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Review Paper

POTENTIAL CHALLENGES AND THREATS ASSOCIATED WITH PINE NUT CULTIVATION AND MARKETING IN PAKISTAN

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ABSTRACT

Pine nut or chilgoza pine (*Pinus gerardiana*) is considered one of the most valuable non-timber forest species (NTFP) of Pakistan Pine nut is a rich source of many valuable food constituents including unsaturated fatty acids, sugar, vitamins and minerals. Due to the poor management policies and heavy exploitation, it has been listed as threatened species by the IUCN. Pine nuts lose their quality and nutritional value due to poor processing technologies that tend to lower their acceptability in big markets. In order to increase the market value of pine nuts, research institutes should work in collaboration to conserve this endangered valuable species by developing good quality pest-resistant seeds. Moreover, they should propose such treatments which help to extend the shelf life of pine nut seeds during processing and storage on a commercial level. Meanwhile, the government should launch new projects to understand the dynamics of the pine nuts life cycle together with sustainable conservation.

Keywords: Pine nut, chilgoza, marketing, natural regeneration, forest, Pakistan

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INTRODUCTION

Pine nut or more commonly known as chilgoza (*Pinus gerardiana.* L) belongs to the family *Pinaceae* and is one of the superior nuts having both nutritional and medicinal value. Pakistan is considered the second largest pine nut-producing country after China. Over the globe, the demand for pine nuts produced in Pakistan has increased due to their aroma and peculiar taste (Wazir and Javed, 2018). Chilgoza pine tree is native specie to Western Himalayas, the Hindukush mountainous ranges of Pakistan and Afghanistan with further extensions toward the south of the Suleiman ranges in Baluchistan. However, some species of chilgoza were also geographically identified in the inner dry valleys of Chitral, Kurram, Upper Swat, Astore, Shingar, and the Northern Areas. Chilgoza forests are mainly present in the dry temperate zones of Pakistan, where the natural rainfall rate is found to be less in comparison to the snowfall. Archeological studies depicted that chilgoza pine is the only edible pine nut species present in Pakistan, India, and Afghanistan among all the pines (Trak and Giri, 2017). Few pine nut species also grow across North America and European terrains. These pine nuts are either used raw, roasted or combined with other different nuts for trading purposes in national and international markets across the world (Shalizi and Khurram, 2016). The nomenclature used for pine nuts across the world and its detailed taxonomic classification is presented in Table 1.

Table 1: Nomenclature of chilgoza and its taxonomic classification (Singh *et al.*, 2021).

Nomenclature	
English	Pine nut, Edible pine, Neosa pine
Urdu	Chilghoza, Chilgoza
Hindi	Chilghozaa, Neoza, Gunobar, Rhee
Taxonomical classification	
Kingdom	*Plantae* (plants)
Sub kingdom	*Trachiobionate* (vascular plants)
Superdivision	*Spermatophyta* (seed plants)
Division	*Coniferophyta* (conifers)
Class	*Pinopsida*
Order	*Pinales*
Family	*Pinaceae*-Pine family
Genus	*Pinus*
Specie	*gerardiana*

Botanical features and nutritional profile of pine nuts: A pine is a medium-sized tree ranging from 12-18 m in length and 0.4 m in diameter with a short and rounded crown and flat branched network. The cones tend to bloom in June and July, and the female cone develops fruit and turned reddish-brown on ripening. When the seed's get develop and mature, they shed from the female cones in September and October (Ahmed *et al.,* 1991).

Chilgoza pine wood is reportedly found as resinous, soft, even-textured, and sturdy with sapwood (white-yellow colored), and heartwood (reddish brown-dark brown colored). The average wood density of the chilgoza tree is reported as 580 kg/m^3. The traditional chilgoza nut is reported as 17-23 mm long and 5-7 mm wide which is further covered by a thin shell. A pine tree grows at an elevation of 2001-3000 m where the bark, leaves, wood, and cones produce oleoresins (Kanderian *et al.,* 2011; Malik *et al.,* 2012). These oleoresins are present in small quantities and extracted by tapping the tree bark. Oleoresins contain turpentine oil that can be employed in cosmetics, wax, cooking oil, varnishes, pitch, and traditional medicinal production (Groninger, 2012).

Pine nuts are a nutritionally rich source of carbohydrates, and proteins whereas fresh seeds contain 24.4% moisture, 4.1% sugar, and 52.1% oil contents (Malik *et al.,* 2013; Malik *et al.,* 2009). Chilgoza nuts are also considered a concentrated source of polyunsaturated fatty acids (PUFA) (Awan and Pettenella, 2017, Destaillats *et al.,* 2010), many vitamins including beta-carotene, thiamin (B1), riboflavin (B2), niacin (B3), pantothenic acid (B5), vitamin B6, folate (B9), vitamin C, vitamin E. Likewise the mineral proportions (Table 2) include calcium, iron, magnesium, manganese, phosphorus, zinc, potassium and phosphorus that promotes multiple curing and nutritional properties (Brufau *et al.,* 2006; Savage, 2001). Some pine nut species also exhibit inherent antioxidation potential due to the presence of flavonoids including catechins, flavanols, and flavanones (Miraliakbari and Shahidi, 2008).

Around the globe, about 20 species of pine nuts are available, which have been reported as energy boosters, helping to enhance vision and reduce anti-aging issues (Wazir and Javed, 2018). However, this high-value crop is under threat of weakened land management for many years, in Pakistan Resultantly, this issue compromised the integrity of this crop and also social instability (Ingalls and Mansfield, 2017). The continuous decline of these forest reserves, unsustainable processing practices, illegal harvesting of timber, and restricted technical knowledge in surrounding communities rapidly degrade the situation (Groninger, 2012), overgrazing, livestock farming, and logging consequently decline the growth of this specie (Lee, 2017; Urooj *et al.,* 2020).

Pharmacological potential of pine nuts: Along with effluent nutritional profile, pine nuts also possess medicinal potential and act as an antioxidant, carminative agent, stimulant, expectorant, and aphrodisiac (Khan *et al.,* 2011). The antioxidant potential is owing to the presence of phytochemicals including gallocatechin, catechins, tocopherols, lutein, lycopene, and carotenoids. Additional biochemicals present in nuts are alkaloids, flavonoids, glycosides, triterpenoids, saponins, phenolics, tannins, and β-carotene (Hosseini *et al.,* 2020; Sharma *et al.,* 2018). Pine nuts are reported to contain a significant amount of chiro inositol, pinitol, numerous glycosyl cyclitols (galactinol, galactopinitol A1, faopyritol B1, and other glycosyl-inositols) (Destaillats *et al.,* 2010; Ruiz-Aceituno *et al.,* 2012). A study reported that the oral administration of pine nuts (dose-specified) improved the oxidative stress indices, decrease fasting blood glucose levels, improved insulin resistance, and promote weight loss in streptozotocin-induced Wistar diabetic rats (Hosseini *et al.,* 2020; Zulfqar *et al.,* 2020). The results for the methanol plant extract treated chilgoza nuts for oxidative stress in diabetic rats reported a decrease in catalytic activity while an insignificant difference was observed in malondialdehyde in disease during treatment. In a study, pine nuts also helped to increase the superoxide dismutase and peroxidase content in diabetic rats at 750 mg/kg of methanol extracts (Zulfqar *et al.,* 2020). Pine nuts tree bark with hydro-alcoholic extract at a concentration of 500, 1000, 1500, 2000, and 2500 µg/mL exhibited strong *in vitro* anti-inflammatory activity resulting in the denaturation of albumin protein (Sharma *et al.,* 2018). This anti-inflammatory potential in pine nuts is associated with the presence of 3-carene, α-pinene, camphene, longifolene, caryophyllene, and bornyl acetate phytochemicals (Sharma *et al.,* 2020). Moreover, the hydroalcoholic extract at 500, 100 and 1500 µg/mL also exhibited strong antibacterial activity against gram-positive bacteria (*Staphylococcus aureus*) and gram-negative bacteria (*E. coli*, *P. aeruginosa*, *K. pneumonia*) (Cai *et al.,* 2017; Sharma *et al.,* 2020; Taipina *et al.,* 2009). Likewise, the antifungal activity of pine nuts was reported in a study against *Candida albicans* (Sharma *et al.,* 2015). Past research confirmed that the pine nuts concentrate prevented platelet aggregation and presented fibrinolytic activity, resulting in clot lysis (Sharma *et al.,* 2020).

Production and export status of pine nuts in Pakistan: Pine nut trees have been contributing 20% of the total cover of Pakistan (Urooj *et al.,* 2020). Fig. 1 represents the map of dry temperate forests (chilgoza forest) in selected areas of Pakistan The annual production of chilgoza is reported to be around 5600 tons with a 90% contribution from South Waziristan. South Waziristan covers approximately 20% of its forests with pine nuts from Shakai to Angoor Adda along the Afghanistan border. The harvested nuts are then sold in Bannu, D.I. Khan, Peshawar, Rawalpindi, and Lahore where after processing these nuts are packaged for sale in national and international markets (Wazir and Javed, 2018). Pakistan exports approximately 3500-4000 metric tons of pine nuts annually which is a total of 15% of the worldwide pine nuts production. A major proportion of pine nuts is exported to the Middle East, China, UK, USA, and Europe (Saeed, 2019). The details on the past

few years production rates and area under cultivation of pine nuts in major producing countries are presented in Table 3.

Table 2: Nutritional profile of pine nut seeds.

Nutrients	Unit	Value (g) per 100 g	Reference
Proximate composition			
Water	g	2.28	Awan and Pettenella, (2017)
Energy	Kcal	673	Awan and Pettenella, (2017)
Protein	g	13.69	Awan and Pettenella, (2017)
Total lipids (Fat)	g	68.37	Awan and Pettenella, (2017)
Carbohydrate	g	13.08	Awan and Pettenella, (2017)
Oil Content	g	45-65	Xie *et al.* (2016)
Total dietary fiber	g	3.7	Awan and Pettenella, (2017)
Total Sugar	g	3.95	Awan and Pettenella, (2017)
Ash	g	2.34 - 4.5	Zhang and Zhan, (2019)
Minerals			
Calcium (Ca)	mg	16	Awan and Pettenella, (2017)
Iron (Fe)	mg	5.53	Awan and Pettenella, (2017)
Magnesium (Mg)	mg	251	Awan and Pettenella, (2017)
Phosphorus (P)	mg	575	Awan and Pettenella, (2017)
Potassium (K)	mg	597	Awan and Pettenella, (2017)
Sodium (Na)	mg	2	Awan and Pettenella, (2017)
Zinc (Zn)	mg	6.45	Awan and Pettenella, (2017)
Vitamins			
Vitamin C	mg	0.8	Awan and Pettenella, (2017)
Thiamin (B1)	mg	0.364	Awan and Pettenella, (2017)
Riboflavin (B2)	mg	0.227	Awan and Pettenella, (2017)
Niacin (B3)	mg	4.387	Awan and Pettenella, (2017)
Vitamin B-6	mg	0.094	Awan and Pettenella, (2017)
Folate	µg	34	Awan and Pettenella, (2017)
Vitamin B-12	µg	0	Awan and Pettenella, (2017)
Vitamin A	µg	1	Awan and Pettenella, (2017)
Vitamin A (IU)	IU	29	Awan and Pettenella, (2017)
Vitamin E (α-tocopherol)	mg	9.33	Awan and Pettenella, (2017)
Vitamin D (D2+D3)	µg	0	Awan and Pettenella, (2017)
Vitamin K	µg	53.9	Awan and Pettenella, (2017)
Lipids			
Fatty acids (Total Saturated)	g	4.899	Xie *et al.* (2016)
C16:1	g	0.1627	Zhang and Zhan, (2019)
C18:1	g	22.66	Zhang and Zhan, (2019)
C20:1	g	2.1497	(Zhang and Zhan 2019)
Fatty acids	g	18.764	Xie *et al.* (2016)
C18:2	g	42.022	Xie *et al.* (2016)
C18:3	g	16.638	Zhang and Zhan, (2019)
C20:2	g	1.0422	Zhang and Zhan, (2019)
Cholesterol	mg	0	Awan and Pettenella, (2017)
Fatty acids (PUFA)	g	34.071	Awan and Pettenella, (2017)

Policies and role of the public and private sector in supporting the marketing of pine nuts in Pakistan: Pine nut comes under the category of international trade items because they can be consumed in both raw and processed forms. Apart from the whole nuts, different value-added products such as nut powder, nut butter, nut toffees, and caramel products are also in demand by consumers around the globe (Sharma *et al.,* 2013). Pine

nuts shared a huge economic market value on both national and international levels in comparison to its timber. However, the marketing of the pine nut is not so significant, as in Pakistan only two sectors; WWF-P and Federal institutions are working to raise the regeneration and marketing of the pine nuts. Still, there are no proper policies or legal enforcement have been made to conserve this threatened biological resource in Pakistan (Urooj, 2019). The current average natural regeneration rate of pine nuts is reported only 15%. Due to the high demand and market value, every loop of the chilgoza is being sold The seeds which fall on the ground get easily decomposed by the fungi or eaten by the insects. Moreover, the area under pine nur distribution is also very scarce, therefore, the harvested seed is only sold in big markets of Pakistan or used for export (Xiang *et al.,* 2019). The demand for pine nuts has been increasing day by day in the US as well, but sufficient data is not available for the global trade of this nut, even EUROSTAT, and Codex Alimentarius have not properly devised protocols for the pine nut trade in Pakistan (Awan and Pettenella, 2017). Past studies have reported that the processing of pine nuts has been raised by double due to the high demand in international markets and more will be supplied, therefore the professional involvement of local communities has also been increasing in the past few years (Latif and Shinwari, 2005).

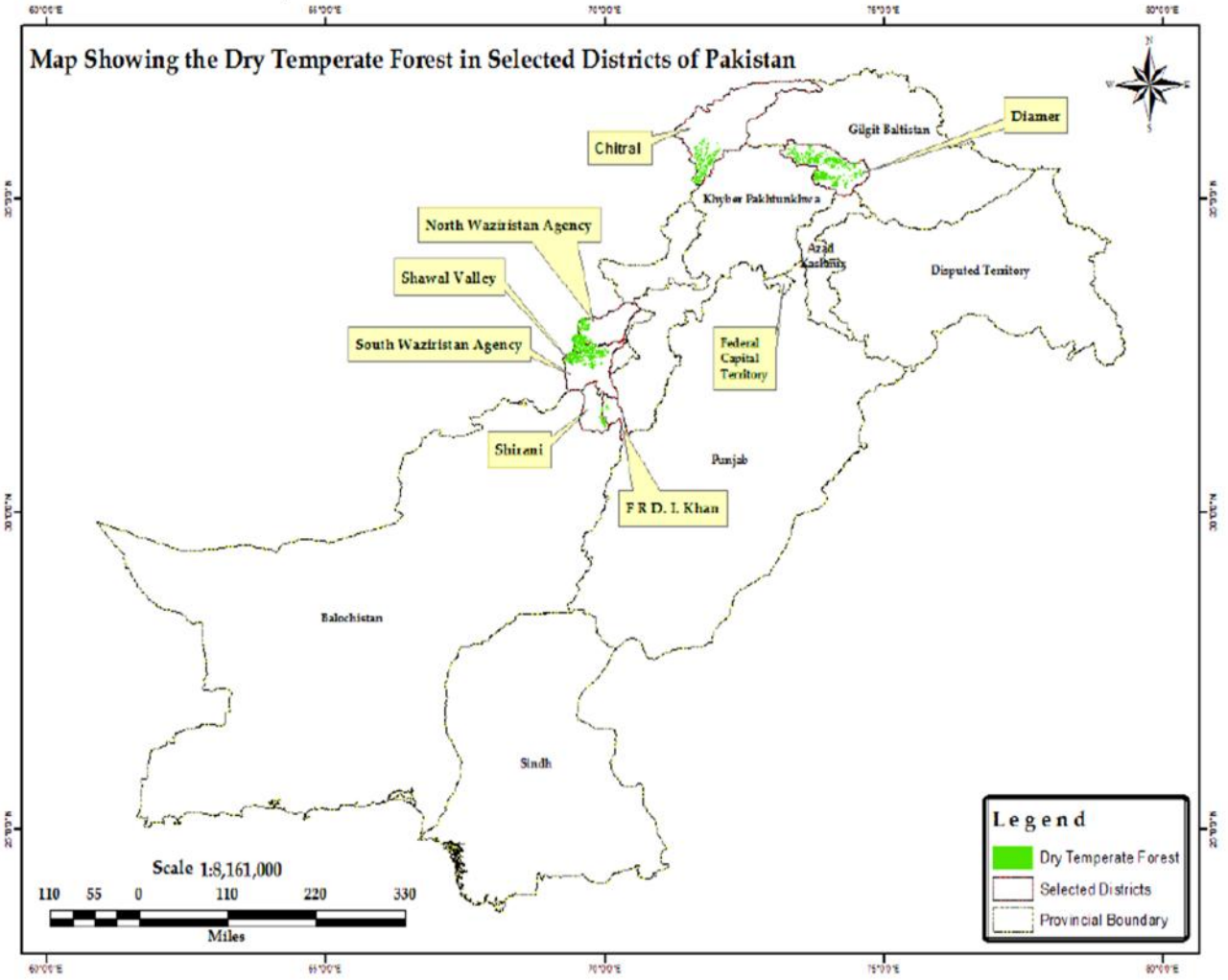

Figure 1: Map showing the chilgoza forest land cover in selected districts of Pakistan

Review Objectives and Data Collection: Pine nuts are proven an important trade specie in Pakistan due to their health and nutritional benefits. Although, Pakistan is a major pine nut distributor and is exported worldwide, however, still there are significant challenges that lower the quality and quantity of nuts. Considering the importance of pine nuts, this review is compiled with the aim, to sum up, all the challenges faced by the pine nuts during harvesting, processing, and marketing. Based on the challenges, the strategies will be designed in the last to cope with the challenges. The data is collected for this

review collected from online search engines including google scholar, science direct, and online survey portals.

Challenges associated with the chilgoza nuts in Pakistan: Natural forests play an important role to maintain the earth's ecosystem and in sustaining the livelihood of communities. In developing countries including Pakistan, the communities still lack advanced food processing technologies. Specifically, in rural areas and northern areas, people still lack advanced agricultural techniques and are truly dependent upon the forests to earn their livelihood. These people used to cut the natural forestation, therefore excessive cutting of trees and manual harvesting ultimately increase the deforestation rate. According to the report of ICUN, pine nut species have been declared ICUN red-listed and near threatened, endangered species (Urooj, 2019). There are many issues prevailing with the growth of pine nuts in different regions of Pakistan Some of the issues are natural as climate change, less rainfall, frequent droughts that result in less vegetation, and ultimately deforestation. Other major concerns are manmade such as illicit cutting of trees, excessive use of pasture for grazing of animals and weak law enforcement which cause slow growth of these trees (Ali *et al.,* 2014). WWF also reported that the local communities use these trees for timber and fuel extraction, instead, these trees have high economic value due to the growth of nuts. Therefore, chilgoza pine has remained in debate for many years due to associated preharvest and post-harvest issues in Pakistan

Challenges associated with the growth and harvesting of pine nuts in Pakistan: Chilgoza is a native pine species of Pakistan and is one of the slow-growing plants that required about 64 years to attain the 2 m girth at the stump of the plant. At the start of growth, it requires 3 to 4 years to attain plantable size. Pine trees that grow in low temperate regions faced low temperatures and scanty precipitation issues during their growth phase (Akbar *et al.,* 2014; Kumar *et al.,* 2016). The natural regeneration of this tree has very low and almost is decreasing over time. The main triggering factor of its slow regeneration is the unplanned cutting of trees and collection of pine cones by the local community for consumption and sale purposes (Kumar *et al.,* 2016). The production of fewer seeds in seed-producing years and seed dormancy due to the biotic stress also led to slow germination and regeneration. Only a few research projects have been conducted till now to address the reduction in seed germination time by controlling the biotic factors in the natural habitat, but this limited research is not enough to grow plenty of chilgoza trees used for commercial purposes (Kumar *et al.,* 2014).

Pine seeds are not lightweight therefore the wind dispersal of the seeds is also a limiting factor that contributes to the slow regeneration of the trees. Moreover, environmental factors such as very less humidity, high heat and frost also slow down the germination rate of the chilgoza trees. The newly emerged seedlings of this tree are more prone to tissue damage and desiccation from environmental stress than the older ones (Shalizi *et al.,* 2018). Seed growing medium and seed size also significantly influence the growth of the seedlings. The small seeds grow less because of nutrient deficiency as compared to the large seeds; therefore, the growth rate of such seeds is very low. The positive effect of the large seeds and growing medium which contain vermicompost on the growth of seedlings has been studied in many studies (Kumar *et al.,* 2016; Parker *et al.,* 2004; Seiwa, 2000).

The growth of the *P. gerardiana* species located in the Sulaiman Mountain Range (SMR) of Pakistan, where the latitude is between 2700 m to 3400 m above sea level, has been badly affected due to excessive anthropogenic conditions which are prevailed for the last 50 decades. Moreover, in the lower zone of SMR, this species completely vanished which possesses an alarming situation for the extinction of chilgoza from the SMR. Other associated factors of poor regeneration in this zone are excessive cutting of trees, unrestricted grazing of the animals, easy access to local communities, and uncontrolled nut collection. The soil and environmental conditions like soil erosion, sandy soil, drought conditions, infrequent nutrients in soil specifically nitrogen, sunlight, undesirable winds, and steepness of the slope are playing a direct role in the slow regeneration of this *P. gerardiana* (Aziz *et al.,* 2017). Natural regeneration due to earlier loss of seed viability is the major issue prevailing worldwide as this species is near extinct and red-listed as an endangered species in Red Data Book. Other factors associated with slow regeneration are the infrequent seed year and early dormancy (Malik and Shamet, 2009). Overgrazing of the animals in the pine forest is also a major threat to the regeneration of forests. Goats cause more damage by eating newly growing seedlings and tree leaves. Moreover, the outbreak of fires due to the negligence of the visitors is a responsible factor for the slow regeneration. A study reported the outbreak of fire in chilgoza forests in Kunday Qaisa in 1999 that turned the forest into a deforested area (Shalizi *et al.,* 2018). The reforestation of chilgoza pines is also a major problem due to the heavy pruning and branch removal at the time of harvesting (Groninger, 2012). Chaprote forest is also a natural conifer forest with an area of about 3.5 sq km and about 14.5 sq km is the lower and patchy cover. Chilgoza tree stand is only 10% and timber is used mainly for the firewood here, therefore, the growth in this region is very slow (Mumtaz and Dani, 1991). The pests of that region also found affecting the growth of trees. A similar study reported that in forest areas of the Gilgit Sai and Garobad Balti Gali regions of Pakistan, the wooly flying squirrels used to live in pine trees including blue pine *(P.*

wallichiana) and chilgoza pine for their food. The fecal samples of four wooly squirrels were collected and investigated. The result of all four samples confirmed that these squirrels were completely dependent upon the pine needles for their food. These studies confirmed that the presence of squirrels ultimately destroyed pine trees located at high elevations (Zahler and Khan, 2003). During growth stages, chilgoza trees are mainly attacked by pathogens and seed borers. A past study reported that the seed borer (Indian meal moth) *(Plodia interpunctella)* infested the seeds of the chilgoza tree and reduce the seed rate (Kumar, 2016). Another study conducted in the Himalayas, north India, showed that the insects that cause resistance in the natural regeneration of the pine trees are *Dioryctria abietivorella* (Grote), fir cone-worm, and *Euzophera cedrela* (cedar cone-moth). Their larvae used to lay in the cones and consume the seeds to fulfill their protein requirements. Moreover, the fallen seeds on the ground are normally consumed by birds specifically *Nucifraga caryocatactes* subsp. multipunctate and Eurasian nut-crackers, which hindered natural regeneration (Peltier and Dauffy, 2009). Pine seeds require adequate drainage at the time of planting in the nursery, if not available the seedling growth is directly affected. Still, there is insufficient work reported to determine the effect of seed size and growing medium on plant germination (Kumar *et al.,* 2016).

Harvesting, grading and post-harvest issues of chilgoza in Pakistan: The harvesting of nuts from the chilgoza cones was considered the most crucial step due to the use of crude methods. Most of the time the whole branch was cut for the cone and in severe cases, the whole tree was cut down, one of the major causes of the chilgoza forest degradation (FAO, 2018). Deforestation in any country also causes environmental problems including heavy floods, soil erosions, and a reduction in the supply of forest products. A study reported that the low forest area (4.8 million hectares only) and high deforestation rate (39,000 hectares) per year, made Pakistan a red Hot spot for deforestation (Zeb, 2019). Harvesting time is also a major concern, as there is no specified time for harvesting the pine nuts, some farmers harvested the pine nuts too early, some harvested too late and only a few of them harvested on time. The nuts which early harvested are very lighter in weight because of the immature kernels. The harvesting of the pine nuts depends upon the elevation, the trees located at lower elevations get harvested early as compared to trees grown at upper elevations (Kuhn *et al.,* 2006). After the harvesting, the nuts collectors grade the chilgoza nuts into three classes: Extra class, Class I, and Class II. This classification is not based on any national or international standards but is done by the natives based on a few distinguishing features including color, size, etc. Pine nuts that are harvested on time graded as Extra grade or Ist grade. Locally made sieves commonly known as "Chaj" of varying sizes are used for sorting and removal of dust, and dirt debris. These classes are proposed with specifications by the United Nations Economic Commission for Europe (UNECE) for the commercialization of forest products including nuts. However, the problem in grading is that collectors used only a few features for grading nuts instead of following the standards due to poor knowledge and law enforcement hence failing to earn maximum benefits. Chilgoza comes under the category of that NTFPs which is a source of income for 80% of the people living around the forests. These people rely only on indigenous knowledge for harvesting, collecting, processing, drying, packing, marketing, and consumption, and have no knowledge regarding advanced practices. About 65% of the product loss occurs after harvesting until the final consumption (Latif and Shinwari, 2005).

Impact of the biotic factors on quantitative losses of chilgoza during growth: One of the major threats to chilgoza trees is the attack of insects and pests during their growing stages, specifically at the cone development stage from (16-18 months). At that time trees are mostly attacked by cone borers and bark beetles due to slow growth. The seeds present inside the cones are mostly attacked by the moths (Akbar *et al.,* 2014). The climatic conditions that prevail in Pakistan are highly suitable for the growth of microorganisms including bacteria, fungi, and their metabolites. A study reported that the level of aflatoxins in the pine nut varieties growing in Pakistan was higher than the value of 4 µg/kg suggested in European Union (EU) regulations. Almost 20% of the pine nuts species were identified as infected with mycotoxins specifically aflatoxins and ochratoxins (Ali and Afzaal, 2014). A similar study was also conducted in India, where about 58 samples of chilgoza were investigated and 52 samples were found infested with mycotoxins. Among these 52 samples, the number of positive samples infected with aflatoxin, ochratoxin A, and patulin was 27, 21, and 4, respectively. The presence of mycotoxins lowers the quality and organoleptic properties of the seeds and nuts (Ono *et al.,* 2020). Another survey-based analysis was conducted in Jammu, India to evaluate the mycotoxins level including aflatoxins, ochratoxins A, and patulin in chilgoza during the year 2011-2012. For this survey, 58 samples of pine nuts were collected from different retailers of dry fruits and stored in sterilized polythene bags to avoid further contamination. All the samples found contaminated with aflatoxins (*Aspergillus flavus)* and infection rate was more than the maximum tolerable limits of (4µg/kg) proposed by the EU Commission (Sharma *et al.,* 2015). Table 4 present the details of the insect and pests that attacked the chilgoza at different stages of growth and storage.

Table 3: Production rate of pine nuts and area under cultivation of major producers.

Year	Country	Area under cultivation	Production Share	Reference
	China	5800 MT	34%	
	Russia	3380 MT	20%	
2019-2020	Korea DPR	3000 MT	17%	INC (2019-2020)
	Afghanistan	1500 MT	9%	
	Pakistan	1500 MT	9%	
	Korea DPR	4000 MT	23%	
	China	3500 MT	20%	
2018-2019	Afghanistan	3000 MT	17%	INC (2018-2019)
	Pakistan	3000 MT	17%	
	Russia	1575 MT	9%	
	China	8800 MT	39%	
	Korea DPR	3000 MT	13%	
2017-2018	Afghanistan	3000 MT	13%	INC (2017-2018)
	Pakistan	3000 MT	13%	
	Russia	2000 MT	9%	
	Korea DPR	6000 MT	25%	
	Russia	4900 MT	21%	
2016-2017	China	4000 MT	17%	INC (2016-2017)
	Afghanistan	3000 MT	13%	
	Pakistan	3000 MT	13%	
	China	5000 MT	26%	
	Russia	4050 MT	21%	
2015-2016	Korea DPR	3000 MT	15%	INC, (2015-2016)
	Afghanistan	3000 MT	15%	
	Pakistan	3000 MT	15%	
	China	25000 MT	62%	
	Korea DPR	5000 MT	12%	
2014-2015	Afghanistan	3100 MT	8%	INC (2014-2015)
	Pakistan	3000 MT	7%	
	Russia	2500 MT	6%	
	Pakistan	4000 MT	39%	
	China	2500 MT	24%	
2013-2014	Korea DPR	1500 MT	15%	INC (2013-2014)
	Russia	1000 MT	10%	
	Spain	375 MT	4%	
	Russia	10000 MT	54%	
	Pakistan	3000 MT	16%	
2012-2013	Korea DPR	2500 MT	13%	INC (2012-2013)
	China	2000 MT	11%	
	Turkey	350 MT	2%	

Challenges associated with the processing and storage of pine nuts in Pakistan: After collecting the nuts from the trees, the first processing step involved dumping off the chilgoza cones in the form of heaps into a closed room. The local collectors of nuts estimated that about 30% of the losses occur during the piling of the cones. The next step is the extraction of nuts from the cones and for this purpose pinecones get unpiled on a wooden cot after bursting up followed beaten by a wooden stick to remove nuts from the cones. This step is considered critical because the nuts present at the base of the cone get damaged. There is no specific instrument available for this purpose and the most locally made wooden spatula used yields >10% of the broken nuts. The overall nut recovery is very low by using this method and only about 5% of healthy seeds are collected. These extricated cones after removing seeds then used for fuel purposes only (Aziz *et al.,* 2018). Chilgoza nuts exhibited the lowest antioxidant activity among all the nuts, therefore, they are more prone to lipid oxidation specifically when they get unshelled. Lipid oxidation causes the formation of different aliphatic ketonic, aldehyde, and alcoholic

compounds that produce an off-flavor and painty smell in nuts (Haq and Abid, 2013). The roasting of pine nuts is an important processing step to stabilize the quality and enhance the flavor of the pine nuts. The commonly used methods by the processors for roasting nuts are gas and wood roasting. Wood roasting is considered an expensive process and difficulty occurs in the accumulation of wood fuel, which ultimately imparts hot spots on the nut and causes discoloration. Furthermore, for wood smoking manual labor is required all time to cut the wood and stroke the fire (Kuhn *et al.,* 2006).

The storage of sound nuts is a major concern in pine nut producing countries. In the existing literature, very little information is available on the best practices used to store pinenuts. A study suggested that if the seeds are stored at 1^{o}C in earthen pots, they can remain viable from November till May (the sowing period) without losing their viability (Malik *et al.,* 2013). Pine nuts are at great risk of the development of off-flavors and bad smells due to lipid oxidation and get rancid easily during long-term storage (Hoon *et al.,* 2015). The unsold nuts stored in storage houses get attacked by fungi and nut borers most of the time and lose quality within a few weeks of harvesting. A study recommended solar drying before the packaging and aluminum laminate pouch packaging to extend the shelf life of these nuts (Aziz *et al.,* 2018; Thakur *et al.,* 2012). This agreement is in support of the study that the long-term storage of pine nuts causes the development of off-flavor. However, the temperature storage of nuts can be able to reduce the oxidation rate. Moreover, low moisture treatment can be able to maintain the sensorial properties of seeds for up to 12 months (Cai *et al.,* 2013).

Table 4: Insect pests responsible for the quality losses of chilgoza.

Insect/Pest	Scientific name	Infestation area	Quality Issues	Reference
Indian meal moth	*Plodia interpunctella*	Chilgoza cones and seeds	Hollow cones	Pawan (2016)
Lepidopteron borer	*Homaloxestischolopis*	Chilgoza stored seeds	Damaged seeds	Kumar *et al.* (2016)
Seed bug	*Leptoglossus corculus*	Cone seeds	Limit the seed production in cones	Kumar and Kumar (2011)
Seed bug	*Tetyra bipunctata*	Chilgoza seeds	Limit the seed production in cones	Kumar and Kumar (2011)
Pine seed worms	*Cydia spp*	Chilgoza seeds	Seed losses	Kumar and Kumar (2011)
Pinecone looper	*Nepytia semiclusaria*	Chilgoza cone	Poor cone development	Kumar and Kumar (2011)
Aflatoxins	*Aspergillus flavus*	Chilgoza stored seeds	Contaminated seeds	Sharma *et al.* (2013)
Ochratoxin A	*Aspergillus ochraceus*	Chilgoza stored seeds	Contaminated seeds	Sharma *et al.* (2013)
Patulin	-	Chilgoza stored seeds	Contaminated seeds	Sharma *et al.* (2013)
Wood inhibiting fungi	*Ganoderma applanatum*	Rots in tree woods	Week tree trunk	Nasir (2005)
Wood inhibiting fungi	*Ganoderma lucidum*	Rots in tree woods	Week tree trunk	Nasir (2005)

Technological hurdles associated with the processing of pine nuts: One of the major constrain in the processing of the chilgoza is the unavailability of the latest technology from seed harvesting to storage. A survey-based study conducted in the district of Jammu, Kashmir reported that about 64.88% of people depend on pine nuts harvesting to earn their livelihood. During harvesting, the involvement of local and unskilled manpower damages the nuts. Further damage occurs during the extraction of seeds from the kernels due to the lack of scientific knowledge and the unavailability advance technology (Masood *et al.,* 2016).

Regulatory and marketing issues associated with pine nuts in Pakistan: There are only a few regulations available regarding the marketing of pine nuts in Pakistan to generate revenue for the country. As pine nut trees are grown in small patches in southern Chitral, at an elevation ranging from 1800-3500 m, and are popular among the people of Chitral as dry fruit. For many years, the native community used to harvest seeds even at immature stages for consumption purposes or to gifted to friends and families on different traditional occasions. Over the last 2-3 years, people become well aware and started marketing pine nuts to generate revenue (Ahmed, 2007). A study was conducted in the Doyan valley, located about 50 km away from the Tehsil Jaglot, district Gilgit. This valley consisted of about 400 houses and the community that lived there used to rear cattle and was dependent on pasture grazing for their cattle. Pine nut grows at a high rate in this valley, but the growth could not reach the maximum due to weak law enforcement and overgrazing by cattle. The lack of awareness about floral species leads to the cutting of valuable trees in this valley because most of the population living in this region are illiterate and they do not know the worth of endangered

species (Ali *et al.,* 2014). Marketing remained one of the major issues from the past years in the growth of the chilgoza. A supporting survey-based study was conducted in the Kalash valley, located in the southwest part of the Chitral district of Pakistan This valley is blessed with agricultural cultivation and other biological activities. The major cultivation of this region is corn, wheat, bean, potato and vegetables, walnut, chilgoza, and almonds. The people of Kalash are dependent upon agricultural and forest products for their economic and business needs. Chilgoza is grown in small patches and people collected seeds by climbing the trees. They used to remove all the seeds from the cones and sometimes cones are also removed from the trees. There is no trend of marketing the seeds in cities and most seeds are consumed by the local people, therefore, there is no natural regeneration of the trees in this range. Results of this study reported that about 156 people are involved in the collection of seeds and they used to sell seeds in only nearby regions to earn a profit (Ahmed and Latif, 2007). The other major issue in the marketing of pine nuts is the lack of local markets and long-distance from big markets therefore most of the harvested pine nuts are sold to local traders and common people. The amount of revenue generated is distributed among local people and villagers based on their work done (Shalizi and Khurram, 2016). Another study conducted in Kalash valley reported that the collectors used to sell their nuts to the local markets of Wana via a middleman (as a trader) as they have no access to other big markets of the country, in consequence, they face economic losses and the middleman collects all the benefits. Moreover, people are even not aware of the marketing strategies and techniques involved in the value addition of the nuts. In this scenario, there is no up-gradation has been done by the regulatory authorities in the supply chain and marketing of the chilgoza in Pakistan (Sher *et al.,* 2014). During trading over the globe, there are a lot of marketing and economic issues faced by Pakistan's chilgoza nuts due to the presence of toxins and pine mouth syndrome (PMS). PMS usually appears after 24 hours of consumption of the infected nut. This issue is mainly found in the Chinese nut species which imparted a negative effect on the European market and they banned the import of Chinese nuts (Ballin, 2012).

Role of management policies and research projects in the conservation of chilgoza forests in Pakistan

Current Scenario: Pine nut forests are among those forests that have never been managed by any formal forest management system in the country. The main reason for this is that all of these forests are privately owned by many tribes. The chilgoza forest cover present in SMR, Balochistan is managed by the Sheranis tribe, which is further divided into Largha Sherani in KPK and Bergha Sheranin in Balochistan. Bargha Sherani tribe is further divided into Oba Khel, Chual Khel, and Hassan Khel, and the major portion of forests is owned by the Oba Khel and Hassan Khel and a small portion is in the custody of Chual Khel. As per the discussion with people, management has full ownership of all the resources and production of this forest in Balochistan (Urooj and Jabeen, 2015). Pakistan has committed to increasing the forest cover by about 6% under the Millennium Development Goals, which could not be accomplished due to certain provisional and federal government constraints. In the last few years, a few major attempts (in the form of sustainable projects) have been taken by the government to increase the chilgoza afforestation. The major hopes for the resolution of financial issues are Green Climate Fund (GCF), Global Environment Facility (GEF), and Reducing Emissions from Deforestation and Forest Degradation (REDD) (FAO, 2018). Besides all, there were only a few projects initiated by the WWF-P to conserve the chilgoza in Pakistan, in 1991 WWF-P started a two-pronged strategy to control the logging of pine nut forests and restrict the hunting of Markhor. Another research project was offered by the Federal Ministry for Economic Cooperation and Development in 1998, under the title "Integrated Conservation and Development Program for Chilgoza Forest Ecosystem and the Dependent Community in Suleiman Range". Another project was started by WWF-P entitled "Conservation of Chilghoza and associated scrub forest in selected villages of Tehsil Sherani District Zhob" to improve the management of chilghoza rangeland and increase alternate sources of livelihood, in 2005-2007 (WWF-Pakistan, 2013). In Suleiman Region, WWF-P conducted another project for two years to conserve the chilgoza forest by increasing the forest area by about 260 hectares along with the increase in nut production and agricultural practices to earn more livelihood (Urooj and Jabeen, 2015). A research-based study was carried out in Suleiman Ranges, Balochistan to determine the health of the chilgoza trees and land cover these trees from the year 1999 to 2019 using advanced techniques of mapping Satellite Remote Sensing (SRS) and Geographical Information Systems (GIS). For this purpose, the supervised machine learning algorithm was used to classify chilgoza into seven major classes including thick chilgoza, sparse chilgoza, olives, vegetation, water, barren land, and mountains of that land cover, and calculate the cultivable cover area under each class and their rotation. Meanwhile, the Arc Model was used to calculate the health status of each class. During the study, a total of 256 random points were selected for sampling through satellite imaging, and these sample points were then compared with the geocoordinate systems recorded by the GPS, with further verification performed by google earth. The results of this study exposed that the area of about 174 km^2 was fully covered by thick chilghoza in the year 1999, but in 2009 it tend to

be decreased to 84.9 km^2. According to the results for the year 2019, a significant increase has been observed in the thick forest cover of upto 127 km^2. The sparse (thin) chilghoza cover occupied an area of 77.5 km^2, 247.7 km^2, and 139.9 km^2 for the years 1999, 2009, and 2019, respectively. These results showed the main factors for the decline in chilghoza cover during the 1999–2009 year were overexploitation and overgrazing. On the other hand, the gradual increase in land cover of chilghoza was seen after the year 2009 due to the involvement of some governmental and non-governmental organizations in the conservation efforts of the chilgoza forest (Urooj and Jabeen, 2015).

The Swiss Development Cooperation has helped to conserve the chilgoza forest in the Chitral district by conducting awareness programs, providing resources and marketing opportunities, and practices for the value addition of the chilgoza forest that helped in the capacity building of the chilgoza farmers. Pakistan's army remained a part of the rehabilitation program in conflicted areas of FATA and has been involved in the establishment of a chilgoza processing unit in Wana (FAO, 2018). Moreover, the Food and Agriculture Organization (FAO) has decided to help the Baluchistan Forest and Wildlife department to conserve the pine nut forest in the province by conducting a project entitled Reversing Deforestation and Degradation in High Conservation Value Chilgoza Pine Forest in Pakistan". The main aim of this project was to improve the growth of chilgoza trees, the introduction of sustainable management practices for the chilgoza forest for the generation of a variety of products, services, and functions for the development of a valuable supply chain of chilgoza nuts and to improve the livelihood of the people of Balochistan (FAO, 2021).

Conclusion and recommendations: Table 5 is presented a SWOT analysis as important conclusive evidence for the improvement of chilgoza cultivation. Chilgoza is one of the valuable NFTPs having both nutritional value and medicinal properties and is considered a highly demanded nut species in both national and international markets. It also provides revenue for the local community living in these forests. This review was conducted to collect data from the literature to understand the issues during the harvesting till the trade of pine nuts in Pakistan The focus was on the management practices, processing, storage, and regulatory issues that cause hurdles in the commercialization of (*P. gerardiana)*. The review concluded that the local community is unaware of the quality and safety standards and marketing linkages. These people do have not enough revenue to build storage houses to store the pine nuts and are not able to purchase advanced instruments for harvesting, collecting, and processing nuts. The only value-added practice used for the pinenuts is roasting which is also not performed by every collector due to high investment. The profit generated by the sale of this product is not equally distributed among all agents of the supply chain, therefore, mostly pine nut collectors used to distribute the pinenuts among their relatives and friends. Apart from these problems generated due to human activities, natural factors such as temperature, slow natural regeneration, weather disasters, insect pest attack and overgrazing of trees by animals are also responsible for the poor chilgoza trees growth in Pakistan The poor law enforcement by the regulatory authorities and weak established national laws to conserve this valuable species made it near to extinct species. One of the main gaps is the lack of research activities that can conserve the status of chilgoza nuts. At the time no improved varieties or resistant varieties are being developed to increase chilgoza cultivation. In the literature, only a few research studies are found that provide solutions to increase the shelf life of the chilgoza nuts at storage, moreover, the practical applicability is limited to the farm level. Overall, it has been analyzed that the growth and marketing of pine nuts in Pakistan are very heterogenous with mixed management approaches. In order to improve the economic status and conserve pine nuts in Pakistan, certain steps should be taken by the management and regulatory authorities. In a nutshell, all the baseline work highlighted in the aforementioned sections, the significant barriers to the conservation of chilgoza forests are:

- Governmental issues include land problems, the development of organizations and training centers for chilgoza farmers, and the involvement of the local community.
- Poor understanding and exposure to REDD+ and other research programs by the chilgoza farmers.
- Availability of insufficient or limited forest extension resources.
- Unavailability of chilgoza research institutes and lack of research on the production of resistant chilgoza varieties.

Policy Recommendations: Few recommendations have been proposed to improve pine nuts status in Pakistan and to solve the problems of their farmers:

- Pine nuts forests must be managed by Government officials only and a proper management plan should be proposed to conserve this endangered species.
- The complete inventory should be managed of standing trees and their growth year should be determined by counting the growth rings. This practice would be helpful to estimate the tree's age and will tell its production status.
- There should be a ban on the illicit cutting of trees for wood and overgrazing by animals. And heavy penalties should be imposed on the lawbreakers.

- Like other forest trees, Government should step forward for natural regeneration and increase the number of pine trees growing per year in an area.
- Disaster management cells should be established, and their training should be done to prevent deforestation in any forest area due to natural disasters like storms, and forest fires.
- Government should introduce training plans for the pine nut harvesters and provide them with advanced technologies to reduce processing losses.
- The grazing pattern for an area should be on rotation so that there would be an equal load of grazing on every pasture. The limits for biomass consumption should be decided to overcome the overgrazing issues.
- The established marketing links should prolong, and local collectors should have easy excess to the big markets. This would be possible if both Governmental officials and non-governmental organizations work hand to hand to develop a direct link between local people to big markets by providing transport just to avoid the involvement of the middleman, this will ensure maximum benefits for the local community.
- The standards for the trade of NTFPs should be updated for national and international markets. The enforcement of trade standards must be encouraged by the local harvesters and nuts collectors.
- The forest department should involve the native community in training and introduce them to new tools and techniques that are used for harvesting and processing chilgoza nuts.
- Research institutes should also work in collaboration to conserve such endangered valuable species by developing seeds with good quality pest-resistant and that can grow early. Moreover, research institutes should propose treatments that can help to extend the shelf life of the pine nuts during processing and storage on a commercial level. Government should launch such projects and provide them with incentives.
- The packaging of nuts should be improved to resist the biochemical changes in nuts during storage due to auto-oxidation.

Table 5: Swot analysis of chilgoza pine challenges in Pakistan.

Strengths	Weaknesses	Opportunities	Threats
Grown in a large cultivable area of Pakistan	Slow regeneration of chilgoza pine.	Production of improved varieties of chilgoza in research laboratories. Conservation of the natural regeneration area of the forest. Use of GIS and SRS to determine the health status and growth rate of chilgoza trees.	Pinenut trees are near extinction due to slow regeneration rate and rapid deforestation for fuelwood.
Pine nut forests are a source to earn livelihood for native people.	Many pine nut forests are not under the authority of the government; instead, they are managed by the local tribes and many of them used the chilgoza trees for timber production.	Government should develop management policies to conserve this natural habitat and should maintain the inventory of the standing trees. The provision of alternate energy resources for native communities would help to conserve forest resources.	The uncontrolled cutting of trees and poor management policies would ultimately cause deforestation.
Chilgoza grown in Pakistan is considered one of the best varieties in terms of taste, shape, and nutrition.	Poor harvesting and processing technologies used for the chilgoza.	Introduction of advanced technologies for harvesting and processing of chilgoza Advanced and safe transporting and storage facilities should be provided to increase the quality and quantity of the produce.	Reduction in the ultimate production of the chilgoza nuts
Can generate high revenue for the country due to high demand in the export market.	Less availability and poor follow-up of the regulatory standards used for the export of chilgoza.	Increase the export rate by strict enforcement of laws and regulations for the export market. Export should be conducted	The export will be reduced if conditions prevail the same in the coming years.s

		under government laws and through legal channels.	
Source of food for grazing animals	Overgrazing by the animals specifically the goats reduces the nut production rate	Overgrazed areas should be prohibited by the government official for grazing and allow the natural regeneration of the chilgoza trees. Afforestation should be encouraged and fencing of the specific area can reduce the access of animals.	Overgrazing would remove the trees and the forest will be blank ultimately causing deforestation.
The soils of Pakistan have plenty of nutrients and allow natural seedlings to grow.	The low germination rate of the seedlings and difficulty to survive in harsh conditions.	Pretreatments should be applied in seedling growth nurseries and directed in the forest areas to the survival of species during growth Most important genetically improved multipurpose varieties should be developed to increase the growth and uplift the socio-economic status of the local community.	Slow germination would reduce the growth of the new trees and ultimately production will be reduced
Easy harvesting on maturity and locally available community involved in the harvesting.	Harvesting is done by local traders who are not aware of the harvesting stage and most of the time they remove the cons from the trees.	Government should establish regulatory authorities and train the harvester regarding the use of advanced harvesting techniques.	Chilgoza trees will not remain productive due to unstable and illegal harvesting.
Pinenuts collection and storage are performed by the local community no additional labor is required.	No proper tools and equipment are available for nut collection, cleaning, and storage, and most of the time collectors get harm themselves by damaging the kernels.	Capacity-building training of collectors for proper fruit collection and value addition of the nuts to earn more profit that would be beneficial for the local communities as well.	Low profit and unavailability of nut collection tools would discourage the working potential of the community as well.
Due to its small size, transportation is easy to market.	Fewer market linkages of collectors to the market increase the involvement of middlemen and profit agents.	Forest departments and international bodies e.g; ICUN, and WWF should develop non-timber products marketing committees and develop a direct linkage with the national and international market to avoid the involvement of the middleman and commission agent.	All the profit earned by the middleman or commission agent would generate low profits for the chilgoza nuts collectors and ultimately, they would not compete with the challenges and their business will be stopped in the coming years.
The timber produced from forest trees can generate revenues.	Excessive cutting of fruit and seeds-producing trees can cause deforestation.	Timber tracking systems should be developed to track the origin of wood, and sand validity of the area. Frequent inspections of wood processing industries and cross-verify the rate of received wood and products made from these woods.	Excessive cutting of trees for timber would reduce production and ultimately cause deforestation.

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