SELECTING THE BEST SKIDDING SYSTEM USING AHP:
A CASE STUDY IN NORTHERN IRAN

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Abstract: Selecting the best harvesting system based on the physical characteristics of the logging area and economical parameters is an important decision for forest engineers. To consider different environmental, economical and social criteria this study uses an AHP decision making method to choose the best skidding system for a mountainous mixed hardwood forest. The possible available skidding alternatives are mule logging, wheeled cable skidder and tractor in the case study area. The AHP results showed that the best alternative is mule logging if all criteria have the same weight. But if the economical parameters are more important for the forest managers, then the tractor logging is the best choice.

Key words: Skidding system, mule logging, skidder, tractor, multiple criteria decision, AHP

INTRODUCTION

In forest management plans, the logging phase plays an important role due to the high costs and impact on the forest stands. To minimize the cost of harvesting and decrease the harvesting impact, the first step is choosing a suitable logging system. There are different factors influencing the logging systems such as stand characteristics, topography, soil condition, silvicultural treatments, costs, technology availability and social interests. In the past years the harvesting systems were mostly selected based on the cost production studies. Recently the social and environmental issues of the state forests have been increased. Therefore the forest managers need to consider more parameters in their decision making process. In the past years linear programming methods have been used for forest planning but these methods are not regarded as sufficient with respect to ecological consideration (Shugart, Gilbert, 1987). There were also problems due to spatial dimensions of the problems, non-linearity and uncertainty. Spatial and heuristic optimization was developed to solve such a problem (Pukkala, 2002). To consider different criteria for decision, multiple criteria decision aid methods are often involved in forest planning (Kangas, 1994). Naghdi et al. (2008) applied the Analytic of Hierarchical Process (AHP) method to choose the best method for road network planning in Northern Iran.
The environmental and social interests have been influencing the forest use recently. Considering these parameters in the conventional economic evaluation is not possible. Therefore this study applies AHP to consider different environmental and social attributes as well as economical parameters to choose a suitable skidding system in a mountainous forest area in Northern Iran.

**MATERIALS AND METHODS**

**Study area**
The study area is located in Northern Iran near Caspian sea. The second district of Kheiroudkenar forest is a mixed broad leave forest under single and group selection cutting. The district covers the area of 1080.9 ha with standing volume of 434 m$^3$/ha. The broadleaved stands mostly consist of *Fagus* sp., *Quercus* sp., *Carpinus* sp. The cutting volume of the district is 5850 m$^3$ per year which means 5.41 m$^3$/ha. The slope ranges from 15% to 60%. The felling is done motor-manually using chainsaws. The felled trees then are delimbed and bucked to the assortments. The sawmill logs are skidded by wheeled cable skidders or tractors (tracked skidders) to the landings. The extracted logs are loaded using grapple hydraulic loaders on the trucks at the landings. The fuel woods are extracted by mules. Also, for the steep terrains which can not be harvested by skidders or tractors, the logs are processed to the small lumbers to extract by mules. Namkhaneh district consists of 27 compartments. The compartment N 201, 202, 203, 204 and 205 are protected parts with no logging operation due to their steep slope and to have natural reserve areas in this research forest centre. The existing road network has a density of 28.16 m/ha.

**Method of study**
The AHP method was applied in this study which was originally developed by Saaty (1977). AHP has been used to solve many forestry problems (Murry, von Gadow, 1991; Kangas, 1992; Rauscher et al. 2000; Reynolds, 2001; Vacik, Lexer, 2001). The goal of this study is selecting the best skidding systems. The main criteria included economical attributes, environmental and social criteria (Fig. 1). There are three alternatives for wood extraction: cable wheeled skidder, crawler tractor and mule.

The criteria are defined in Table 1. The previous research studies (Jourgholami, 2005; Sobhani, 2004; Ghaffarian, 2003; Naghdi, 2004; Lotfalian, 1996; Naghdi et al. 2008; MacDonald, 1999) were used to get the information for each criterion.

The basic information presented in Table 2 was used for pair wise comparison to calculate the preferences. The numerical comparison was used in
pair wise comparison. Numerical judgments are made in the top pane. Two elements are compared with respect to their parent using a numerical scale.

It was assumed that all criteria have the same weight for forest manager.

**RESULTS**

The synthesize analysis with respect to the goal of selecting the best skidding system showed that the mule logging is better than the other alternative. The overall inconsistency ratio was about 0.01. The sensitivity analysis was performed to graphically see how the alternatives change with respect to the importance of the objectives or sub-objectives. There are five types of analyses. Each sensitivity analysis can be performed from the goal or from a selected objective or sub-objective.

The Performance graph (Fig. 2) displays how the alternatives perform with respect to all objectives as well as overall.

Dynamic sensitivity analysis (Fig. 3) is used to dynamically change the priorities of the objectives to determine how these changes affect the priorities of the alternative choices.
<table>
<thead>
<tr>
<th><strong>Criterion</strong></th>
<th><strong>Definition</strong></th>
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<tbody>
<tr>
<td>Skidding cost</td>
<td>Cost of hauling or skidding from the woods to the road sides (landing) per m³</td>
</tr>
<tr>
<td>Payload</td>
<td>Gross weight of a loaded vehicle minus weight of the vehicle itself</td>
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<tr>
<td>Road density</td>
<td>Forest road length per hectare</td>
</tr>
<tr>
<td>Max. skid trail slope</td>
<td>Maximum allowable slope of the skid trail surface in the direction of travel</td>
</tr>
<tr>
<td>Price of the extracted woods at the landing per m³</td>
<td>Wood price depending on quality and dimension of wood or timber size capability</td>
</tr>
<tr>
<td>Rest time requirement</td>
<td>The time needed for rest especially for mules</td>
</tr>
<tr>
<td>Soil compaction</td>
<td>Increase soil density in relation to the primary density resulting from pressure effect of machines moving over the soil</td>
</tr>
<tr>
<td>Soil disturbance</td>
<td>Disturbance of the soil surface by the movement of vehicle</td>
</tr>
<tr>
<td>Soil erosion</td>
<td>Amount of the soil eroded and measured as sedimations</td>
</tr>
<tr>
<td>Seedling damage</td>
<td>Includes destroying, crushing and any wound caused by the logging operations</td>
</tr>
<tr>
<td>Standing tree damage</td>
<td>Include crushing, rooting and any wound caused by the logging operations</td>
</tr>
<tr>
<td>Water recourses pollution</td>
<td>The percent of the pollution (fuels, lubricants, and the other chemical pollutions) in the forest watercourses</td>
</tr>
<tr>
<td>Ability to perform in deep snow</td>
<td>-</td>
</tr>
<tr>
<td>Ability to perform in swampy area and wet soils</td>
<td>-</td>
</tr>
<tr>
<td>Ability to perform in hot or cold weather</td>
<td>-</td>
</tr>
<tr>
<td>Employment rate</td>
<td>Number of crews who work in logging team</td>
</tr>
<tr>
<td>Work accident rate</td>
<td>Accidents include death and injuries</td>
</tr>
<tr>
<td>Stress</td>
<td>Any mental pressures during working to the workers</td>
</tr>
<tr>
<td>Strain</td>
<td>Any physical or chemical pressures</td>
</tr>
</tbody>
</table>
The gradient graph (Fig. 4) shows the properties of alternatives with respect to one objective at a time. Cable tractor is better than the others regarding to economic criteria.

Mule logging is preferred to mechanised logging regarding to social and environmental criteria (Fig. 5, 6).

If the weight of economic criteria is increased up to 86%, the cable tractor would be better than the other alternative (Fig. 7). Increasing or decreasing the weight of social and environmental criteria has no impact on the rating.

**CONCLUSIONS**

The multiple criteria decision making using AHP has been used to solve different forestry problems. In the past years, the logging engineers se-
lected the best harvesting system mostly based on cost-production evaluation. However to consider more different attributes on decision making process, this study used AHP method to compare three alternatives for harvesting in selective logging block using different economic, social and environmental criteria. The results showed if the criteria have the same weight, the mule logging is better alternative but if economical criteria are more important for forest planners, then the cable tractor can be chosen as the best alternative. It should be noted that these results are only valuable for the areas where all alternatives are technologically possible to be used based on the slope, logging volume, availability of the technology and soil conditions.
Fig. 4. Gradient analysis respect to economic criteria

Fig. 5. Gradient analysis with respect to environmental criteria
The AHP method can be used to compare cut to length and tree length systems in Northern forest of the country in different forest companies for the next study.

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ИЗБОР НА НАЙ-ДОБРА СИСТЕМА ЗА ИЗВОЗВАНЕ ЧРЕЗ ИЗПОЛЗВАНЕ НА АНАЛИЗ НА ЙЕРАРХИЧНИЯ ПРОЦЕС: ПРИМЕР ОТ СЕВЕРЕН ИРАН

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(Резюме)

Различни фактори вляхват на системите за сечене и извозване на трупи – характеристиките на насаждениято, топографията, състоянието на почвата, лесовъдски мероприятия, цените, наличност на техника и социален интерес. В миналото системите за събиране са били избрани основно според разходите за производство. В последно време с нараснала тежест са социалният фактор и околната среда. Поради това горските ръководители имат нужда от повече параметри в процеса на вземане на решения. Един от полезниите методи за тях е вземане на решения с многостранни критерии (Multiple criteria decision making, MCDM). Анализът на йерархичния процес (АП) е един такъв и се използва за решаване на горски проблеми. Целта на настоящото изследване е да се избере най-добрата система за извозване от наличните: колесен трактор, трактор и изнасяне с мулета за райони със смесени гори в Северен Иран. Дефинирани са икономическите и социалните критерии, като и тези за околната среда. Въз основа на наличната предварителна информация за всеки критерий, е направена сравнителна оценка на алтернативите според целта. При еднаква тежест на критерите, и установено, че извозването с животинска тяга (мулета) е по-добро от влекач и трактор. Анализът показа, че животинската тяга е предпочитана пред механизирани алтернативи, отделно като социалните аспекти и тези на околната среда. Ако горските ръководители биха искали по-икономична алтернатива, то гъсеничният трактор е по-добрана.

Ключови думи: система за извозване, извозване с мулета, трактор, MCDM, АП

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