Application of Goal Programming for Optimization of Carbon Sink in Youngdong-Gun, Korea

Hyun-Kyu Won[1], Young-Hwan Kim[1], Jeong-Weon Seo[1], Byoung-Il Yoo[1] , and Chan-Woo Park[1]
([1]Korea Forest Research Institute)

Background

Rapid industrialization and increment of population, occurred during the last century, have brought several environmental problems such as global warming, ozone depletion and deforestation of tropical forests. Now sustainability is a big trend or a basic paradigm in forest management over the world. Forest management objectives have become more and more complex and complicated, and thereby it is hard for forest owners or managers to make a decision. In Korea, to facilitate sustainable forest management, large landscapes should be classified into several zones according to their priority for forest functions. Therefore, in this study, we intended to develop a long term management plan for a large landscape that enable one to achieve a stable carbon sink and an even harvest volume.

Study site

The study site of this study is Young-Dong Gun, located in the central region of South Korea (Figure1). The size of the area is approximately 44,216ha (70% of the entire forestlands), which has been managed for carbon sink and other objectives. Most of the area is composed of pine trees or oak trees.

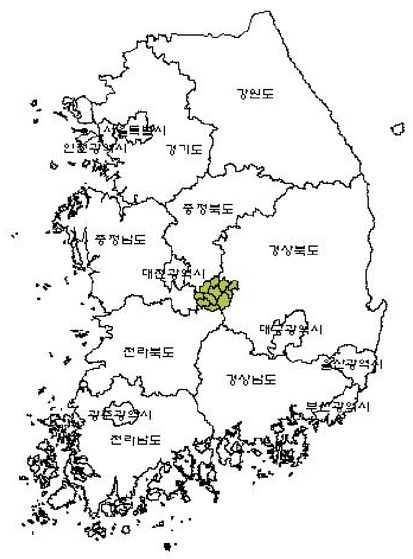

Figure 1. Study Site

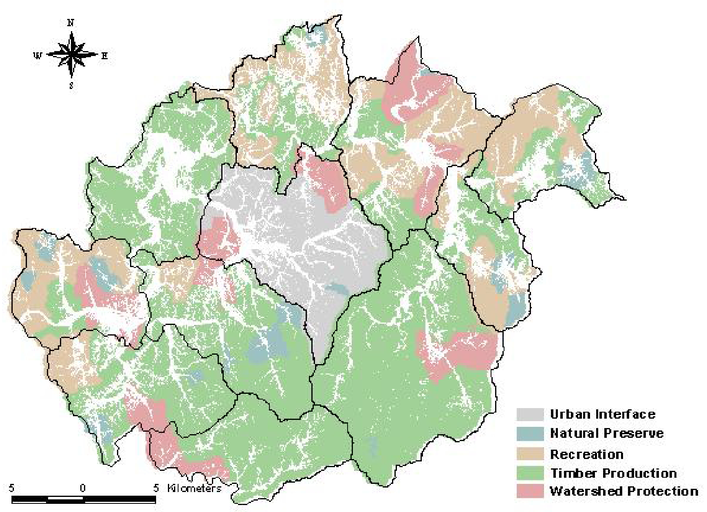

Figure 2. Forest Functions in Youngdong-Gun

. Currently, the study site has a skewed distribution of forest age classes. The majority of forestlands are occupied by age classes 3 (47%) and 4 (24%). The area was classified into 5 zones according to their priority of functions (Figrue2 & Table 1).

Table1. The Forest Area by Forest Functions in Youngdong-Gun

Forest Funtion	Urban Interface	Natural Preserve	Recreation	Timber Production	Watershed Protection	Total
Area(ha)	4,346	1,638	8,543	25,082	4,607	44,216
Rate(%)	(9.8%)	(3.7%)	(19.3%)	(58.0%)	(9.2%)	(100%)

Goal Programming

Management planning was conducted with a 5-decade time horizon (2009 - 2059). It is assumed that timber harvesting is available in a stand of age class 3 or over and reforestation is implemented right after the harvesting. The followings describe the priority of management goals:

1st goal: a balanced age classes distribution in the function of timber production
2nd goal: 10% increment in the harvest volume to the prior decade
3rd goal: Harvesting limited to 30% of the overall area of urban interface or recreation, 20% of watershed protection, 10% of natural preserve.
4th goal: maximize the harvest volume

To handle a number of decision variables and constraints, goal programming was applied for the management planning and the following objective function was resulted:

- Objective function

$$MinZ = W_4\sum_{i=1}^{I}(d_n^- + d_n^+) + W_3\sum_{i=1}^{I}(e_i^- + e_i^+) + W_2\sum_{i=1}^{I}(a_i^- + a_i^+) + W_1(q^- + q^+)$$

- Deviation to optimum amount of timber volume

$$\sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{k=1}^{K}\sum_{m=1}^{M} C_{ijkm}X_{ijkm} + q^- - q^+ = H$$

- Existing areas by functions and age classes

$$\sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{k=1}^{K}\sum_{m=1}^{M} X_{ijkm} = A_n$$

- Difference between areas of age classes

$$\sum_{m=1}^{M}\{\sum_{j=1}^{J}\sum_{k=1}^{K} X_{4ijm} + d_m^- - d_m^+\} = N_m$$

- Limitation of harvested area for functions

$$\sum_{i=1}^{I}\{(\sum_{j=1}^{J}\sum_{k=1}^{K}\sum_{m=1}^{M} X_{ijkm} + a_i^- - a_i^+)\} = \beta_i A_i$$

- Decadal increment of harvest volume

$$\sum_{m=1}^{M}\{(\sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{k=1}^{K} X_{ijkm}) - \alpha_m(\sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{k=1}^{K} X_{ijkm+1}) + (e_m^- - e_m^+)\} = 0$$

Result and Discussion

The optimization software, LINGO6.0, was utilized for the modeling. The optimization model developed in this study enables one to generate a management solution which is feasible for the various management goals and constraints (Table2). It is able to achieve a stable distribution of age classes (Figure3). Especially in the function of timber production, 4,180ha was evenly distributed for each age class. Overall, 25,892ha of forest area were scheduled for harvesting and 6.3 million m^3 would be harvested during the time horizon.

Table2. Schedule of Harvesting Optimized from the Goal Programming

	Area scheduled for Harvesting (ha)					Area of No Harvesting (ha)				
	Period 1	Period 2	Period 3	Period 4	Period 5	Period 1	Period 2	Period 3	Period 4	Period 5
Urban Interface	188	1,115	-	-	-	119	581	1,884	459	-
Natural Preserve	91	84	-	-	-	-	192	890	381	-
Recreation	2,085	-	499	-	-	-	1,452	1,964	2,082	461
Timber Production	4,180	4,180	4,180	4,180	4,180	-	-	782	2,293	1,107
Watershed Protection	87	758	85	-	-	124	969	1,404	1,165	15
Total	6,631	6,137	4,764	4,180	4,180	243	3,194	6,924	6,380	1,583

This result supported the fact that goal programming seemed to be an effective method to achieve stable carbon sink in the study site.

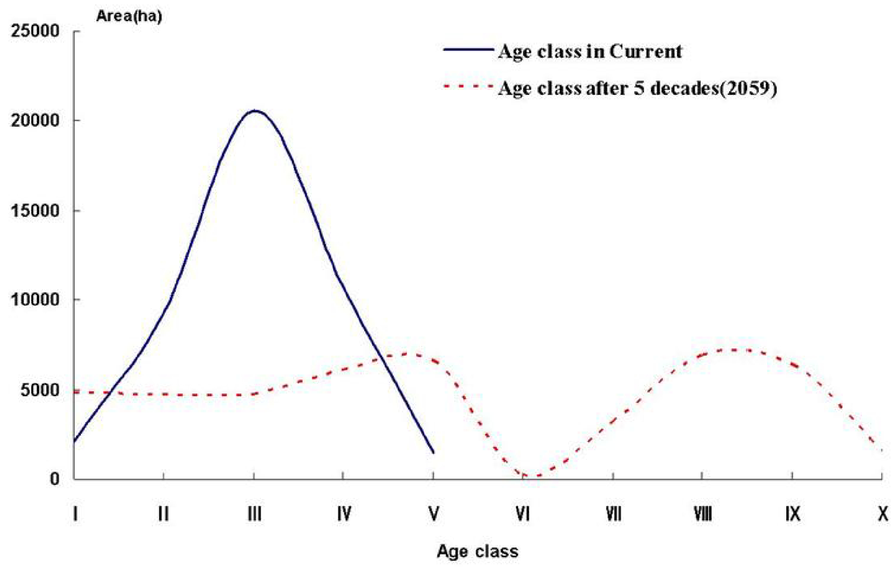

Figure3. Changes in the Distribution of Age classes after 5 decades in Youngdoong-Gun