Effects of vegetation type and horizontal curve radius on the rate of tree pruning to provide line of sight on main access roads

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ABSTRACT: The present investigation was carried out to assess the influence of vegetation type and horizontal curve radius on the rate of tree pruning to provide the line of sight on horizontal curves in Caspian forests of Iran. For this purpose, the DBH (diameter at breast height) of trees around the curves which must be pruned was measured. Also, the horizontal curves radius was divided into 4 classes and for each class 10 horizontal curves (for each species) were selected and the species which required pruning were measured. The rate of radial pruning was determined to provide a minimum stopping sight distance by means of laser rangefinder along the line of sight. We found an inverse relationship between DBH and the rate of pruning. To provide sight vision, the radial pruning rate decreased regularly with the increasing radius of horizontal curves for coniferous species, while it increased irregularly for broadleaves. There was a significant difference in pruning between different radii of horizontal curves ($P < 0.05$). According to results, pruning should be done for mixed hardwood trees with widespread crowns and no sharp horizontal curves should be designed at the top or bottom of hills.

Keywords: tree pruning, vegetation type, sight line, horizontal curve, vegetation control

The types of forest roads are different due to their role in transport. These roads can be used as public roads or forest roads. Since the type of pavement can be asphalt on forest roads, therefore the design speed and traffic increases. Obstructions such as cut slopes and plants on the inside of horizontal curves can cause vision loss and increase the risk of traffic accidents (Ronald et al. 2008).

Sight distance is maintained at a safe level for stopping by designing the curve at or above the desirable minimum standard and ensuring a clear zone adjacent to the forest roads. Where the sufficient stopping sight distance is not available due to sight obstructions (plants or cut slopes), alternative designs such as increasing the offset to the obstruction, increasing the radius or reducing the design speed should be considered for safety and economic reasons (Nasiri 2012). The clear distance is measured from the centre of the inside lane to the obstruction. Using the radius of curvature and minimum sight distance for that design speed gives the clear distance from the centreline of the inside lane to the obstruction (Aashto 2001). Measuring the clear distance can be a problem for forest engineers due to environmental factors such as the shape of tree stems. Stems in the crowns of broadleaved species are typically multi-branched with specific shape. Crowns of these species are widespread and sight limitation often occurs on horizontal curves. The shape of conifer stems is often an incomplete cone (Zobeiry 2006). Some coniferous species can establish on cut slopes because of their tolerance to a difficult situation (Zare 2001). This can decrease the right of way in roads and limit sight on curves. Nasiri (2012) conducted a study in forest roads of Iran and stated that the horizontal curve radius has an important role in relation to the rate of horizontal sight line offset, earthwork limit and standard right of way.

In studies performed until now, less attention has been paid to the sight distance on forest roads. Potential hazards exist where brushes limit visibility at the inside of a curve or where heavy snow loads on roadside trees may cause the trees to bend over the road surface, restricting the use of the road and creating a safety hazard. A recent study has found that in Denmark, about 20% of all personal injury accidents and 13% of all fatal accidents occur on curves in rural areas; and in France, over 20% of fatal accidents occur on dangerous curves in rural areas (Herrstedt, Griebe 2002). Therefore, the present investigation was carried out to assess the influence of vegetation type and horizontal curve radius on the rate of tree pruning to provide the line of sight on horizontal curves in coniferous and broadleaves trees in Caspian forests of Iran.

MATERIALS AND METHODS

Study area. The study was conducted in the Seyedkola and Atoo forest roads in Caspian forests of Iran (Fig. 1). The forest road type is the main access road with low-volume traffic. Coniferous plantation (*Cupressus sempervirence* var *horizontalis*) and natural broadleaved stand (*Alnus glatinusa*) were located around the Seyedkola and Atoo roads, respectively. The general slopes are less than 60%. The geographical position is between 52°43' and 52°48' eastern longitude and between 36°33' and 36°35' northern latitude for Seyedkola forests and 52°50' to 52°54' eastern longitude and 36°36' to 36°42' northern latitude for Atto forests.

Data collection. Sight distance on horizontal curves was determined using a laser rangefinder. The number of trees which must be pruned to provide a minimum stopping sight distance were recorded in each investigated area. In order to investigate the effects of tree species on pruning and to provide a minimum stopping sight distance in the internal lane of horizontal curves, the stopping sight distance (SSD)(Eq.1) and horizontal sightline offset (M)(Eq. 2) were calculated according to design speed, coefficient of friction, curve radius and width on curve (Aashto 2001).

$$SSD = v + 0.13v^2/30f \qquad (1)$$

where:
v – speed (s),
f – coefficient of friction between the vehicle tires and the road surface.

$$M = R\,(1 - \cos \beta/2) - (W/2 + 1.5) \qquad (2)$$

where:
R – horizontal curve radius (m),
β – central angle of curves,
W – width on curve (m).

The diameter of trees at breast height (DBH) was measured with a calliper and the rate of radial pruning was determined to provide a minimum horizontal sightline offset through the passage of laser line along the line of sight (Fig. 2). In order to investigate the effects of the horizontal curve radius on radial pruning, the horizontal curve radius was divided into 4 classes (16 to 18, 18 to 20, 20 to 22 and 22 to 24) and for each class 10 horizontal curves (for each species) were selected and the species which required pruning were measured. For curves with a radius of more than 24 meters the rate of the clearing limit was considered zero because of the level of friction coefficient and low level of design speed (Nasiri 2012). The effects of the horizontal curve radius on the rate of pruning necessary to create minimum stopping sight distances were analysed using the univariate linear analysis and Tukey's tests. SPSS v. 16.0 (Tulsa, USA) was used for statistical analyses.

RESULTS

The rate of radial pruning needed to create minimum stopping sight distances for curves with small

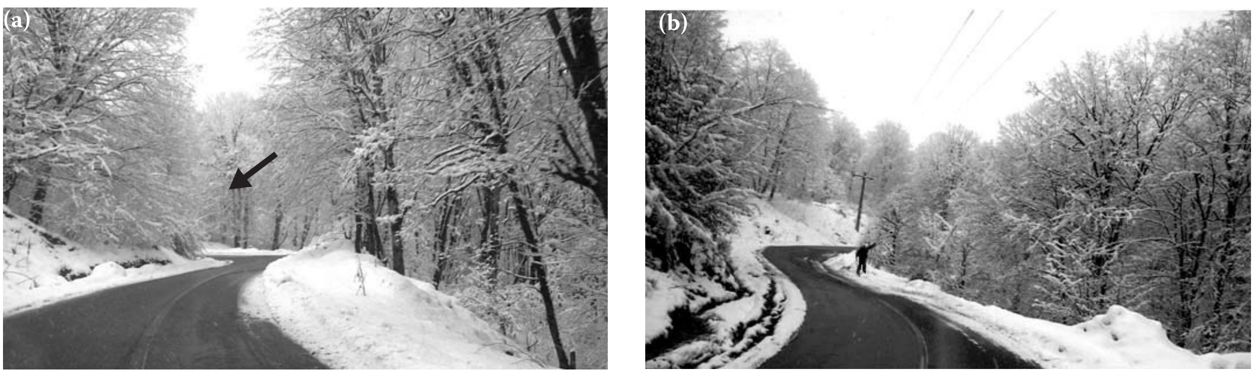

Fig.1. High risk area for snowy or rainy days in forest roads

radius is higher than that for curves with large radius. There was a significant difference (Table 1) in the pruning necessary for hardwood trees in horizontal curves with radii of 16 to 18 m and in the curves with radii 22 to 24 m ($P < 0.05$). Also, there was a significant difference in the pruning necessary for coniferous trees in horizontal curves with radii of 22 to 24 m and other classes. The radial pruning rate of coniferous species (to provide sightlines) decreases regularly with the increasing radius of horizontal curves (Fig. 3). This decrease is erratic for broadleaved species.

An inverse relationship was found between the diameter of trees and the rate of pruning on the inside of lanes (R^2 = 0.65 for coniferous species; R^2 = 0.61 for hardwood species). The length of the bare stem (without branches) decreases with the increasing tree diameter. The rate of pruning for broadleaved species was greater compared with coniferous species (Fig. 4).

DISCUSSION

Horizontal curves on all forest roads will be laid out as the arc of a circle having a preselected radius. For the best alignment, the largest radius possible should be selected, consistent with topographic limitations and the economics of the construction (Lugo, Gucinski 2000). Therefore, fixed numbers are not useful for determining the horizontal curve radius or right-of-way in mountainous forest road construction. These numbers are frequently ignored by the executives and road constructors in order to preserve valuable trees and avoid cutting these trees on sensitive points such as cut slopes (Parsakhoo et al. 2009). Given the standard criteria of main access roads the largest radius possible should be selected because the driver's safety is more important than preserving trees on the roadside. According to the results it can be understood that when the horizontal curve radius is above standard criteria, the radial pruning decreases. So the probability of traffic accident decreases (Herrstedt, Griebe 2002).

The pruning rate necessary to maintain the adequate sight distance in forests of coniferous species decreases regularly with the increasing radius of horizontal curves. But this decrease is irregular for broadleaved species. The longitudinal growth of broadleaved species in an open area is low, whereas their branches can grow phenomenally. Therefore, according to the level of sunlight the pruning decrease in broadleaved species is greater than that of coniferous species. The main reason for the reduction of pruning rate with increasing diameter is natural pruning. The result is in agreement with Mohajer

Table 1. Statistical comparison of tree pruning for different radii of horizontal curves

Treatment	Curve radius (m)			
	16– 18	18–20	20–22	22–24
Hardwood pruning	1.07[a*]	0.89[ab]	0.93[ab]	0.54[b]
Coniferous pruning	0.88[a]	0.7[a]	0.54[ab]	0.42[b]

followed by different lower-case letters are significantly different at a probability level of 95%

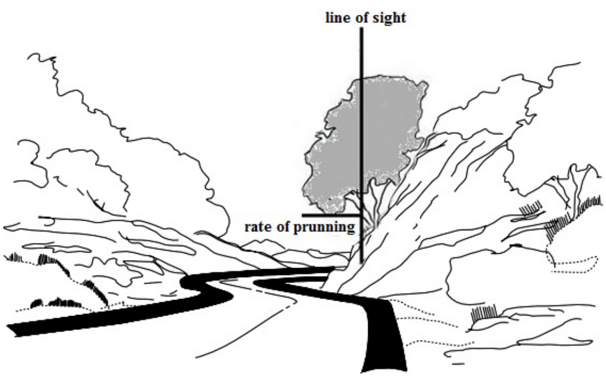

Fig. 2. Measurement method of tree pruning on the inside of the curve

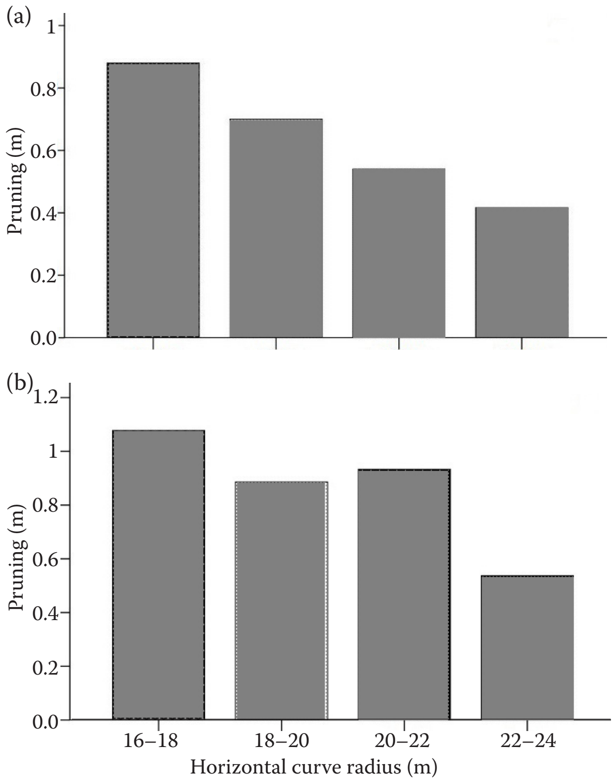

Fig. 3. Comparison of tree pruning necessary in different radii of horizontal curves for coniferous species (a), hardwood species (b)

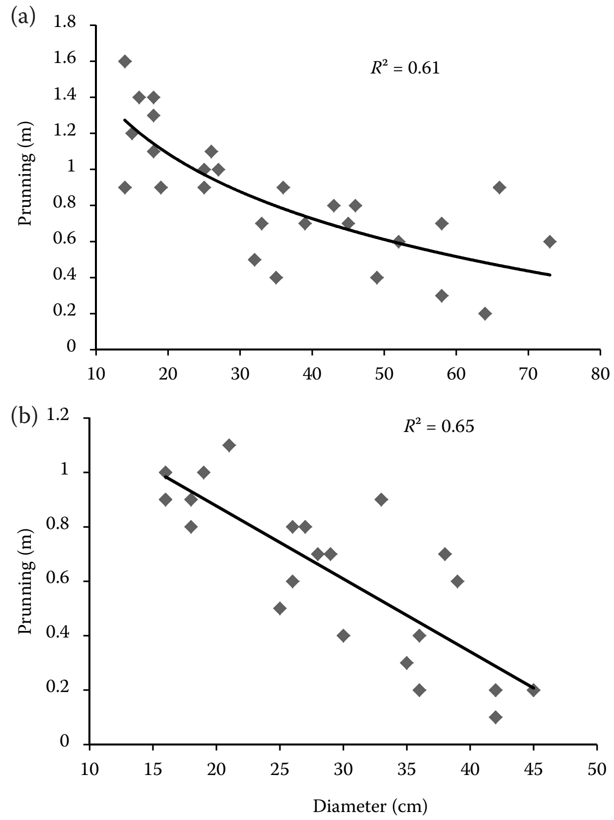

Fig. 4. Relationship between the tree diameter and the rate of pruning for hardwood species (a), coniferous species (b)

(2007). The length of the bare stem is dependent on genetic characteristics, site properties and method of tending operation (Zobeiry 2006). The pruning type in coniferous species is dry pruning (pruning of dead branches) and for the broadleaved species it is green pruning. To provide a minimum stopping sight distance in forests with coniferous species, dry pruning should be done for trees with diameter more than 15 cm during the thinning operation (Mohajer 2007). According to the growth form of broadleaved species (open angle of branches and widespread crown), the rate of pruning in these species is higher than that of coniferous species. It is necessary to prevent the growth of the saplings of coppice species and seeding crop species, because the crowns of these species are too broad.

CONCLUSIONS

Brushing of the road clearing width should be carried out to provide safe sight distances. The following suggestions can be used in order to reduce the level of hazard and environmental damage:

– A height of 2 feet (0.61 m) can be used as the midpoint of the sight line where the cut slope usually obstructs sight.
– Pruning should be done on the inside of the curve, especially for mixed hardwood trees with the open angle of branches and widespread crown to provide stopping sight distance.
– Using appropriate tools and formulas to determine the sight distance, stopping sight distance and horizontal sightline offset should be used according to the road type.
– Prevent the growth of the saplings of coppice species.
– Sharp horizontal curves should not be designed at the top or bottom of hills.

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