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Indigenous knowledge and stand characteristics of a threatened tree species in a highly insecure area: Chilgoza pine in Afghanistan

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ABSTRACT

Chilgoza pine (*Pinus gerardiana*) is an important source of income in forested eastern Afghanistan through the harvest of edible seeds. Since the late 1970s, the resource has been largely inaccessible to researchers and government personnel from outside the region, except for the years 2002–2015, roughly coinciding with Operation Enduring Freedom. We assessed physical and social attributes of chilgoza pine forests and the management capacity of indigenous communities. We employed interviews/questionnaires and field measurements performed by Afghan forest scientists from Kabul, trained local residents, and U.S. forest scientists associated with military operations to examine stakeholder perceptions of chilgoza pine forest resilience, assess forest health, stand structure and natural regeneration status. Intensive cone collection, tree damage caused by cone harvesting, grazing, fuelwood collection, and other biotic/abiotic factors (insects, diseases, and drought) were associated with chilgoza forest degradation. Most interviewees observed natural regeneration in the understory layer of chilgoza forest stands, but perceived the overall rate of natural regeneration to be insufficient. Respondents from villages prohibiting grazing and fuelwood collection reported the greatest regeneration while the converse was associated with the lowest levels of regeneration. Field measurements confirmed the scarcity of natural regeneration of chilgoza pine, portending the further decline of this species in Afghanistan. Field surveys indicated diverse stand conditions, age class structures and land use practices employed by local stakeholders, suggesting the need for situation-specific forest management recommendations. We discuss the opportunities and limitations for forest resources data collection in highly insecure environments.

1. Introduction

High value tree crops from forests and semi-natural orchards represent an important food and income source in many forest resource-dependent communities worldwide. However, where governing and land management institutions are weakened by conflict, the integrity of these resources becomes compromised, contributing to further social instability (Ingalls and Mansfield, 2017). In Afghanistan, lawlessness, exploitation, and ubiquitous threats of violence have fostered forest resource degradation and limited the impact of efforts to build management capacity (Groninger and Ruffner, 2010; Groninger and Pense, 2013). The current forest cover ranges between 20 and 60% of original forest conditions, with decline accelerating since the Soviet invasion in the late 1970s (Formoli, 1995; Azimi, 2007; Reddy and Saranya, 2017). Important factors contributing to this significant loss of forest cover are government instability, unsustainable land management practices, illegal timber harvests, poor security, and limited technical knowledge among user communities (Groninger, 2012; Bader et al., 2013).

An economically and ecologically important tree species impacted by this degradation and decline is *Pinus gerardiana* Wall. ex D. Don. (chilgoza pine). Chilgoza pine forests grow on dry, temperate sites in scattered groups, mainly distributed between 30° to 37° N latitude and 66° to 80° E longitude (Fig. 1) (Critchfield and Little, 1966; Ahmed and Sarangzai, 1992; Malik et al., 2012). The region is classified as the Eastern Forest Complex (EFC) and has been characterized as Palearctic realm and Himalayan Highland Province (Sayer and Van der Zon, 1981). Chilgoza pine is distributed broadly between 1800 and 3350 m elevation, but are dominant in stands between 2100 and 2500 m (UNEP, 2008).

Chilgoza pine seeds (pine nuts) are highly nutritious and palatable

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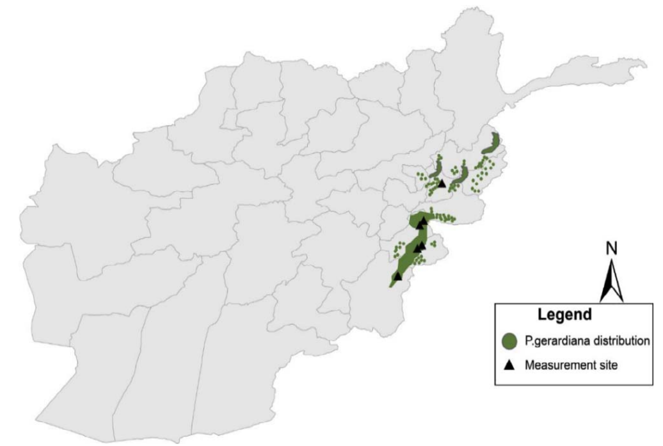

Fig. 1. Map of chilgoza pine distribution in Afghanistan and locations of surveyor field data collection. (Adapted from Critchfield and Little, 1966.)

and are therefore collected by local communities and traded worldwide (Sharma et al., 2013). Unshelled pine nuts are extracted by local villagers or contract workers and sold to local markets. The average annual income from sales of unshelled pine nuts was $1251 USD per family in 2015 (Shalizi and Khurram, 2016). Chilgoza pine forests also provide fuelwood (both wood and cones), medicinal plants, pasture, and shelter for livestock, as well as wildlife habitat and other environmental services (Shalizi and Khurram, 2016). Chilgoza pine forests are recognized as vulnerable to decline by the International Union for Conservation of Nature (IUCN) and the species was classified as endangered (Dogra, 1964). Currently, it is listed as a "near threatened" species by IUCN (Red Data Book, version 3.1) with a decreasing trend in the populations (Farjon, 2013). Mature trees are decreasing and fragmentation in populations is occurring across the range of the species (Farjon, 2013).

Natural regeneration of chilgoza pine is solely by seed with annual cone production varying as a function of environmental conditions (Malik and Shamet, 2008). Seed viability is low and seeds are heavy, limiting wind dispersal (Saeed and Thanos, 2006; Eckenwalder, 2009; Alam, 2011). Germination rates are extremely low and newly emerged seedlings are highly prone to desiccation and tissue damage from low soil moisture, intense heat, and frost (Ahmed et al., 1991; Kumar et al., 2013), all contributing to poor regeneration success (Malik and Shamet, 2008; Malik et al., 2008) especially during dry periods and particularly in shallow, sandy soils (Singh et al., 1973). Generally, a chilgoza pine seedling requires two years to establish a taproot. Dry spring and summer conditions inhibit seed germination and seedlings fail to establish a tap root system when germination occurs late (Peltier and Dauffy, 2009).

Chilgoza pine can successfully regenerate naturally, but only on inaccessible sites without human-related disturbances (Fig. 2) (Chandra and Khushdil, 1977; Malik et al., 2012). Overgrazing contributes to poor natural regeneration (Peltier and Dauffy, 2009; Kumar et al., 2016; Azizi et al., 2017). The few emerging seedlings are often consumed by livestock, as evidenced by widespread and intensive grazing damage across the landscape (Fig. 3). Goats cause the greatest damage; by eating seedlings and climbing into mature trees to consume leaves and branches, further limiting cone production.

Intensive cone and seed harvesting threatens natural regeneration (Chandra and Khushdil, 1977; Kuhn et al., 2006; Peltier and Dauffy, 2009; Kumar et al., 2016). The vast majority of cones are collected with few left on the tree for natural seed dispersal, even during abundant crop years. In Paktia province, Groninger and Ruffner (2010) observed over-mature chilgoza trees that were heavily damaged during cone collection and the absence of regeneration. However, in other areas, natural chilgoza pine stands were converted into nut producing orchards to optimize production, but also with no regeneration and evidence of degradative branch removal (Groninger and Ruffner, 2010).

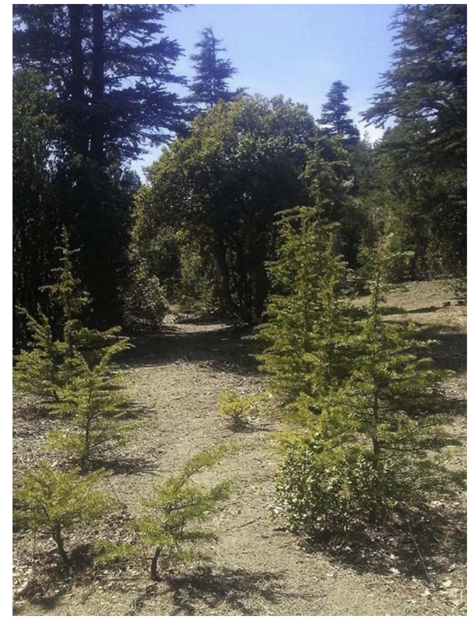

Fig. 2. Chilgoza pine seedlings and saplings in the understory of a chilgoza pine-dominated forest stand in Urgun district, Paktika province.

Fig. 3. Chilgoza pine-dominated forest stand showing evidence of grazing damage (Zazai Aryob, Paktia province).

A persistent challenge throughout the EFC is sustaining economically important natural resources in the face of lawlessness and a constant threat of armed attack by anti-government elements (AGE). Contact with natural resources management personnel was always rare in this region, due to inter-tribal conflict, contempt for outside governance, and remote mountain terrain, even during times when Kabul-based central government function and influence was at its peak. Rural villages often were under the rule of strongmen or connected warlords who benefit from controlling transportation routes and exploiting natural resources, making meaningful cooperation with outside entities difficult to impossible (Groninger et al., 2013). In other instances, particularly in the most remote mountain areas, tribal self-governance occurs at the village and multi-village levels. Traditionally, *harbakai* (community-based range and forest protection forces) prevented exploitation of natural resources. However, this institution has declined across the region beginning during the period of Afghanistan's Soviet occupation in the late 1970s. Since the rise of the Taliban, illegal timber cutting and overgrazing, originating from both outside and within the community, has been associated with the absence of knowledgeable and armed resource managers capable of defending community assets (Bader et al., 2013).

Continued conflict throughout eastern Afghanistan, including attacks directly by or in consort with internationally recognized terrorist organizations, severely limits freedom of movement by Afghan and international personnel alike (Groninger and Pense, 2013). Representatives and agents of the Afghan government, including extension agents, typically are confined to district centers or, more often, their offices. In other cases, those positions are unfilled altogether (Groninger and Pense, 2013). Despite these limitations, the period 2002–2015, roughly coinciding with Operation Enduring Freedom, was associated with frequent service by contracted aircraft between Kabul and the region and International Security Assistance Forces (ISAF) aircraft and road improvements between provincial centers and remote forested districts. Hence, this period provided an unprecedented, and perhaps unrepeatable, degree of outsider access to EFC.

The objectives of this study were to assess forest health, stand structure, natural regeneration status, and local knowledge of the chilgoza pine resource in EFC. We used multiple methods as dictated by regional and local security limitations. A local knowledge survey addressed local villagers' perception toward the natural regeneration status of chilgoza pine forests throughout EFC. Additionally, field measurements were conducted to assess stand structure and natural regeneration status of chilgoza pine forest stands. Based on these experiences, we outline and evaluate strategies for collecting forest management and stakeholder assessment data in highly insecure areas.

2. Materials and methods

Our study was based on a series of forest composition and regeneration field measurements and villager surveys led by Afghan Scientists (MNS and SK) with additional dendrochronological measurements by U.S. scientists (JWG and CMR).

Forest composition and regeneration field measurements were conducted during December 2015-January 2016. Study site selection was based on the need to balance site access, safety of surveyors, and the desire to minimize sampling bias. For forest composition and regeneration field measurements, all 66 districts in Afghanistan containing chilgoza forests were identified and categorized according to security level. Approximately 80% of those districts were deemed too insecure, and others too remote to allow access from the training location. In some districts that met both minimum security and accessibility criteria, a field surveyor who was able and willing to perform site visits and collect data could not be identified. Data were collected from the six districts that met all of the above criteria (Fig. 1, Table 1). Within these districts, surveyors selected secure villages, and identified suitable sampling locations 1–5 km apart. These were typically close to roads or near villages, allowing escape or protection in case of contact with hostile elements. Within these stands, sample plots were selected randomly. To minimize the risk of detection by potentially hostile parties, site sampling protocols were designed to be conducted within 30 min of arrival.

At each site, a fixed-area circular plot (radius of $12.6\ m = 500\ m^2$) was established using a center stake and a measured rope to assess tree species composition and density of overstory and regeneration strata (Avery and Burkhart, 2002). Within each plot, the total number of trees by species was recorded for all individuals > 5 cm measured at DBH). Seedling/sapling (≤5 cm diameter measured at ground level) were also tallied for major tree species. Additionally, the largest chilgoza tree in each plot was measured for DBH with a measuring tape. Evidence of livestock grazing and fuelwood collecting were noted. Plot field data were collected by surveyors (one per province) who were trained in Kabul by Afghan scientists in forestry field collection techniques. Surveyors had post-secondary education and family connectivity to a district within their assigned province. Data were collected using a tree diameter tape and a length of rope measured to delineate the plot boundary.

Additional field data were collected in Paktia and Paktika by forest scientists from the U.S. who were temporarily attached to ISAF military units (Groninger and Ruffner, 2010). Tree cores, dbh and height for live dominant trees were collected at one site each in Paktia (Shawat, Sayid Karam and Mirzaka) in October 2009 and Paktika (Sarobi) in August 2009 using a tree increment borer, diameter tape, and clinometer, respectively. Some tree heights were measured using photogrammetric image analysis if field time was insufficient for clinometer measurements. Increment cores were processed in the Forest History laboratory at Southern Illinois University using standard dendroecological methods including air drying, mounting, sanding, and cross-dating cores (Stokes and Smiley, 1968). Pith dates were determined using standard skeleton plots and visual cross-dating methods (Stokes and Smiley, 1968).

In order to study perceptions of socio economics, harvesting practices, and natural regeneration status of chilgoza pine forests of Afghanistan, Afghan forests scientists developed and administered a survey for local villagers/community members living in the EFC close to chilgoza pine forest stands. The survey consisted of 10 multiple choice, yes/no and short answer type questions. Selected survey respondents were asked to rate the level of natural regeneration occurring in the forests that they manage using a 5-point graded scale consisting of (1) no regeneration; (2) poor; (3) fair/medium; (4) good; or (5) very good. No regeneration indicated zero number of seedlings ≤5 cm in diameter in the forest floor. Poor indicated less than 5 m distance between newly regenerated seedlings in the forest floor. Fair/medium indicated 2–5 m distance between regenerated seedlings. Good indicated 0.5–2 m distance between regenerated seedlings. Very good indicated > 0.5 m distance between newly regenerated seedlings. Respondents were also asked to list tree species present in their village forests.

Prospective interviewees were approached at chilgoza markets at provincial capitals, wood markets, and at a workshop pertaining to chilgoza. In-person interviewees were selected at random from individuals encountered by researchers who identified as coming from a village where chilgoza pine is found. Additional prospective subjects representing districts too insecure for researcher visit were solicited

Table 1
Mean (± standard error) of stand density (trees per hectare) diameter at breast height (dbh) of largest chilgoza trees in chilgoza dominated forest stands surveyed in 17 plots, 6 districts and 4 provinces in the eastern and southeastern forests of Afghanistan.

Location (District, Province)	Plots No.	Species (trees/ha)				Largest chilgoza Dbh (cm)
		P. gerardiana	*C. deodara*	*P. wallichiana*	*Q. baloot*	
Musakhel, Khost	4	640 (153)	–	–	–	44.6 (2.1)
Qalandar, Khost	4	320 (42)	5 (5)	–	–	48.5 (1.7)
Zazai Aryob, Paktia	2	350 (70)	–	–	–	46.8 (0.0)
Ahmadkhel, Paktia	2	490 (170)	–	–	–	34.0 (3.7)
Urgun, Paktika	4	425 (33)	65 (40)	–	165 (79)	52.0 (10.8)
Alisheng, Laghman	1	340 (0)	–	160 (0)	440 (0)	24.2 (3.8)
Overall Mean		445 (48)	16 (11)	9 (0)	65 (34)	45.0 (3.0)

from in-person interviewees and a subset of these contacts were selected randomly for telephone interviews. A total of 56 subjects living around chilgoza pine forests were interviewed. The number of subjects varied from one subject/province to 23 subjects/province for a total representation of 29 districts across the 8 provinces containing chilgoza pine forests. Interviewee selection was impacted by security conditions, availability of subjects, and importance of chilgoza pine tree in a province. For instance, Paktia was the most secure and important chilgoza pine forest province. Thus, more subjects were selected from districts of this province. In contrast, Kunar was the most insecure and less important chilgoza province, so only one subject represented the entire province.

All of the interviewees were male, with ages ranging between 25 and 70 years, with a median age of 40 years. Those 50+ years old were village or community elders. Others were farmers, chilgoza forest guards, local chilgoza nut traders (20%), and other community members. 90 percent of the participants were illiterate. 10 percent had high school and college level education. Women are unrepresented among interviewees, given that land management issues and addressing outsiders are male-specific roles in EFC, making access to women informants practically impossible given the resources available to researchers. Additionally, this sampling scheme undoubtedly undersampled remote communities who are less likely to be present in markets or workshops. Since many of the subjects were illiterate, the majority of surveys were completed through in-person interviews where security allowed for direct contact with the researchers travelling to EFC from their offices in Kabul, or phone-based interviews in less-secure areas. All interviews were conducted November-December 2015, i.e. outside the fighting season. Kruskal-Wallis rank sum test was used to test significance of regeneration rankings at $\alpha = 0.05$. Fisher's exact test was used to compare regeneration status related to the impacts of livestock grazing and fuelwood collection and natural regeneration status of chilgoza pine at $\alpha = 0.05$.

3. Results

3.1. Chilgoza forest stand structure

Chilgoza pine was surveyed in monospecific stands and mixtures, with pure stands on dry slopes of the southern-most and western-most edges of EFC. In, Khost, Laghman, and Paktia (field data and villager survey data) as well as Kunar, Nangarhar and Nuristan (villager survey data), forest stands were most diverse. In these provinces, *Quercus baloot* Griffith. (holm oak), *Cedrus deodara* (Lamb) G.Don (deodar cedar), *Pinus wallichiana* A.B. Jacks (blue pine), *Abies spectabilis* (D.Don) Spach (east Himalayan fir), *Picea smithiana* (Wall.) Boiss (west Himalayan spruce), *Juglans regia* L. (walnut) (lower elevations) and *Reptonia buxifolia* A. DC. (gurgura) co-occurred with chilgoza pine. The forest communities in Paktika and Kapisa provinces were least diverse in that only holm oak and chilgoza pine were predominant in forest stands. Where field data were collected, the number of chilgoza trees in chilgoza-dominated stands ranged from 320 to 640 trees/ha (Table 1). In some stands, other tree species such as deodar cedar, blue pine, and holm oak were found as well. In southern provinces (Khost, Paktia and Paktika), chilgoza pine dominated the overstory. Only in one stand surveyed (Laghman province) was chilgoza pine mixed with holm oak and blue pine. Here, holm oak was the dominant species.

3.2. Chilgoza pine size and age class data

Wide variation in tree sizes and ages were found within each site with diameters ranging from 12.9 to 79.1 cm, with the managed orchard site in Paktika having the largest and oldest trees (average age 211.8, between 79 and 309 years old), and the tallest specimens (10.4 m) (Fig. 4). The natural stand sites in Paktia yielded an oldest tree date of 241 years at 51.6 cm dbh with additional recruitment represented by measured trees aged 68–159. In response to unstable security conditions, tree growth increment core collection was limited to large, and presumably older trees, within a stand. However, some of the largest individuals that appeared at risk of containing a decayed core were excluded from sampling. Therefore, it is likely that older and younger trees were present in these stands but this could not be confirmed due to accessibility limitations given the constrained sampling timeframe (approximately 30 min per site).

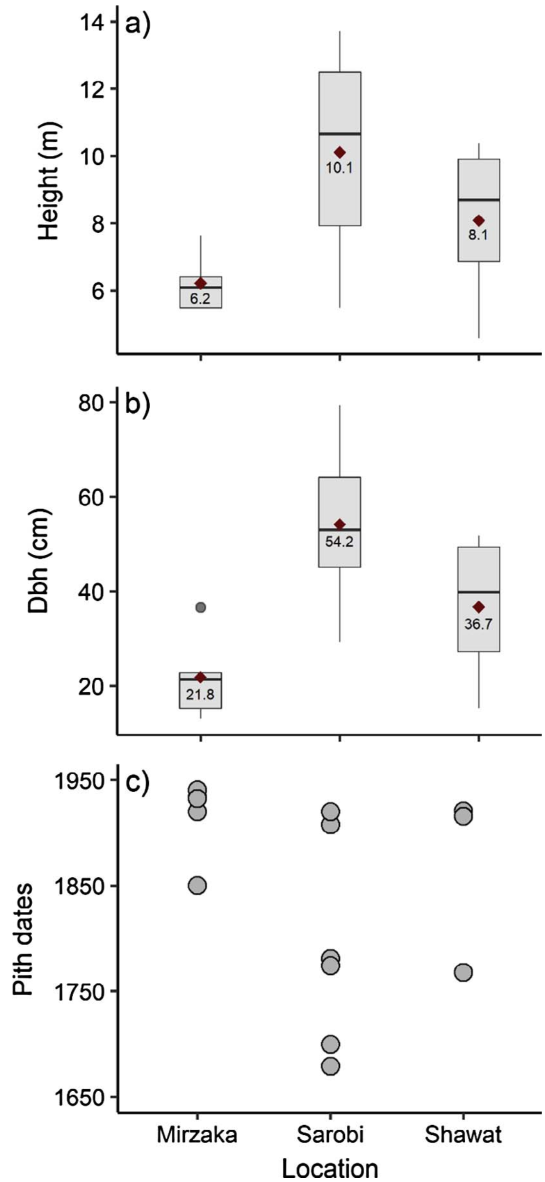

Fig. 4. Dendrochronology data from chilgoza pine trees from mixed stands in Paktia (Mirzaka (n = 5) and Shawat (n = 3)) and a managed orchard in Paktika (Sarobi (n = 6)) Provinces collected in 2009.

3.3. Community representative perception of the status of chilgoza pine forests

The vast majority of surveyed villagers (95%) in the chilgoza pine region did not realize the declared threatened status of chilgoza pine trees (Table 2). However, most of the respondents were aware of chilgoza forest degradation and that human activities played a role in this decline (59%). Frequent cone collection, tree damage during cone harvesting, grazing, and fuelwood collection were each recognized as contributing to the observed degradation.

Table 2
Knowledge of local villagers on threatened status of chilgoza pine and their perception of chilgoza pine forest degradation and its contributing factors. Perception of local villagers on natural regeneration occurrence of chilgoza pine; and rate of natural regeneration in chilgoza pine forest stands.

Question	Sub-question	Yes (%)	No (%)
Threatened species		5	95
Degradation		59	41
Threats to degradation	Tree damage during cone harvesting	86	14
–	Too many cone collection	82	18
–	Grazing and trampling seedlings	82	18
–	Fuelwood collection	91	9
–	Insects, diseases and drought	71	29
Grazing		79	21
Fuelwood		86	14
Regeneration		95	5

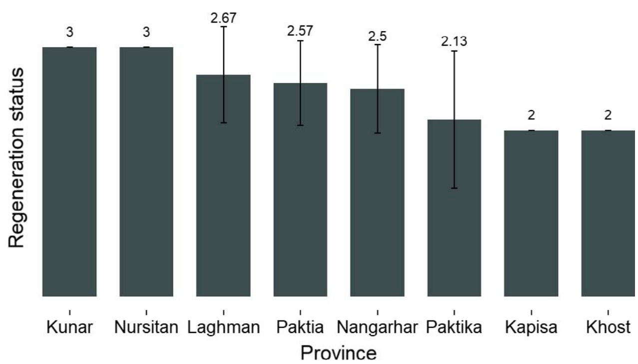

Fig. 5. Mean natural regeneration status of chilgoza pine among provinces based on survey of villagers' perception. 1 = no regeneration, 2 = poor regeneration, 3 = fair regeneration, 4 = good regeneration, and 5 = very good regeneration. Kruskal-Wallis rank sum test was significant at α = 0.05 (chi-squared = 14.4, df = 7, p-value = 0.04).

Survey respondents reported poor (50.0%) or fair (46.4%) natural regeneration with the remainder reporting no regeneration. At the provincial level, Kunar and Nuristan provinces were found to have fair chilgoza natural regeneration and Kapisa and Khost reported poor levels, with the remaining provinces ranging between poor and fair (Fig. 5). The survey data also suggested that villages allowing grazing and fuelwood collection had lower levels of regeneration than those prohibiting those practices (Fig. 6a and b).

Table 3
Mean (± standard error) number of naturally regenerated chilgoza pine, *C. deodara*, and *Q. baloot* seedlings and saplings per hectare in chilgoza dominated forest stands surveyed in 17 plots, 6 districts and 4 provinces in the eastern and southeastern forests.

Location (District, Province)	Plots No.	Species (No./ha)		
		P. gerardiana	*C. deodara*	*Q. baloot*
Musakhel, Khost	4	100 (22)	–	–
Qalandar, Khost	4	20 (8)	–	–
Zazai Aryob, Paktia	2	3030 (690)	160 (0)	280 (100)
Ahmadkhel, Paktia	2	1530 (110)	–	210 (0)
Urgun, Paktika	4	270 (100)	–	–
Alisheng, Laghman	1	240 (0)	–	260 (0)
Overall Mean		642 (254)	19 (19)	73 (35)

The field survey of chilgoza pine stands also revealed that natural regeneration of this species was variable between sites (Table 3). Natural regeneration was best, with 3030 and 1530 stems ha^{-1} in Zazai Aryob and Ahmadkhel districts of Paktia province. In these districts with the highest regeneration success, livestock grazing and fuelwood collection were prohibited by local tribal councils (*shuras*). Natural regeneration in the districts of other provinces (Khost, Paktika and Laghman) was lower, ranging between 20 and 270 istems/ha (Table 3). The forest stands in these areas were unmanaged by *shuras* and heavy cone collection, livestock grazing, and fuelwood collection were common practices.

4. Discussion

Our results suggest that chilgoza forests of EFC are diverse in structure, reflecting a socio-ecologically complex environment. In this study, stand densities were sometimes much higher than numbers reported for chilgoza forests outside of Afghanistan (Ahmed et al., 2006; Akbar et al., 2011; Khan et al., 2015). Several factors may account for the greater chilgoza stand densities than those reported from other countries. One is that the stands surveyed in this study targeted chilgoza dominated forests within its native range. Another factor is that chilgoza forests of Afghanistan are located in the western-most edge of the species range and the environmental conditions (low precipitation, well-drained and sandy textured soils, and other allogenic disturbances) might favor colonization of chilgoza over associated mesophyte tree species (Troup, 1921; Ahmed et al., 2010; Kumar et al., 2013).

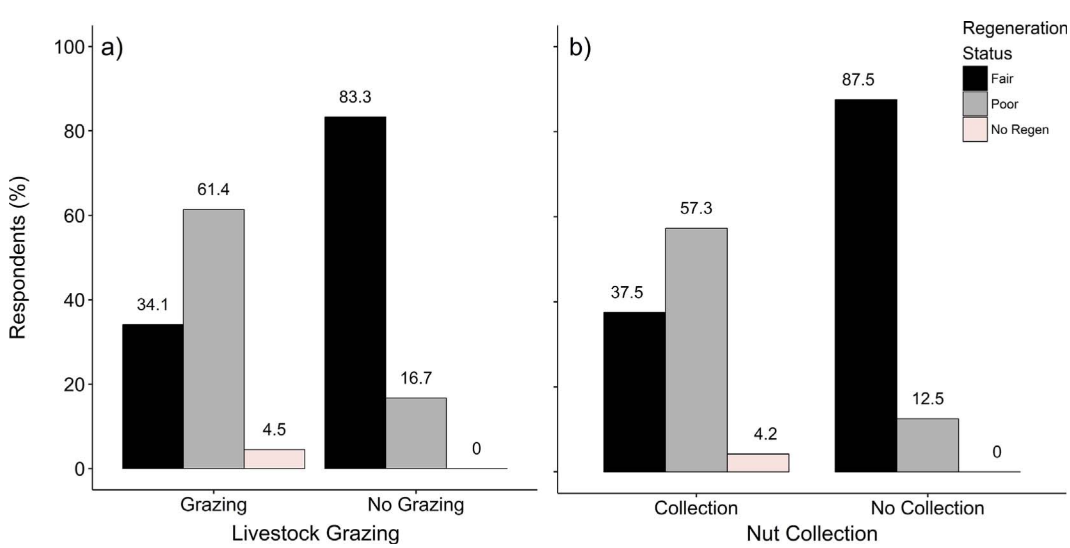

Fig. 6. Survey results showing effects of, (a) livestock grazing and (b) fuelwood collection on natural regeneration status of chilgoza pine forests. Fair = few number of scattered seedlings 2–5 m apart from each other, Poor = very few number of scattered seedlings > 5 m apart from each other, No regen = zero number of seedlings. Natural regeneration status was determined by selected survey respondents. Fisher's exact test of association was significant for both tests at α = 0.05. P-value of a = 0.01; and, P-value of b = 0.03.

Occurrence, density, and dominance of chilgoza and associated tree species may be affected by precipitation, and utilization patterns. For instance, in Laghman, greater precipitation levels may have provided better growing conditions for fast growing species such as blue pine and holm oak.

Low stand density was associated with multi-cohort management and maintenance of *Pinus pinea* L. (stone pine) (Calama et al., 2008). In the present study, partial cutting that falls short of that observed under commercially-driven illegal logging may also positively impact chilgoza recruitment. Local villagers tend to favor chilgoza trees by removing oaks growing underneath their crowns. Natural regeneration we observed on some sites may have originated from illegal logging activities. Specifically, chilgoza trees occupied the understory and mid-story following selective logging of deodar cedar and blue pine. Local elders surveyed in this study corroborated this explanation mentioning that chilgoza trees were less common in forest stands prior to the illegal logging that proliferated since 1979. Removal of these other timber species may have promoted environmental conditions for successful regeneration and establishment of chilgoza. However, chilgoza mortality results from aggressively stripping all branches from small trees to ease cone harvesting. Also, young chilgoza trees are cut for firewood and their stems are used to make shovel and axe handles that may counteract the benefits of partial overstory removal on understory biodiversity (Khurram and Shalizi, 2016). Chilgoza seed harvesting intensification, but undertaking no site preparation, planting, or protection of seedlings from ongoing grazing and firewood collection may similarly degrade chilgoza forests without providing forest floor conditions needed to establish new cohorts.

Precipitation and illegal logging may interact to impact regeneration dynamics. The late 20th century was the wettest on record for central Asia and might be associated with relatively favorable regeneration reported here (Treydte et al., 2006). Furthermore, the two provinces with the highest precipitation rates exhibit the least unfavorable regeneration status. At these wetter sites, maturing chilgoza trees occupy gaps likely created by illegal logging. In contrast, the number of chilgoza seedlings was lower on dry sites where harvesting was not managed. Further study is needed to determine the net ecological effects of climate and myriad anthropogenic disturbances across the forests types of EFC.

All three stands yielding dendrochronological data exhibited multiple periods of recruitment throughout the past three centuries, suggesting at least two-aged stand structure at the Paktia sites, and unevenaged structure in Paktika. The large diversity in tree ages indicates that the silvical properties of chilgoza pine provides for sustained cone production with the possibility for developing new cohorts within the same stand, provided grazing and fuelwood collection are restricted sufficiently to allow opportunities for recruitment. This is very fortunate, given the limited number of suitable sites for commercial cone production and the continued importance of this enterprise for local people.

The EFC of Afghanistan and adjacent portions of Pakistan are among the least documented temperate regions in the world. Accordingly, published tree ring studies from any species here are non-existent (Singh et al., 2009). The number of core samples collected in this study across such a variety of sites are insufficient to construct a regional tree chronology. Chilgoza tree growth tends to be positively correlated with winter precipitation prior to the current growing season, and to spring temperatures which regulate the rate of snowmelt (Singh and Yadav, 2007; Singh et al., 2009). In particular, a fully developed climate model for the region could determine whether periodic chilgoza pine recruitment is linked to climatic variation or to local grazing/wood collection practices. The inter-annual growth variation exhibited by chilgoza pine is more broadly important to watershed management interests within the Kabul-Indus watershed where precipitation rates are also highly variable (Hasson et al., 2014). Dendroclimatic information would help better understand water availability patterns within historic norms. Given the proven cross-datability of chilgoza pine and its demonstrated climate sensitivity (Bhattacharyya et al., 1988; Singh et al., 2009), the species should be prioritized for further study to help address watershed management concerns, as well as to enable scientists to see how these populations responded to past climate patterns.

Fig. 7. Mixed chilgoza pine forest stand in Paktia province (district unknown). From left to right, are *P. wallichiana*, *P. smithiana* and *P. gerardiana*. Approximately 15 mature trees were logged in this particular spot creating microenvironments conducive to chilgoza pine recruitment.

Previous reports were very general in describing drivers and incidence of chilgoza pine degradation. These included intense fuelwood and cone collection, poverty, lack of governance, armed conflict, lack of education and awareness, and insufficient access to science and technology (UNEP, 2008; Groninger, 2012). Additionally, our data suggest that vulnerability to damage may specifically relate to forest composition. We found the concentration of chilgoza-dominated stands in the southern provinces (Paktika, Khost, Paktia) may be most subject to degradation through intensive crown harvesting rather than removal of individual cones favored by local harvesters working in the mixed stands that characterize chilgoza forests elsewhere (Fig. 7). Degradative cone harvesting in the southern region is associated with heavy reliance on outside contractors (Khurram and Shalizi, 2016). The contractors are more prone to stripping cone-bearing branches from trees to maximize extraction efficiency and without regard for subsequent tree health. During such a harvest, all cones on chilgoza trees are commonly removed. Occasionally, a few cones remain at the very top of the crown due to inaccessibility. These cones may release seeds resulting in some natural regeneration. However, after germination and establishment, newly regenerated seedlings may be browsed by livestock or trampled during fuelwood collection, thereby reducing the potential to attain adequate natural regeneration density.

Few respondents reported regulation of cone harvesting within their village. While villagers seem to be aware that severe cone collection, in association with uncontrolled grazing, led to gradual decline of their forest stands, they appear to lack the knowledge, skills, or financial incentives to improve the situation. We suggest that this condition stems from customs and practices in harvesting, and the need of these communities to maximize immediate revenue due to economic hardship (Groninger and Pense, 2013). Potential longevity of chilgoza may also decrease the perceived urgency of establishing and maintaining regeneration cohorts.

Most of those surveyed reported that regeneration is present but that local stakeholders perceive the rate of natural regeneration to be insufficient. Previously published research based on limited informant interviews that were restricted to portions of a single province suggested that tree regeneration was more typically scarce or absent and that local people did not perceive this to be an issue of concern (Groninger and Ruffner, 2010). The present study indicates a more diverse situation, perhaps by surveying communities farther from passable roads. At these more remote locations, where natural resource exploitation is less rampant, the presence of regeneration and recognition that it is inadequate suggests that natural forest dynamics remain somewhat intact, stakeholders are more knowledgeable, and forest land tenure remains more stable.

The study indicated that traditional natural resource institutions are present and functioning in at least some locations in EFC. The agencies representing the central government in most of the EFC lacks technical expertise, plans or accessibility, thus there is no conventional management of grazing, nut collection, or timber harvesting activities in most of the forest stands (Groninger, 2012; Groninger et al., 2013). In places where forests are managed, it is the local council (or shura) composed of community elders and other individuals (all are men) who make decisions. Lacking a management plan, the council determines the time of cone collection, forest guard recruitment, whether or not to graze or collect wood, and fining individuals who violate the council laws. All respondents who indicated the presence of forest management or protection attributed responsibility to the local shura.

This study was severely limited by poor security conditions and limited physical access, constraining sampling to just a few sites, with a bias toward areas accessible by road, and for short time periods. The results of this study support the value of multiple approaches to data collection for characterizing the diversity of forest conditions where field and questionnaire survey opportunities are highly constrained by security concerns. Villager surveys were conducted by Afghan forestry professionals from Kabul who were native Pashto-speakers. Their primary risks were being kidnapped for money while in transit by automobile, or being captured by AGE while in the villages. They minimized risk by wearing traditional clothing, carrying modest personal possessions, and restricting travel to relatively safe villages. Trained surveyors had the best access to field sites, particularly within their home districts. However, while in the field, they too avoided any behavior that would arouse suspicion and refused to carry or use specialized forestry data collection equipment due to fear of detection and detention by AGE. Even these Afghan personnel with local connections did encounter villagers who perceived their presence and work as threatening or potentially destabilizing. U.S. personnel had access to field sites as part of multi-mission military maneuvers using armored vehicles. Their field visits were very visible and attracted AGE attacks. While in the field, researcher movement in mountainous terrain was impaired by the need to wear heavy body armor, as part of armed dismounted military patrols. Forests were accessed through long distance mounted patrols accompanied by multiple armored vehicles and armed security forces. This protection allowed use of specialized equipment without the risk of U.S. researcher detention experienced by Afghan counterparts. However, opportunities to enter chilgoza forests were limited by characteristically complex missions that rarely accessed native chilgoza forests, and very short small sampling timeframes when forests could be accessed. Attempts to collect further dendrochronological data, including more trees at the sites reported here, were thwarted by orders from dismounted patrol leaders to vacate chilgoza stands in order to reduce the risk of becoming the target of active snipers in the area. The need for rapid data collection was compounded by the difficulties associated with traversing steep terrain with body armor. This necessarily biased field visits toward locations nearest road access points, suggesting that forests potentially less impacted by other human access-dependent activities such as fuelwood harvesting or logging are certainly under-sampled under the security conditions we encountered. For Afghan surveyors and U.S. researchers alike, field data collection was generally limited to a single visit of 30 min or less per site to avoid attracting attention and contact from forces hostile toward surveyors and to prevent retribution against hosting villages. For all personnel in this study, including villagers, inadvertent exposure to incidental clashes were a constant concern.

The need for accurate and practical data remains in landscapes that are both ecologically and socially unstable. Scientific and natural resource management communities should strive to establish cooperative efforts that can foster more collection of standard forest and dendrochronological measures to build a database of connected monitoring sites under similarly extraordinary conditions. We suggest that the approach demonstrated in this study, utilizing multiple methodologies during small windows of opportunity, provides a model that may represent a best-case scenario in remote regions where security is poor and unlikely to improve.

5. Conclusions

Chilgoza forests exist in various states of degradation throughout eastern Afghanistan and across much of its range. The data collected here reveals generally poor chilgoza regeneration adequacy across EFC. However, variation in its status suggests a level of complexity not previously reported and that is associated with excessive and unregulated local fuelwood and grazing practices in chilgoza forest understories. With this information, situation-specific policies and public education programs could be tailored to specific local socio-ecological conditions, similar to those suggested for edible nut bearing trees in Europe and North America (Calama et al., 2008; Lopez-Mata, 2013). Primary areas of focus should include sustainable cone collection, improved grazing practices, prudent fuelwood collection, and highlighting the economic benefits for doing so. We suggest that a cooperative data collection strategy pooling the relative strengths of local, national, and international entities, may enable data collection and inform natural resource recovery efforts, even under conditions of extreme insecurity.

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