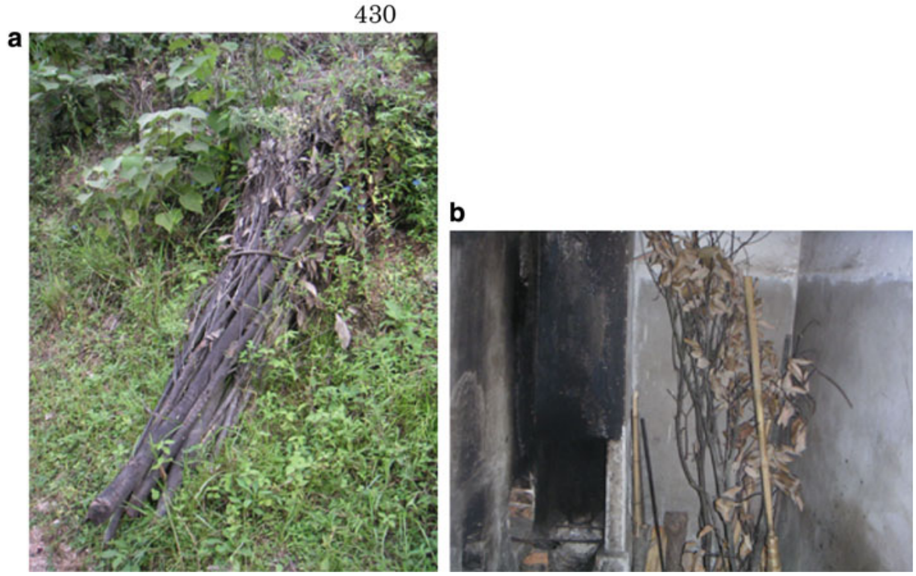


Fig. 5 *Cyclobalanopsis* (*Quercus*) *glauca* stems collected for fuelwood and **a** stored outside and **b** in the residents' kitchens

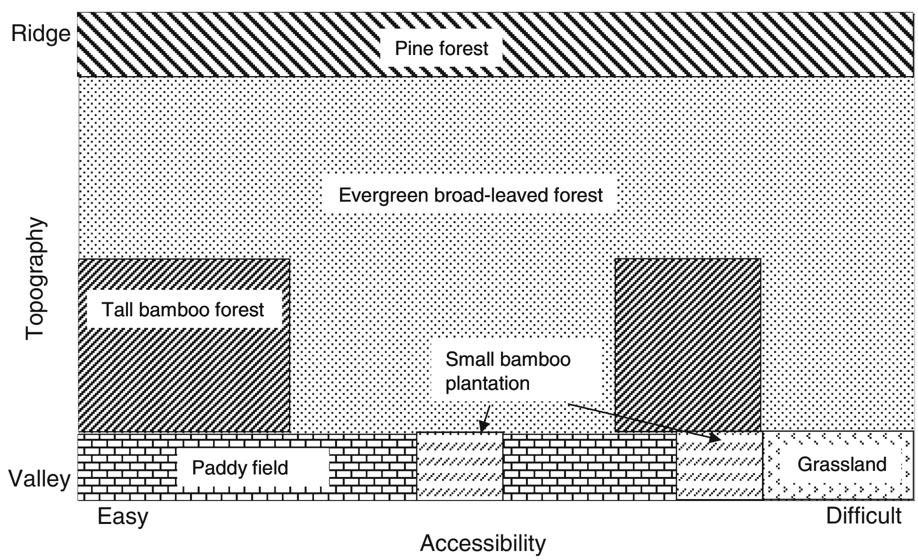


Fig. 6 Types of landscape features according to their topography and accessibility

species composition and forest structure within a particular area were dependent on the extent to which that area was accessible to local residents. Figure 6, which was derived from stand- and watershed-level research, shows a schematic diagram of the landscape structure of the study site in terms of the topography and accessibility.

In Korea, it has been shown that a decrease in reliance upon natural resources leads to changes in land use and thus to changes in landscape mosaics and forest structure (Kim et al. 2006). In our study site, there is a continued impact of human activity on the landscape because the source of energy for most residents comes from natural resources. Thus, the landscape mosaic and forest structure were found to be affected by land use. The extent and structure of forests are dependent upon their accessibility (Kim et al. 2006). Fujihara and Kikuchi (2005) identified downstream urbanization and upstream abandonment as driving forces of the landscape change observed in the Nagara River Basin in central Japan. Fujihara et al. (2005) reported that urbanization influences the boundaries of landscape elements in urban fringes. In the site examined in our study, there were no severe effects of either urbanization or abandonment. There was no evidence of underutilization of land. Most forested areas had degraded from their natural state to secondary forests. The balance between the amount of fuelwood collected and the rate of regrowth appeared to be important.

Wang et al. (2007) examined the importance of resprouting as a key mechanism in secondary succession following forest clearance in eastern China. Bond and

Midgley (2001) emphasized the importance of persistence in plant demography and persistence in a diversity of ecosystems. Tang (2006) reported that trees of the *Quercus* species sprout more vigorously after being cut. Almost all areas in our study site were impacted by human activities, particularly fuelwood collection. The sprouter *C.* (*Q.*) *glauca* responds and remains under disturbances, such as selective and clear cutting of rural forests (Table 5). Using methods similar to that used in our study, Kalindekafe et al. (2000) determined the preferred species and measured the size of fuelwood collected from the miombo forests of a rural area in Malawi; a preference for indigenous species over exogenous species was found. In our study site, the preferred fuelwood distributed in forested areas was also a common indigenous tree, *C.* (*Q.*) *glauca* (Tables 6, 7). Trees of this species seemed to be adapted to frequent cutting, with sprouting an important mechanism of regeneration (Tables 5, 7).

The succession pattern of evergreen broad-leaved forests is similar in southwestern China and southwestern Japan (Tang and Ohsawa 2009), and the succession from evergreen coniferous (*Pinus*) to evergreen broad-leaved (*Castanopsis*) forest was representative of progressive succession (Toyohara 1984). Based on species composition and stand structure, the succession pattern of our study site was considered to be from *Pinus* to *Castanopsis* (personal observation). The change in vegetation appears to be gradual, because many species were common to both pine and evergreen broad-leaved forests (Table 4). For example, *S. superba* was present in all types and stages (early to late) of forest. In the natural forest, the distribution patterns of component species indicate that *C. carlesii* and *S. superba* were adapted to various topographical habitats, whereas *C. fargesii* was adapted to a limited habitat (Yang et al. 2006). *S. superba* seems to adapt to a wide range of habitats across different levels of disturbance and microlandform units.

Ren et al. (2007) reported a significant degree of degradation levels (78% of cropland, 72% of forest, and 90% of grassland) across various terrestrial ecosystems in China. An analysis of deforestation patterns is important for understanding landscape alterations (Jung et al. 2005). The reason for degradation and deforestation are attributed to the over-use of land. However, deforestation does not seem to be severe in our study area, because there were only a few areas of bare ground formed by tree felling. With the intent of restoring and sustainably managing degraded areas, it would be beneficial to provide stakeholders with adequate historical and ecological information (Shoyama 2008). However, only limited historical land-use data exist for our study site. Lou et al. (2008), on the basis of ecological transformation and utilization, pointed out that ecological public welfare forests should be oriented for multiple benefit utilization to maintain sustainable management. In our study, we determined the landscape structure of a region and the extent to which this was influenced by human activity. However, further research on historical changes concerning cultivated and forested lands is warranted.

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