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Research Article

Forest Health Assessment in the Jingouling Forest Farm of Changbai Mountain Based on GIS and RS

Ning Yangcui and Zheng Xiaoxian
Beijing Forestry University, Beijing 100083, P.R. China

Abstract: Forest health is defined as the ability of forest to maintain ecosystem vitality and stability and the ability to provide the necessary ecological and forest product. In the study, the forest health status, which is the Jingouling Forest Farm of Changbai Mountain Poplar-Birch secondary forest, was assessed based on GIS and RS techniques. The forest health assessment index was filtered by the method of expert consultation. The forest health assessment index weight and value range were calculated by Analytic Hierarchy Process (AHP). The health status was divided into five grades: Disease, not health, sub-health, healthy and high quality. The results showed that there was 20 not health plots, 738 sub-healthy plots, 154 healthy plots and there was no disease and high quality plots. The conclusion was that most plots of Jingouling forest farm were in sub-healthy status. To improve the health situation, dominant factors should be determined to guide the further management of the stands.

Keywords: Assessment system, forest health, poplar-birch, secondary forest

INTRODUCTION

The conception of forest health was generated for plantation forest problems: the diseases, insect pests, fire, recession and so on (Callieott and Haskell, 1992; Chen *et al*., 2002). In 1930, the United States in view of the plantation forest threat by long-term drought, diseases and insect pests, the FIA (Forest Inventory and Analysis) project was established. The FIA project mainly committed to collecting, sorting and analyzing the data of forest health and tendency, at the same time release the forest health on a regular basis. In the late 1970s, Germany and other European countries appeared a serious problems of forest health, including the soil acidification, the leaves change color in the plantation, the forest massive death, the forest fire and the threat of diseases and insect pests, etc., which all caused by acid rain of pollution (Lorenz and Mues, 2007). Germany and other European countries in view of the serious problem of forest first proposed the concept of forest health and carried out the monitoring work. In the early 1990s, the United State improved the forest disease and insect pests' prevention into the forest health (Oszlányi, 1997). In 1992 the United State published a law which about the forest ecosystem health and recovery that the understanding of forest health tend to be uniform (McLaughlin and Percy, 1999).

The forest health was defined as the forest doesn't have plant diseases, insect pests and the threat of fire. With the development of the research, the concept of forest health has been extended to the generalized forest health, which is defined as the ability of forest to maintain ecosystem vitality and stability and the ability to provide the necessary ecological and forest product.

Forest health assessment was defined as the researchers according to the relationship between the forest ecosystem structure index and the forest ecosystem function index, construct the assessment model (Larsen, 1995; Frohlich and Quednau, 1995; Meyer, 1952). Then through the model analysis and calculate the level of forest health in order to make a quantitative, reasonable forest management plans. At present, there are many experts focus on forest health assessment (Ferretti, 1997; Ma *et al*., 2007). According the different area, different assessment purpose and the different forest management type, the experts has constructed different forest health assessment index system and forest health management measure (Lankford, 1994; Suter, 1993). The forest health assessment index can be divided to 5 aspects: forest ecosystem vitality, forest ecosystem structure, forest ecosystem recovery and resistance, forest ecosystem performance, forest ecosystem management measure and forest stand environment (Christine and Nicholas, 2004; John *et al*., 2005).

According to the development of digital technology, the 3S technology was successfully applied to the monitoring and evaluating regional development system (Jeremy, 2002). GIS and RS provide effective technical methods for land use change research (Laurent, 1999; Laurent *et al*., 1999; Diane *et al*.,

Corresponding Author: Ning Yangcui, Beijing Forestry University, Beijing 100083, P.R. China, Tel.: 0086-10-62337744; Fax: 0086-10-62337744

2010a) and forest resource management (Diane *et al*., 2010b; Xiao *et al*., 2003). In recent year they have been used successfully to classify forest health (Jones *et al*., 1997; Zheng and Zhou, 2000; Li *et al*., 2005; Wang, 2010).

However, the forest health assessment index systems have focus on forest ecosystem structure. The forest health assessment index systems focus on both forest ecosystem and product function was an unresolved problem.

In this study, we attempt to construct a forest health assessment index system which taken the Jingouling Forest Farm of Changbai Mountain Poplar-Birch secondary forest as an example was constructed based on GIS and RS techniques (Latham *et al*., 1998; Mageau *et al*., 1998). The study will provide an applicable approach to monitoring and evaluating the state of health of the dynamic forest ecosystem and provide a theoretical foundation for the making of plans for the sustainable management of the forest.

MATERIALS AND METHODS

This section describes the study area and the methods of field assessment.

Overview of the studied area: The studied area was located at the Jingouling forest farm (43°22′N, 130°10′E) at the Xueling branch range of Laoye Ling Mountain in the Changbai Mountains, China. This research takes Spruce-fir natural forest as an example, other main tree species are *Pinus koraiensis*, *Betula costata*, *Tilia amurensis*, *Ulmus pumila*, *Acer mono* and so on; the main shrub species are *Acer tegmentosum*, *Acer ukurunduense*, *Lonicera japonica*, *Spiraea salicifolia*, *Corylus heterophylla* and so on, herb species main are *Brachybotrys pariformis*, *Paris verticillastrate* and so on and the Spruce-fir forest mainly located at an altitude of 800-1000 m. The study area is in Jingouling forest with a monsoon climate, which is a part of the Changbai Mountain (Zhang *et al*., 2011), located in Wangqing County, Jilin Province. This area is a hilly landscape area, the height rise from 550 to 1100 m, the Sunny slope is steep and the shady slope is gentle, the slope gradient rise from 10 to 25°, the lowest average temperature in January is minus 32°, in July the average maximum temperature is 32° and the annual average temperature is 4°. The early frost start at mid-September and the late frost ended in May of next year. The annual precipitation is from 600 to 700 mm which mostly concentrated in July; growing season is nearly 120 day.

Data: The data sources were as follows:

- Multi-spectral data of Land sat 5 TM data in September 2007
- 1: 10000 the stock map, road map and forest resource inventory resources in 2007
- 1: 50000 topographic maps in the study area
- Field survey data of land category control point and plots of major forest types

Construction of index system:

Forest health level model: Costanza selected vigor, organization and resilience as the indicators to assess forest ecosystem health (Xiao *et al*., 2003; Costanza and Daly, 1992):

$$HI = w_1V + w_2O + w_3R \tag{1}$$

While HI is ecosystem health level, range is (0-1), V, O and R are vigor, organization and resilience of ecosystem, w_1,w_2 and w_3 are the weights of V, O and R, respectively, $w_1+w_2+w_3 = 1$.

In this study, the forest health level model was improved; addition the vigor, organization and resilience of ecosystem index, there are forest management measure, stand environment and efficiency of ecosystem index:

$$HI_M = \frac{1}{6}(V + O + R + E + S + M) \tag{2}$$

While HI_M is ecosystem health level, range is (0-1), V, O, R, E, S and M are vigor, organization, resilience forest efficiency, management measure, stand environment of ecosystem.

Index dimensionless: In the study, all indexes were dimensionless by dimensionless method. The calculate formula was shown in formula 2:

$$X_i = \frac{H_i - H_{min}}{H_{max} - H_{min}} \tag{3}$$

X_i = The indicator dimensionless value
H_i = The indicator value
H_{max} = The maximum value of the indicator
H_{min} = The minimum value of the indicator

The criterion indicators of V, O, R, E, S and M were all composed of several sub-indicators. Mixing degree was calculated in Equation:

$$C_i = \sum_{r=1}^{n}(b_1x_1 + b_2x_2 + \cdots + b_nx_n) \tag{4}$$

$$b_1 + b_2 + \cdots + b_n = 1$$

While C_i is criterion indicators, x_i is the sub-indicators dimensionless value which range from 0 to 1. The b_i is the weight of sub-indicators which range from 0 to 1.

In the study, the HI_M was divided into 5 grades by equidistant division method. The forest health index grade was shown in Table 1.

Table 1: The forest health index grade standards

	Disease	Not-health	Sub-health	Healthy	High quality
Health grade	I	II	III	IV	V
HI_M	$0<HI_M\leq0.2$	$0.2<HI_M\leq0.4$	$0.4<HI_M\leq0.6$	$0.6<HI_M\leq0.8$	$0.8<HI_M\leq1$

HI_M: Ecosystem health level, range is from 0 to 1

Table 2: The health assessment index system of Jingouling

Total index	Criterion	Indicator	Sub-indicator	Weight
Basic indicator	Vigor	Biomass	Timber number	0.0570
			Average DBH	0.0570
			Average height	0.0570
	Organization	Structure	Crown density	0.0280
			Shrub density	0.0140
			Grass density	0.0073
		Space structure	Vertical structure	0.0230
			Horizontal structure	0.0260
		Biodiversity	Tree species	0.1100
	Resilience	Disturbance	Naturalness	0.1700
Management indicator	Efficiency	Economic value	Volume	0.0160
			Large wood grade	0.0160
			Coniferous proportion	0.0160
		Eco-efficiency	Water conservation	0.0160
	Stand environment	Soil	Soil type	0.1000
			Soil thickness	0.0460
	Management measure	Harvest	Harvest type	0.0710
			Harvest proportion	0.0710
		Thinning	Thinning proportion	0.0960

The index system was composed by 4 index levels: Total index, criterion, indicator, sub-indicator; The sum weight value of every level equal to 1

Table 3: Classification of non-continuous variables

Indicator	Character	Value	Indicator	Character	Value
Grass distribution	Un-uniform	0.0	Large timber grade	0	0.00
	Uniform	1.0		1	0.33
Thinning	Non-thinning	0.0		2	0.67
				3	1.00
	Thinning	1.0	Naturalness	1	0.00
Soil thickness	Thin	0.0		2	0.25
	Middle	0.5		3	0.50
	Thick	1.0		4	0.75
Soil type	Dark brown	1.0		5	1.00
	Meadow soil	0.5	Space structure	Non-shrub	0.00
	Marsh soil	0.0		Shrub-grass	1.00

Forest health assessment index system: The popular-birch secondary forest in jingouling forest farm management mainly type was timber forest. So in this study, the forest health assessment management objective is timber forest. The forest health assessment index was filtered by the method of expert consultation based on the forest resource of inventory in 2007. The forest health assessment index weight and threshold was calculated by Analytic Hierarchy Process (AHP). The health assessment index system and index weight value were shown in Table 2.

The index value or value range: The forest health assessment index weight and value range were calculated by Analytic Hierarchy Process (AHP). The health status of 912 plots polar birch secondary stands in the farm was divided into five grades: Disease, not health, sub-health, healthy and high quality. The results showed that there was 20 not health plots, 738 sub-healthy plots, 154 healthy plots and there was no disease and high quality plots. The conclusion was that most plots of Jingouling forest farm were in sub-healthy status.

Table 4: Classification of continuous variables

	Factor score		
Indicator	1	2	3
Average DBH (cm)	≤14	14<N≤20	>20
Timber number (n/ha)	≤600; >1300	600<N≤800	800<N≤1100
Average height (m)	≤12	12<H≤16	>16
Average crown density	≤0.6; >0.9	0.8<Y≤0.9	0.7<Y≤0.8
Average shrub density (%)	≤5	5<G≤10	>10
Average grass density (%)	≤25	25<CG≤40	>40
Tree species	≤5	5<SN≤6	>6
Average volume (m^3/ha)	≤130	130<V≤180	>180

Table 5: The proportion of different health grade

Health grade		Plot number	Area (ha)	Area proportion (%)
Not-healthy	II	20	99.2	3.0
Sub-healthy	III	738	10516.5	231.4
Healthy	IV	154	2449.4	65.6

The index can be dividend into 2 classes: non-continuous variables and continuous variable. The non-continuous variables value range was according to the

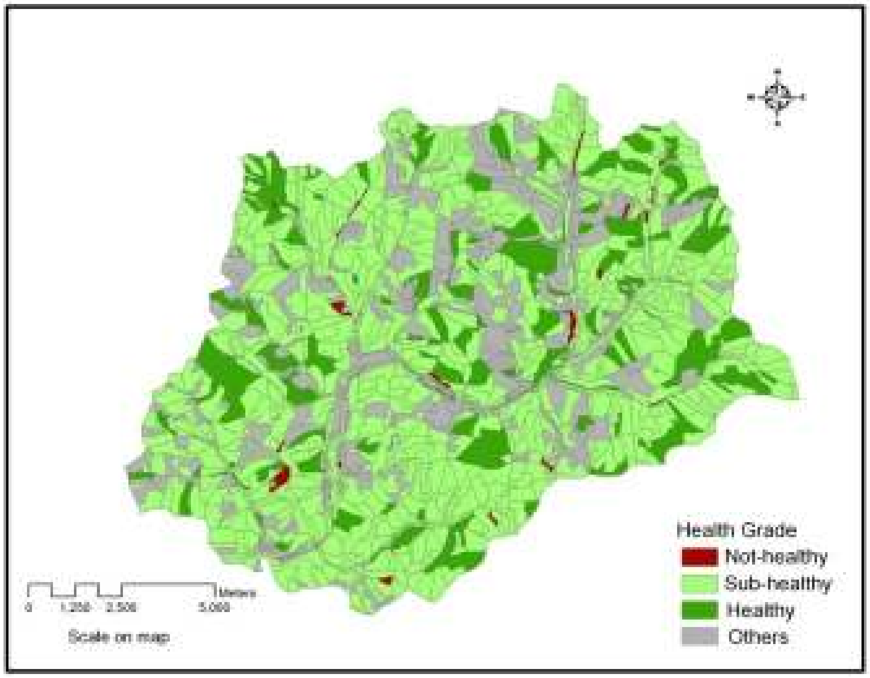

Fig. 1: The health grade distribution of polar-birch secondary forest

forest resource standard, the variables value were shown in Table 3.

The continuous variable was calculated by cluster analysis. The continuous variable value range was shown in Table 4.

RESULTS

The health status of 912 plots polar birch secondary stands in the farm was divided into five grades: Disease, not health, sub-health, healthy and high quality. The results showed that there was 20 not health plots, 738 sub-healthy plots, 154 healthy plots and there was no disease and high quality plots which was shown in Table 5. The secondary stands plots forest health assessment result, which based on the succession stage, distribution map was shown in Fig. 1.

CONCLUSION

In the study, a forest health assessment index system which taken polar-birch secondary forest as an example was constructing based on GIS techniques. The forest health assessment index system was constructed in order to assessment forest health status so as to improve the health situation by further management. The health status of 912 plots polar birch secondary stands in the farm was divided into five grades: Disease, not health, sub-health, healthy and high quality. The results showed that there was 20 not health plots, 738 sub-healthy plots, 154 healthy plots and there was no disease and high quality plots. The conclusion was that most plots of Jingouling forest farm were in sub-healthy status. To improve the health situation, dominant factors should be determined to guide the further management of the stands.

The forest health assessment index system was available for secondary forest which can be applied to assessment the forest health status. Since the plots data were collected from the polar birch secondary forest, the assessment index system should not be used with caution for general applications. Future studies on forest health assessment index system should develop to different forest type so as to assessment forest health status more accuracy.

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