Stand characteristics and distribution of a relict population of Persian ironwood (Parrotia persica C.A. Meyer) in northern Iran

Kiomars Sefidi*a, Mohammad R. Marvie Mohadjera, Vahid Etemada, Carolyn A. Copenheaverb

a Department of Forestry, Faculty of Natural Resources, University of Tehran, Karaj, Iran
b Department of Forest Resources and Environmental Conservation, Virginia Tech, Blacksburg, VA 24061, USA

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A B S T R A C T

Parrotia persica C.A. Meyer (Persian ironwood) is a deciduous tree of the family Hamamelidaceae, native to northern Iran and endemic to the Alborz Mountains. The study objectives were to assess the current status and distribution of Persian ironwood by characterizing four forest stands where the tree was either a dominant or co-dominant species. Species richness within the stands varied from 3 to 16 woody species and from 9 to 27 understory species. Basal area varied between 37 m²/ha and 77 m²/ha and tree density varied from 320 to 367 stems/ha. Parrotia persica represented 63–86% of the relative dominance and 41–100% of the relative density. In non-pure P. persica stands, other important tree species include Fagus orientalis and Carpinus betulus. Parrotia persica regenerates mainly by sprouts and coppicing. Conservation of relict forests, such as the Persian ironwood forests of the Alborz Mountains, is of particular concern because they represent the only natural occurrence of this species in the world. Anthropogenic disturbance, in the form of timber harvesting, livestock grazing, and clearing forest land for agriculture appear to be the largest threats to Parrotia persica's future.

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Introduction

Parrotia persica C.A. Meyer (Persian ironwood) is a deciduous tree of the family Hamamelidaceae and is endemic to the Alborz Mountains of northern Iran. Although this tree is currently not threatened, it has caught the attention of conservation managers because it has some of the characteristics of species at risk of extinction (Shariatnegad, 2005). Parrotia persica occurs in the moist, deciduous forest region south and south-west of the Caspian Sea. Its natural range is limited to the Hycranian forest region with a western limit of the Talish Mountains in Azerbaijan and an eastern limit of the Gorgan province in northern Iran and one small, disjunct population in the forests southeast of the Great Caucasus (Nicholson, 1989; Safarov, 1977). In Iran, the tree is limited to elevations ranging from 150 to 700 m (Mahjoob, 2006). The habit of P. persica is usually low-branched and multi-stemmed and its unique exfoliating bark and colorful flowers and foliage have made it a common horticultural species in North America and Europe (Nicholson, 1989). Although it has been identified as a potential restoration species for re-vegetating steep slopes, its relatively sparse crown makes it relatively ineffective at insuring slope stability (Bibalani and Majnounian, 2008).

As a species of conservation concern, P. persica, comes from a plant family, Hamamelidaceae, in which historical species extinctions have been well studied (Benedict et al., 2008; Maslova, 2003; Zhang and Lu, 1995). Currently, Hamamelidaceae, include five subfamilies: Disanthoideae (1 genus), Hamamelidoideae (16 genera), Rhodoleioideae (1 genus), Bucklandioideae (1 genus) and Liquidambaroideae (2 genera) (Harms, 1930). Many of these subfamilies have disjunct distributions which when combined with the fossil and pollen records indicate a history of migration and extinction across the North American, European, and Asian continents (DeVore et al., 2005). It has been suggested that the cause of most of these extinctions may result from fluctuations in climate; regions with mild climate change resulted in diversification of species, but in regions with more extreme climate change, species became extinct (Guo and Ricklefs, 2000). In the face of predicted warming temperatures and increased precipitation for northern Iran (Abbaspour et al., 2009; Evans, 2010), it is important to collect baseline data on the current status of P. persica to better understand its ecology before any climatic shifts put this species at risk of extinction.

Aside from a general understanding that P. persica exists in both pure and mixed stands, no comprehensive studies have described the structure and composition of natural P. persica stands in the Caspian forests of northern Iran (Browicz, 1982). Therefore, the
objectives of this study were to assess the current status and distribution of *P. persica* by surveying remaining populations and describe their ecological characteristics, with particular reference to stand structure and composition.

**Materials and methods**

**Study site**

The Hyrcanian region is located south of the Caspian Sea (Fig. 1). The Iranian part of this region covers approximately 50,000 km² and is located within the Iranian provinces of Gilan, Mazandaran and Golestan. The region extends throughout the southern coast of the Caspian Sea and due to its humid temperate climate and fertile soil is a highly productive region. Intensive human settlement of the lower elevations as early as AD 1100 left large portions of the lowlands deforested after these areas were converted for agricultural, residential, and industrial uses (Ramezani et al., 2008). The Hyrcanian forest typically has *Fagus orientalis* Lipsky (Oriental beech), *Carpinus betulus* L. (European hornbeam), *Quercus castaneifolia* C.A. Mey. (chestnut-leaved oak), *Pterocarya fraxinifolia* (Lam.) Spach (Caucasian wingnut), *Alnus subcordata* C.A. Mey. (Caucasian alder), *Carpinus orientalis* Miller (Oriental hornbeam), *Diospyros lotus* L. (date plum), *Carpinus schuschaensis* (Pall.) Dipp. (Caucasian Zelkova), *Zelkova carpinifolia* (Pall.) Dipp. (Caucasian Zelkova), *Parrotia persica* Pojark. (boxwood), *Fraxinus excelsior* (Lam.) Spach (Common ash), and *Carpinus betulus* C.A. Mey. (European hornbeam) as dominant woody species (Rad and Shafiei, 2010; Esmailzadeh et al., 2011; Marvie-Mohadjer, 2005). The climate in this region is sub-Mediterranean with mean annual temperature of 8.6 °C and total annual precipitation of 1,380 mm.

Field sampling methods

Initially, twenty forest stands located in the Patom and Chelir Districts of Kheiroud Forest (36°40'N, 51°43'E), Mazandaran Province, Iran were examined for potential *P. persica* populations in July and August 2009. Based on field visits and interviews with local land managers, we reduced this initial list to four stands (PS1, PS2, PS3, and CS1) that had substantial *P. persica* populations (Table 1). At each of the four stands, aspect and slope were measured using compass and clinometer. Vegetation structure and composition were sampled with five belt transects that were 60 m long and 5 m wide and randomly located within each stand. Within each belt transect, species of each tree >2 m tall were recorded and tree diameter at breast height (dbh, at 1.4 m) was measured. Sapling and seedlings less than 2 m in height were counted and grouped into two size classes: <5 cm dbh or >5 cm dbh. *Parrotia persica* seedling density was quantified by counting the number of seedlings within the belt transects. Degree of disturbance was classified as severe, moderate, low, or absent based on the number of dead trees resulting from natural or anthropogenic causes (cutting) and evidence of livestock manure along the transects. Stand health was qualified as high, intermediate or low depending upon the amount of seedling regeneration and the vigor of the overstory tree population. Vigor, specifically as related to *P. persica*, was classified as poor, moderate, or good.

**Data analysis**

The relative ecological importance value (IV) of each tree species was calculated by averaging the values for relative dominance (basal area), relative density (number of stems), and

**Table 1** Location of dominant overstory species, and canopy height of the four *Parrotia persica*-dominated forest stands from northern Iran. The PS stands were located in the Patom District and the CS stands in the Chelir District both of the Kheiroud Forest in northern Iran. All stands were characterized as deciduous broad-leaved forests and the Patom stands were managed while the Chelir stands were unmanaged.

<table>
<thead>
<tr>
<th>Stand</th>
<th>Location</th>
<th>Dominant trees</th>
<th>Canopy Ht</th>
</tr>
</thead>
<tbody>
<tr>
<td>PS1</td>
<td>36°36'13&quot;N, 51°33'47&quot;E</td>
<td><em>Acer cappadocicum</em>–<em>Carpinus betulus</em></td>
<td>21 m</td>
</tr>
<tr>
<td>PS2</td>
<td>36°36'08&quot;N, 51°33'36&quot;E</td>
<td><em>Acer cappadocicum</em>–<em>Carpinus betulus</em></td>
<td>20 m</td>
</tr>
<tr>
<td>PS3</td>
<td>36°36'17&quot;N, 51°33'51&quot;E</td>
<td><em>Fagus orientalis</em>–<em>Carpinus betulus</em></td>
<td>25 m</td>
</tr>
<tr>
<td>CS1</td>
<td>36°31'03&quot;N, 51°39'11&quot;E</td>
<td><em>Acer velutinum</em>–<em>Carpinus betulus</em></td>
<td>18 m</td>
</tr>
</tbody>
</table>

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![Fig. 1. The distribution of Caspian forest in Iran [modified after Nosrati et al. (2005)].](image)
relative frequency (number of plots of occurrence), cf. Curtis and McIntosh (1951). Density and basal area data followed a normal distribution (Shapiro–Wilk W test, P > 0.05) therefore, differences in stand structure between the sites were examined by Analysis of Variance (ANOVA). When significant differences were found, a Tukey–Kramer HSD (honestly significant difference) multiple comparison procedure was used to identify differences between means. The relationships between stand structural characteristics and environmental variables were tested by Pearson correlation.

Results

Vegetation structure in the Parrotia persica forests

Total basal area of trees varied between 37 m²/ha and 77 m²/ha and at least one of the stands had a significantly different amount of basal area than the others (F = 8.97, P = 0.001). The stand from Chelir had the lowest total basal area and P. persica represented between 63% and 86% of the relative basal area at each site (Fig. 2).

Density of trees varied between 320 and 367 stems/ha and differed significantly among study sites (F = 17.06, P = 0.000). Chelir had the lowest stem density and PS2 had the highest stem density (Table 2). Parrotia persica represented between 41% and 100% of the relative density at each site.

Regeneration of seedlings and saplings varied between 5,350 and 6,400 individuals/ha and was not significantly different across the four stands (F = 0.64, P = 0.63). Parrotia persica regeneration ranged between 58% and 86% of the total regeneration present at each site (Fig. 3). Total density of the stand and density of P. persica individuals were significantly correlated (r² = 0.69, P = 0.001).

Diameter distributions from the four stands showed trees represented in most of the diameter classes, with PS1 lacking any of the really large trees (<60 cm dbh) present in the other stands (Fig. 4).

In all stands the largest diameter classes were occupied by P. persica and Fagus orientalis. The unmanaged CS1 site had the diameter distribution that most closely match an inverse-J diameter curve expected for uneven-aged/old growth forests.

Floristic composition and regeneration status

Sixteen different woody plants were identified across all four stands (Table 2). The stand with the highest tree and shrub richness was PS1 (16 species) and the stand with the lowest richness was PS2 (11 species). In all four sites, sapling and seedling importance values for P. persica were higher than for other species, and specifically at the Chelir site (CS1). P. persica sapling and seedling counts were three times higher than those of all other seedlings and saplings. Most of the P. persica regeneration in this area was from natural coppicing and sprouting. On average, 95% of P. persica regeneration was by sprout and of those 17% of the sprouts were a result of detectable animal grazing. Many of the seedlings and saplings showed animal browse damage. Stand PS1 had the highest rate of animal-caused damage with 20% of the regeneration trees having browse damage.

Twelve species dominated the understory of the P. persica-dominated stands. They included: Acer cappadocicum Geditsch (Cappadocian maple), Euphorbia amygdaloides L. (spurge), Hypericum androsaemum L. (sweet amber), Mentha sylvatica Host., Oplismenus undulatifolia (Arduino) Beauv., Poa nemoralis L. (wood bluegrass), Polygonatum multiflorum (L.) Allioni (Eurasian Solomon’s seal), Prunus divaricata Ledeb. (cherry plum), Rubus fruticosus L. (shrubby blackberry), Ruscus hycanus Woron., Ulmus glabra Huds. (Wych elm), and Viola sylvestris Huds. (Viola sylvestris).

Status and disturbance of the stands

Evidence of disturbance was found in all locations in the form of firewood collection, timber harvesting, and cattle grazing. The Chelir region experienced particularly heavy grazing from cattle and 17% of the seedlings showed evidence of animal browsing. In the Patom region, local residents have produced charcoal from dead or living trees and remains of charcoal-making hearths are common in this region. When sites were ranked using a vigor index, P. persica

Table 2

<table>
<thead>
<tr>
<th>Site</th>
<th>Density (stems/ha)</th>
<th>Snags (#/ha)</th>
<th>Cut stumps (#/ha)</th>
<th>History</th>
</tr>
</thead>
<tbody>
<tr>
<td>PS1</td>
<td>353</td>
<td>30</td>
<td>20</td>
<td>Managed</td>
</tr>
<tr>
<td>PS2</td>
<td>367</td>
<td>50</td>
<td>20</td>
<td>Managed</td>
</tr>
<tr>
<td>PS3</td>
<td>365</td>
<td>40</td>
<td>10</td>
<td>Managed</td>
</tr>
<tr>
<td>CS1</td>
<td>320</td>
<td>10</td>
<td>0</td>
<td>Unmanaged</td>
</tr>
</tbody>
</table>
Fig. 4. Diameter distribution of four Parrotia persica-dominated stands in northern Iran. Tree species are differentiated into two species groups: P. persica and all other tree species.

populations in SP2 and SP3 were classed as good performers while the populations of P. persica in CP and SP1 were classed as poor performers.

**Coarse woody debris and snags**

Volume of coarse woody debris (CWD) varied between 3 and 31 m$^2$/ha, but did not differ significantly among study sites ($F = 59, P = 0.63$). The Chelir stand had the lowest volume of CWD. A majority (82%) of the CWD volume in this area originated from P. persica trees. Carpinus betulus and Fagus orientalis each contributed 32% and 6%, respectively, of the volume of CWD.

**Discussion**

Parrotia persica occurs in the moist, deciduous forest region south and south-west of the Caspian Sea, where it has long been considered as the only endemic tree in the Hyrcanian forest region, from the Talish Mountains, Azerbaijan in the west to Gorgan province, northern Iran in the east (Browicz, 1982). Wendelbo (1968) recognized the long-term resilience of the P. persica forests and hypothesized that this species had existed at this site even through the ice ages of the Pleistocene. Given the historical stability of this species, it would be a good indication that the climatic changes experienced are unprecedented, if the likelihood of survival of this species changes.

**Current structure and composition of Parrotia persica stands**

In all the Hyrcanian sites at which P. persica has been recorded, it is a dominant overstory species serving either as a sole dominant or co-dominant (typically with Fagus orientalis and Carpinus betulus) with Dysopyrus lotus common in the subcanopy (Mahjoob, 2006; Table 3). Specifically within the sites sampled in this study, P. persica canopy dominance varied from situations in which P. persica shared canopy dominance with Fagus orientalis (PS3) or Carpinus betulus (PS2 and PS1) to situations where P. persica was the only clear dominant in the overstory (CS1; Table 3). Structurally, the P. persica-dominated stands exhibited variation in density and basal area. Comparing the forest structure found in our stands (basal area varied from 37 to 77 m$^2$/ha and density varied from 320 to 367 stems/ha) with work previously conducted by Mahjoob (2006) where he found a basal area of 108 m$^2$/ha and 227 stems/ha indicates that Mahjoob (2006) had worked in an older stand with larger trees and a lower stem density. Another structural characteristic that may be related to successional status was volume of CWD, which we found to range from 3 to 31 m$^3$/ha which was not substantially different from other mature forests in this region (Sefidi and Marvie-Mohadjer, 2009). Thus, the current structure and composition of these stands reflect their successional status.

**Conservation status of P. persica**

Parrotia persica has a very restricted geographical range in the world, a characteristic that generally raises the risk of extinction.
were stems <5 cm dbh. Values listed after the species are importance values.

Trees were classified as stems >5 cm in diameter at breast height and regeneration

Trees and regeneration from four

manica

est population of

distribution may reflect its relict history. There is currently little effort

restricted range of the species and its fragmented pattern of distri-

dated from each other raises concerns about their sustainability. The

however, our survey of existing P. persica stands found healthy lev-

levels of regeneration in the form of seedlings and saplings (Table 3) and an overall good vigor identified for the existing overstory trees. However the limited geographic range of this species coupled with the fact that these stands are small in size and geographically iso-

lated from each other raises concerns about their sustainability. The

restricted range of the species and its fragmented pattern of distribu-

tion may reflect its relict history. There is currently little effort put towards protection of this tree species and although the small-

est population of P. persica (in the Chelir Forest) is protected from

harvesting, grazing of cattle still occurs in both the Chelir and Patom

Forests. Anthropogenic disturbance, in the form of timber harvesting,

livestock grazing, and clearing forest land for agriculture appear to be the largest threats to P. persica’s future.

### Table 3

<table>
<thead>
<tr>
<th>Trees</th>
<th>Stands</th>
<th>CS1</th>
<th>PS1</th>
<th>PS2</th>
<th>PS3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fagus orientalis</td>
<td></td>
<td>9.0</td>
<td>19.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carpinus betulus</td>
<td></td>
<td>18.1</td>
<td>20.2</td>
<td>9.3</td>
<td></td>
</tr>
<tr>
<td>Parrotia persica</td>
<td></td>
<td>75.0</td>
<td>72.2</td>
<td>60.7</td>
<td>59.8</td>
</tr>
<tr>
<td>Acer velutinum Boiss.</td>
<td></td>
<td></td>
<td>3.4</td>
<td>2.1</td>
<td></td>
</tr>
<tr>
<td>Pterocarya fraxinifolia C.A. Meyer</td>
<td></td>
<td>4.7</td>
<td>1.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alnus subcordata</td>
<td></td>
<td>4.7</td>
<td>1.4</td>
<td>3.4</td>
<td>5.2</td>
</tr>
<tr>
<td>Diospyros lotus</td>
<td></td>
<td>3.1</td>
<td>2.8</td>
<td>3.4</td>
<td>3.1</td>
</tr>
<tr>
<td>Crataegus azarolus L.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.5</td>
</tr>
<tr>
<td>Crataegus pentagyna Waldst. &amp; Kit.</td>
<td>1.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mespilus germanica L.</td>
<td></td>
<td>6.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prunus divaricata</td>
<td></td>
<td>4.7</td>
<td></td>
<td></td>
<td>4.1</td>
</tr>
</tbody>
</table>

| Total importance values     | 100    | 100 | 100 | 100 |

**Regeneration**

<table>
<thead>
<tr>
<th>Trees</th>
<th>Stand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fagus orientalis</td>
<td>2.4</td>
</tr>
<tr>
<td>Carpinus betulus</td>
<td>2.4</td>
</tr>
<tr>
<td>Parrotia persica</td>
<td>13.0</td>
</tr>
<tr>
<td>Acer velutinum Boiss.</td>
<td>13.0</td>
</tr>
<tr>
<td>Pterocarya fraxinifolia</td>
<td>13.0</td>
</tr>
<tr>
<td>Alnus subcordata</td>
<td>13.0</td>
</tr>
<tr>
<td>Prunus cerasifera</td>
<td>13.0</td>
</tr>
<tr>
<td>Ulmus carpinifolia Gleditsch.</td>
<td>0.5</td>
</tr>
<tr>
<td>Minor species*</td>
<td>5.2</td>
</tr>
</tbody>
</table>

| Total importance values     | 100    | 100 | 100 | 100 |

* Minor species included: Crataegus azarolus, Crataegus pentagyna, Mespilus germanica, Prunus divaricata, and Ficus carica L.

### References


