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Abstract. The purpose of this study is to examine the conversions of forests in Northeast China during 1988-2005 by using a 1-km area percentage data model (1-km APDM) with remote sensing data and to find the spatiotemporal characteristics of land conversions between forests and other land uses/covers and internal conversions between forest cover types. Data were derived from Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM) images of bands 3, 5, and 4 acquired in 1988, 1995, 2000, and 2005. Research results show that in the period between 1988 and 2005, the forest area in Northeast China underwent dramatic changes, and 4.11 million ha of forest area was aggregately lost because of the conversions of forests to other land uses/covers; at the same time, the forest area also gained 2.00 million ha because of the conversions from other land uses/covers to forests. The results also demonstrate the forest degradation resulting from the conversions between different forest cover types. This research demonstrates the feasibility and importance of using the 1-km APDM at a finer resolution to trace the spatiotemporal patterns of the forest conversions.

Keywords: deforestation, forest area, land use, land cover, 1-km data set, Northeast China.

1 INTRODUCTION

Estimates of global forest area have traditionally been obtained from country-level, ground-based surveys, in combination with cross-sectional maps and remote sensing monitoring [1]. However, there are large discrepancies in ground-based estimates of land cover information arising from differences in forest definition, processing methodology, outdated sources of information, and confusion between potential and existing vegetation [2], making it difficult to obtain spatially and temporally consistent estimations of the forest conversions at regional level. Fortunately, satellite data offer the prospect for internally consistent estimation for forest area. There are many efforts being undertaken to exploit the characters of forest area based on satellite data [3]. Compared with previous field investigation and inventory-based estimation, integrated estimation using remote sensing and inventory data can exhibit spatially explicit patterns of forest cover and the accompanying temporal changes [4]. However, to date, there are no studies estimating the forest conversions in Northeast China supported by the remote sensing data [5].

Northeast China, with a forest area of 4.99×10^5 km^2 in 2005, occupies approximately 31% of China's total forest area and maintains large areas of forest resources in the country [4,6]. In addition to being one of the most important timber production bases in China, Northeast China is the pilot region for the National Forest Protection Program, Grain for

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Green project, Logging Ban Program, and others [5,7]. Therefore, studying the forest conversions and their spatial and temporal patterns in this region is of significance in managing the forests and understanding the causes and effects of deforestation in China. Because Northeast China has the largest wild forest area and the most important timber reserve in China, it is one of the national key forest zones [7]. However, both the total area and unit stocking volume of natural forest in the Northeast China Forest Zone have declined dramatically because of the forest exploitation and interventions and other human activities. Forest degradation in this zone not only has affected the long-term timber supply but also has resulted in severe ecological disasters, such as soil erosion, catastrophic flooding, and loss of biodiversity [8]. Therefore, it is necessary and imperative to detect the process, pattern, and extent of forest area changes (including the conversions with other land uses/covers as well as the internal transformation between different forest types).

To detect the forest conversion accurately, we used the 1-km area percentage data model (1-km APDM) by indicating proportional forest area within each 1-km grid cell to capture information about the heterogeneity of vegetation at finer scales. By using the 1-km APDM, a grid cell containing trees with small patches of cleared areas, which would likely be categorized as "forest" in a traditional classification, could be detected and represented by an area percentage for cleared land or bare land. By doing this, the 1-km APDM can help the researchers obtain much more accurate results of land use/cover changes. In addition, the 1-km APDM is an efficient data fusion method, given that it bears all the advantages for the raster data model, which can greatly benefit monitoring and assessment for land conversion at regional or even global scales [9]. The 1-km area percentage data generated by the 1-km APDM is organized as an ArcGIS grid.

The primary objective of this study is to examine the conversions of forests in Northeast China from 1988 to 2005 by using the 1-km APDM and to find the spatiotemporal characteristics of land conversions between forests and other land uses/covers and internal conversions between forest cover types. To achieve this goal, we used Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM) data to develop a remote sensing–based, 1-km area percentage data set to trace the forest conversions. The motivations for developing the 1-km APDM based on the original 30-meter Landsat TM/ETM data were as follows: i) to reduce the storage size of the land use/cover database and to expedite the data analysis at 1-km scale without losing any detailed subgrid information; ii) to be comparable with the 1-km land use/cover data sets derived from Advanced Very High Resolution Radiometer (AVHRR), Moderate Resolution Imaging Spectroradiometer (MODIS), and other satellite sensors; and iii) to be ready to be spatially downscaled and used in most of the land surface process models, which are usually run at kilometers rather than tens of meters either because of the computation limitation or because of the coarse spatial resolution of other input variables. We hope that our research can provide information to policymakers about the conversions and some causes of forest area in Northeast China based on remote sensing data using the 1-km APDM so that forest management policy would have a more empirical basis.

2 DATA AND METHODOLOGY

2.1 Study area

Northeast China (38°43′-53°34′N latitude, 115°37′-135°05′E longitude) consists of Heilongjiang Province, Jilin Province, Liaoning Province, and the eastern part of Inner Mongolia Autonomous Region and covers a total area of approximately 1.24×10^6 km^2 (see Fig. 1).

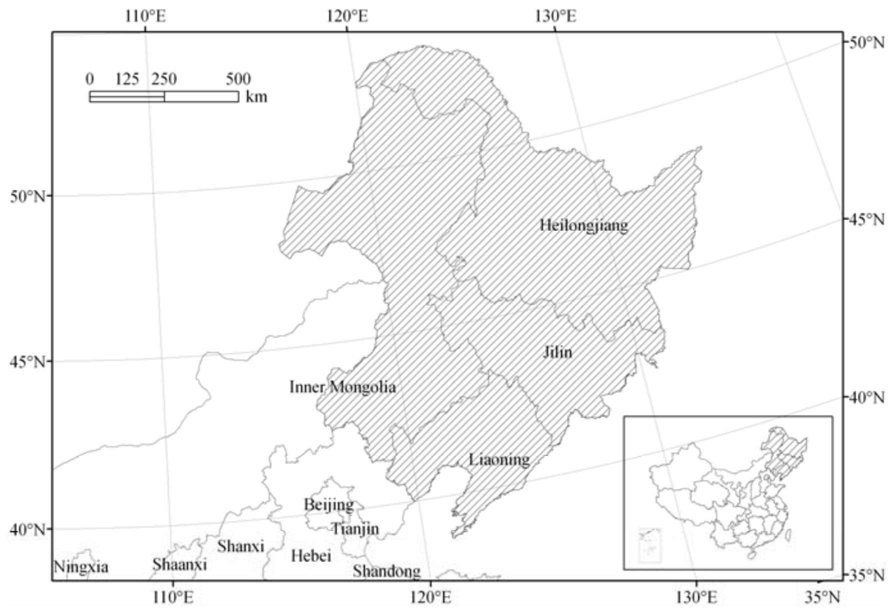


Fig. 1. Location of the study area of Northeast China.

2.2 Data

Remotely sensed Landsat TM/ETM data are widely used for mapping and monitoring the changes in forest area [10]. Time-series data of remotely sensed satellite imagery and ground information are used to form multi-temporal classifications of the presence or absence of forest areas. Our study uses a land cover classification data set developed by the Chinese Academy of Sciences (CAS) [11,12]. The data set is derived from Landsat TM/ETM images of bands 3, 4, and 5 with a spatial resolution of 30m × 30 m. The data set includes time series data for four periods: a) the late 1980s, including Landsat TM/ETM images for 1986-1989 (hereafter referred to as 1988 data); b) the middle 1990s, including Landsat TM/ETM images for 1995/1996 (1995 data); c) the late 1990s, including Landsat TM/ETM images for 1999/2000 (2000 data); and d) the middle 2000s, including Landsat TM/ETM images for 2004/2005 (2005 data). There are two levels of classification in the data set: level I, a classification containing 6 types of land uses/covers; and level II, a classification containing 25 types of land uses/covers [13]. More details on the classification of land uses/covers are included in the following Methodology section.

2.3 Methodology

2.3.1 Definition and interpretation

Interpretation of the forest area data is an analytical process involving the investigation of photographic images, the detection and determination of forest categories, and the quantification of biometric indicators of forest stands. It also includes the determination and delimitation of the borders for both forest categories and major units of inventory and the identification of exact locations of objects. In this study, we identify the forest area polygons for each period, detect the conversion direction and intensity between forests and other land uses/covers, and examine the internal conversions of various forest types. Prior to starting the land cover decoding procedure based on the digital imagery, we developed a hierarchical classification system of six aggregated classes: cropland, forest, grassland, water area, built-up area, and nonvegetated land (see Table 1).

Table 1. Classification system of land uses/covers used in this study.

Land uses/covers	Description
Cropland	Agricultural cropland that includes both paddy and nonirrigated uplands.
Forest	Land covered by trees, shrub, bamboo, and mixed forest.
Grassland	Land covered by herbaceous plants with coverage of more than 5% and mixed rangeland with coverage of shrub canopies less than 10%.
Water area	Land covered by natural bodies of water or land with facilities for irrigation and water reservation, including rivers, canals, lakes, permanent glaciers, beaches and shorelines, and bottomland.
Built-up area	Impervious land for urban and rural settlements, industry, and transportation.
Nonvegetated land	Unvegetated natural land.

Forest area is defined as land with growing trees, shrubs, bamboo, and lands for forest uses. The minimum area considered for classification is 0.25 ha. The forest is further classified as closed forest, shrub, open forest, and other forest. Detailed descriptions of photometric and morphological features for different forest types are shown in Table 2.

Table 2. Spectral and morphological features of the various forest types shown in the Landsat imageries.

Category	Definition	Spectral features
Closed forest	Natural or man-made forest with canopy cover of more than 30%.	Patch or belt pattern; broad-leaf forest with bright red color, conifer forest with dark red color, even and lighter tone; clear boundary with grassland or cropland; ambiguous boundary with shrubs, but distinguished by texture.
Shrub	Land covered by trees less than 2 meters high and with the canopy cover of more than 40%.	Light red color, with dispersed bright red spots for some cases because of the existence of scattered trees; rough texture.
Open forest	Land covered by trees with canopy cover between 10% and 30%.	Light red color, with dispersed bright red spots; with uneven and dark tone.
Other forest	Land covered by tea garden, orchid, and/or non-grownup forest.	Orchard with bright red color, scattering in the cropland or around the residence land. Regenerated land of other forests with cyan or gray color, mixed with shrubs or open forests.

Given that we use the remote-sensing approach to identify the forest area, those clear-cut, regenerating, and partly cut areas with forest canopy covering less than 10% might be visually identified as other kinds of land cover types rather than forest area, which is determined and constrained by the definition of forest area (see Table 1), the classification of which will definitely lead to some aggregation errors or bias. Therefore, we use a location-based validation strategy to test the data accuracy of decoded land use/cover information from remote-sensing digital images. That is to wrap up the decoded land use/cover information at the last step, and we use a stratified sampling scheme to validate the data accuracy of interpretation results. For example, among the interpreted 1-km area percentage data of 1988, a number of decoded land use/cover patches were selected; then by comparing the land use/cover information of these selected patches with that of landscape photos taken in the period between 1986 and 1989 and archived in the library of the CAS, we can evaluate the interpretation accuracy. As for the interpretation of data for years 1995 and 2000, as well as year 2005, we use the same strategy and sampling scheme to identify the interpretation accuracy.

2.3.2 One-kilometer area percentage data

We develop an approach, 1-km APDM, to generate 1-km area percentage data to trace the forest conversions in Northeast China. The generation of 1-km area percentage data set on land uses/covers is based on map-algebra concept, a data manipulation language designed specifically for geographic cell-based systems.

The prototype of the 1-km APDM was developed by the Chinese Academy of Sciences [11]. The procedure to generate the 1-km area percentage data set for examining forest conversions includes four steps. The first is to generate a vector map of land use/cover changes during the study period at a scale of 1:100,000 based on the remotely sensed Landsat TM/ETM data. This is done by an operator-computer interactive interpretation using ArcGIS software. The second step is to generate a 1-km FISHNET vector map geo-referenced to a boundary map of the study area at a scale of 1:100,000. Each cell of the generated 1-km FISHNET vector map owns a unique ID. The third step is to overlay the vector map of land use/cover changes with the 1-km FISHNET vector map. This is done by aggregating converted areas in each 1-km grid identified by cell IDs of the 1-km FISHNET vector map in the TABLE module of ArcGIS software. Finally, the area percentage vector data are transformed into grid raster data to identify the conversion direction and intensity [14,15]. The flowchart of 1-km APDM of generating 1-km area percentage date set for examining forest conversions is illustrated in Fig. 2.

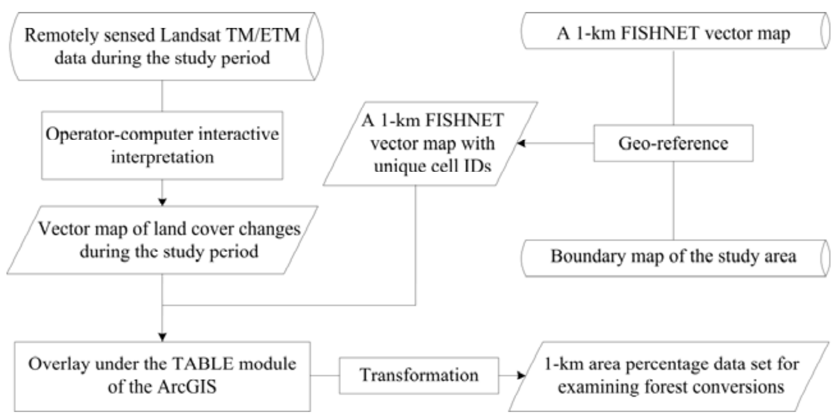


Fig. 2. Flowchart of generating 1-km area percentage data set for examining forest conversions.

The decoded information from Landsat TM/ETM data consists of 25 types of land uses/covers. Under the scheme of the 1-km APDM, each of the 25 types of land uses/covers is given an area percentage of that kind of land use/cover in a grid cell. By summing up the area of the four types, we can get the total area percentage of the forest area within each grid cell.

In a similar way, when we aggregate the area of all the 25 types of land uses/covers, we can get a total of 100 hectares, or 100%, of the total land area for each grid cell.

3 RESULTS

A summary table was generated to show the interpretation accuracy rates of land use/cover types for the four years (see Table 3). The accuracy rates for forest interpretation were further broken down into four kinds of forests: closed forest, shrub, open forest, and other forest, for which the number of patches sampled and the number of patches with interpretation errors were illustrated in Table 3 (e.g., the amounts of interpretation errors of the closed forest, shrub, open forest, and other forest in 2005 were 44, 66, 8, and 28, respectively).[i] The percentage interpretation error of each land cover types in each year, which is less than 10.66%, illustrates that the interpretation accuracy of land use/cover types is acceptable.

Table 3. Summary of the numbers of patches sampled and patches with interpretation errors in accuracy validation for interpretation of land uses/covers in Northeast China.

Year	Items	All land use/cover types	Forest area	Closed forest	Shrub	Open forest	Other forest
1988	Number of patches sampled	2,819	1,073	534	197	223	119
	Number of patches with interpretation errors	200	84	47	21	9	7
	Percentage interpretation error (%)	7.09	7.83	8.80	10.66	4.04	5.88
1995	Number of patches sampled	4,715	2,472	986	709	209	568
	Number of patches with interpretation errors	75	105	38	54	3	10
	Percentage interpretation error (%)	1.59	4.25	3.85	7.62	1.44	1.76
2000	Number of patches sampled	5,461	2,802	1,038	865	275	624
	Number of patches with interpretation errors	139	122	37	57	5	23
	Percentage interpretation error (%)	2.55	4.35	3.56	6.59	1.82	3.69
2005	Number of patches sampled	5,601	3,392	1,224	998	402	768
	Number of patches with interpretation errors	158	146	44	66	8	28
	Percentage interpretation error (%)	2.82	4.30	3.59	6.61	1.99	3.65

The 1-km APDM is capable of presenting the proportion of land uses/covers at the spatial resolution of 1km × 1 km, and the conversions between forests and other land uses/covers and the internal conversions between forest cover types could be perfectly traced. The methodology of 1-km APDM provides a strategy for data aggregation and conversional pattern representation of forest and other land use/cover types over space, whereas the changes of the area in each 1km × 1 km grid pixel can identify the process of the land conversion between forest and other land use/cover types [15].

The aggregated forest area using the 1-km APDM shows that there were 52.00 million ha of forests in Northeast China in 1988. By the end of 1995, 2000, and 2005, the forest areas declined to 51.45 million, 50.60 million, and 49.89 million ha, respectively (see Table 4). Total forest area decreased by 2.11 million ha between 1988 and 2005, accounting for 4.06% of the total forest area of Northeast China in 1988.

Table 4. Forest area of Northeast China in 1988, 1995, 2000, and 2005 (in million ha).

Year	Closed forest	Shrub	Open forest	Other forest	Total forest area
1988	42.22	4.28	4.23	1.26	52.00
1995	41.97	4.73	4.22	0.53	51.45
2000	41.25	4.66	4.13	0.56	50.60
2005	40.73	4.62	4.02	0.52	49.89

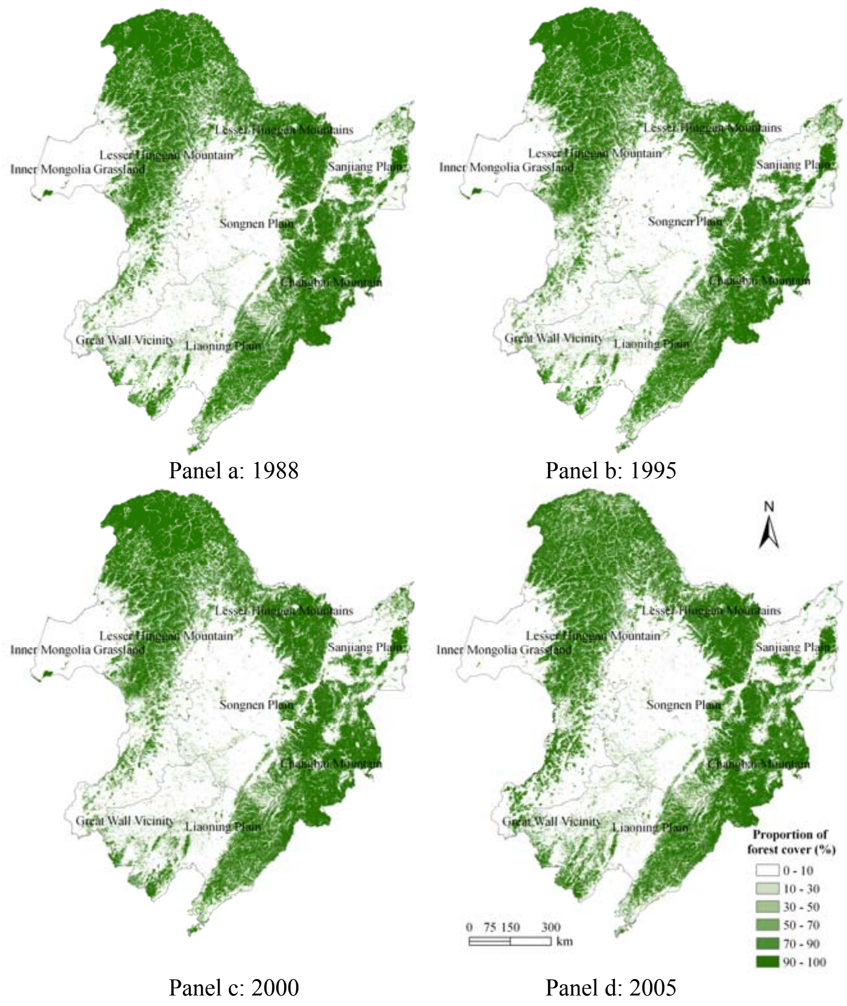


Fig. 3. Spatial patterns of forest cover identified by the 1-km area percentage data set in Northeast China.

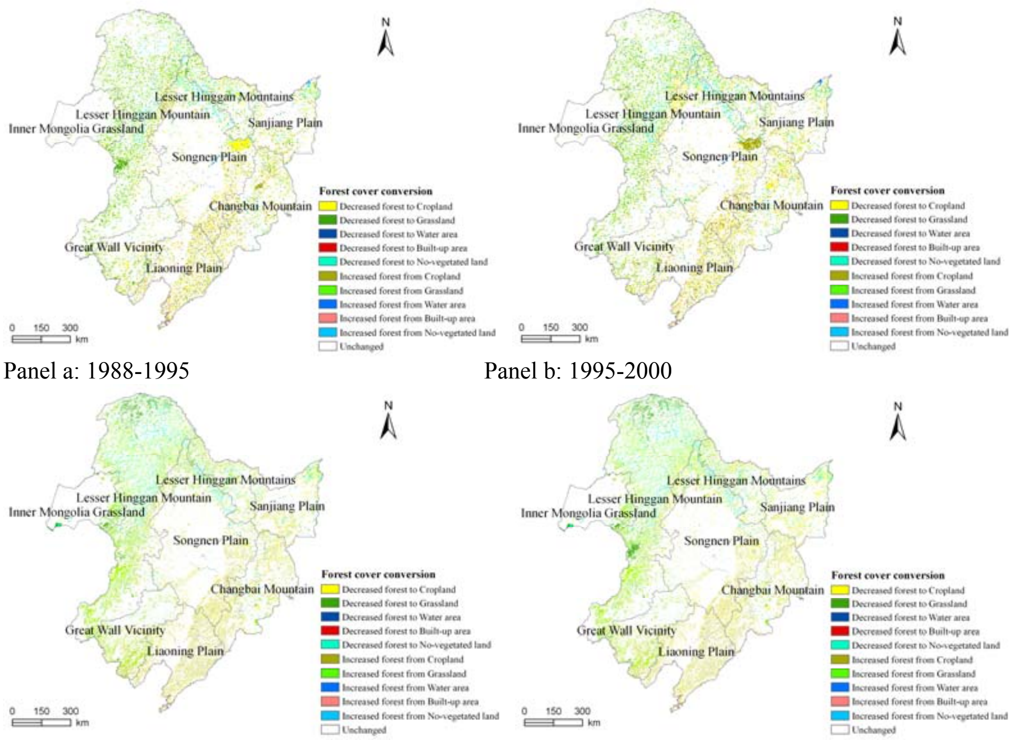
As shown in Table 4, there existed a consistent composition structure of closed forests, shrubs, open forests, and other forests for the years 1988, 1995, 2000, and 2005. The closed forests dominated the forest in Northeast China over time, whereas shrubs, open forests, and other forests accounted for a relatively small share. Even in 2005 when the area of closed forests reduced to its lowest level in history, its share among all kinds of forest types was still as high as 81.64%. That is why this forest zone is the most important timber production area, as well as the most valuable forest ecosystem in China. Thus, we could say that the critical problems for forest degradation in Northeast China are mainly related to closed forests. It can be found from the forest maps in four individual years that the spatial patterns of closed forests reflect the overall distribution characteristics of the forest covers (Fig. 3). Specifically, the distribution of the forest areas, especially the closed forests, is concentrated in the Greater and Lesser Hinggan Mountains and Changbai Mountain zones. There are less forest areas in the Songnen Plain, the north of Sanjiang Plain, the middle of Liaoning Plain, the north of Great Wall Vicinity, and the north of Inner Mongolia Grassland zones. Fig. 3 also indicates that the overall patterns of the forest areas have not varied much during the period 1995-2000.

By using the 1-km area percentage data spatially, we can explicitly identify land conversions among various land use/cover types of the case study area of Northeast China. Following the methods in building cross-tabulation matrix to identify the conversions of land uses/covers at a time interval developed by Pontius et al. (2004) and Pontius and Cheuk (2006), we build a conversion table, Table 5, to illustrate the forest conversions during the period 1988-2005 dominated by conversions between forests and croplands and conversions between forests and grasslands [16,17]. The study found that 1.44 million ha, or 78.11% (=1443.15 / 1847.56 × 100%) of the total loss of forest areas, were converted to croplands during the period 1988-1995. This proportion declined to 65.34% (=764.40 / 1169.92 × 100%) during the period 1995-2000 and 62.13% (=676.34 / 1088.60 × 100%) during the period 2000-2005. As for the whole study period (1988-2005), the croplands expansion mainly occurred in the upper reaches of the Nenjiang River, the eastern fringe of the North China Plain, and the northern end of the Liaohe Plain, where the population expanded dramatically during the past two decades (Fig. 4 Panel d). Conversions from forests to croplands indicated an encroachment of subsistence farming under the pressures of rural population growth.

Table 5. Conversions between forests and other land uses/covers in Northeast China (in thousand ha).

	Items	Cropland	Grassland	Water area	Built-up area	Nonvegetated land	Total
1988 to 1995	Forest area converted from:	1008.97	264.68	6.70	0.05	17.24	1297.64
	Forest area converted to:	1443.15	382.68	5.02	3.53	13.18	1847.56
	Net changes of forest area	-434.18	-118.00	1.68	-3.48	4.06	-549.92
1995 to 2000	Forest area converted from:	107.74	185.65	10.11	0.06	16.33	319.89
	Forest area converted to:	764.40	374.14	8.53	6.07	16.78	1169.92
	Net changes of forest area	-656.66	-188.49	1.58	-6.01	-0.45	-850.03
2000 to 2005	Forest area converted from:	198.05	159.46	9.41	0.05	11.73	378.70
	Forest area converted to:	676.34	386.34	8.22	7.38	10.32	1088.60
	Net changes of forest area	-478.29	-226.88	1.19	-7.33	1.41	-709.90

In the period between 1988 and 1995, 382.68 thousand ha of forests were converted into grasslands, accounting for 20.71% (=382.68 / 1847.56 × 100%) of the total loss of forest areas. While 374.14 thousand ha and 386.34 thousand ha of forest area had converted to grassland during the period of 1995-2000 and 2000-2005, respectively, which are a small conversion area compared with those occurred in the period between 1988 and 1995 when the percentage of the conversion area of the total forest area lost had experienced a remarkable increase (Table 5). This type of conversion mainly occurred in the western fringe of the Lesser Hinggan Mountains and most areas of the Songnen Plains when considering the whole study period (Fig. 4 Panel d). The accumulated area of forests converted to other land uses/covers, including water area, built-up area, and nonvegetated land, was up to 79.03 thousand ha, accounting for only 1.92% of the total loss area of the forest. At the same time, 16.82 thousand ha of forests declined because of the expansions of built-up area during 1988-2005 (Table 5).



Panel a: 1988-1995
Panel b: 1995-2000
Panel c: 2000-2005
Panel d: 1988-2005

Fig. 4. Spatial patterns of the conversions between forests and other land uses/covers in Northeast China.

All in all, the lost forest areas were mainly distributed in the northwest of the Northeast China, the place of the Greater Hinggan Mountain regions between 1988 and 2005, which mainly resulted from the expansion of agricultural practices (Fig. 4). Another crucial reason is that the employees of state-owned forest enterprises paid less attention to forest regeneration, and lower short-term profits from the forests and food-demand pressure forced them to reclaim the cleared forest area as croplands [18].

Nevertheless, other land uses/covers also were converted to forests. The conversions from croplands to forests, identified as the afforestation in Northeast China Plain, amounted to 1088.97 thousand ha, 77.75% of the newly expanded forest areas in the period of 1988-1995.

However, the forest area converted from croplands declined sharply in the succeeding two periods of 1995-2000 (107.74 thousand ha) and 2000-2005 (198.05 thousand ha). There also was considerable forest area converted from grasslands, accounting for 20.40%, 58.04%, and 42.11% of the total reforest area in the period of 1998-1995, 1995-2000, and 2000-2005, respectively. Take the southern Inner Mongolia Grassland as an example, there were huge areas converted from cropland to forest area during the period of 2000-2005 (Fig. 4 Panel c), mainly because of the implementation of reforestation projects in these fragile eco-regions [19]. Net gains of forest areas through conversions from water areas and nonvegetated lands were only 9.47 thousand ha all together (see Table 5). Overall, the analysis results show a considerable change in the forest area—a net decrease of nearly 2.11 million ha in the period between 1988 and 2005.

Further on the internal transformation of the forest, we see that a total of 450.64 thousand ha, 430.03 thousand ha, and 370.35 thousand ha of closed forests were converted to shrubs, open forests, and other forests, in the period of 1988-1995, 1995-2000, and 2000-2005, respectively, which characterizes the degradation of forests in Northeast China (see Table 6). As for the period of 1988-1995, 33.74% or 152.03 thousand ha of lost closed forests were converted into shrubs, 87.34 thousand ha or 19.38% of lost closed forests to open forests, and 211.27 thousand ha or 46.88% of lost closed forests to other forests. In the period between 1995 and 2000, the proportion of closed forests converted to shrubs raised to 44.65% (=192.01 / 430.03 × 100%), and the proportion of closed forests converted to open forests and other forests declined to 17.04% (=73.29 / 430.03 × 100%) and 38.31% (=164.73 / 430.03 × 100%), respectively. In the period of 2000-2005, 164.59 thousand ha of the closed forests were converted to shrubs, 85.97 million ha to open forests and 119.79 million ha to other forests.

Table 6. Internal conversions among forest covers in Northeast China (in thousand ha).

			To				
			Closed forest	Shrub	Open forest	Other forest	Total
From	1988 to 1995	Closed forest	—	152.03	87.34	211.27	450.64
		Shrub	92.51	—	0.33	1.27	94.11
		Open forest	124.28	0.32	—	27.98	152.58
		Other forest	93.28	164.85	65.76	—	323.89
		Total	310.07	317.2	153.43	240.52	
	1995 to 2000	Closed forest	—	192.01	73.29	164.73	430.03
		Shrub	52.46	—	0.12	1.12	53.7
		Open forest	80.19	0.52	—	14.6	95.31
		Other forest	176.47	17.26	121.67	—	315.4
		Total	309.12	209.79	195.08	180.45	
	2000 to 2005	Closed forest	—	164.59	85.97	119.79	370.35
		Shrub	41.12	—	0.45	1.72	43.29
		Open forest	194.33	0.06	—	9.93	204.32
		Other forest	286.28	11.22	122.56	—	420.06
		Total	521.73	175.87	208.98	131.44	

Meanwhile, we also can see the conversions from shrubs, open forests, and other forests to closed forests. All together, closed forest areas had increased by 1140.92 thousand ha because of the internal conversions of forest cover types in the three periods of 1988-1995, 1995-2000, and 2000-2005. Almost half of these areas came from the conversions of other forests to closed forests, with an area of 556.03 (93.28 + 176.47 + 286.28) thousand ha of the total gains in closed forest areas (Table 6). This mainly occurred in the afforestation areas of

Northeast China promoted by the Three-North Shelterbelt Development Program. Nevertheless, these gains in closed forest areas did not offset the loss areas, so we still see a net decrease of closed forests, with an area of 110.1 (450.64 + 430.03 + 370.35 - 310.07 - 309.12 - 521.73) thousand ha between 1988 and 2005 (Table 6).

4 DISCUSSION AND CONCLUSION

This study traced the forest conversions in Northeast China during 1988-2005 at a finer spatial resolution by using a 1-km APDM. We found that the study area experienced some significant forest conversions. For the conversions among various land uses/covers of Northeast China, there was a persistent forest loss during the three periods of 1988-1995, 1995-2000, and 2000-2005. The net conversions from forests to croplands and grasslands characterized the degradation of forests in Northeast China. All together, forest area in Northeast China decreased by 2.11 million ha during the whole study period. This still leave forest degradation because of internal transformations of forest cover types out of consideration, which led to a net decrease of closed forests with an area of 110.1 thousand ha during 1988-2005. There also were some conversions that profited reforestation in the Northeast China during 1988-2005, such as conversions from croplands and grasslands to forests as well as open forests and other forests to closed forests.

Northeast China experienced a persistent deforestation between 1988 and 2000. Our detection of specific forest conversions may help to examine the causes of deforestation and make well-targeted policies. It also is evident that the 1-km area percentage data set generated in this study is a useful tool for generating spatially explicit, internally consistent maps independent of varying definitions of "forest." Such maps are a key requirement to be used in conjunction with other data sets within land conversion models for a baseline or any subsequent year [20,21].

Although we are satisfied with the accuracy of tracing the forest conversion using the 1-km APDM based on the Landsat TM/ETM data, it still could be improved by using other data sources with a relative higher spatial resolution. Satellite images scanned by the enhanced and improved airborne scanners and with higher spatial resolution [9], such as SPOT panchromatic 10-meter images, enable accurate determination of forest extent, particularly in areas of fragmented forest using the 1-km area percentage data set. .Under the framework of the 1-km APDM, if we use the higher spatial resolution imagery data set (e.g., using SPOT panchromatic 10-meter images rather than Landsat ETM 30-meter images) or get a small-scale land use/cover map by a geo-spatial ground inventory, we can generate a set of 1-km area percentage data sets with the scale of one by one square kilometer but reveal more detailed information on land conversions within each 1km × 1 km grid.

Acknowledgments

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[i] Patch is defined as a relatively homogeneous area that differs from its surroundings. Patches are the basic unit of the land use/cover changes. Patches have a definite shape and spatial configuration and can be described compositionally by internal variables, such as number of trees, coverage of trees, height of trees, or other similar measurements.