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Availability and Use of Willow Species in Representative Cold Desert Areas of Northwestern Himalaya, India

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Abstract: Willow species (*Salix fragilis* L. and *S. alba* L.) are important elements of cold desert agroforestry systems in the Lahaul valley, north-western Himalaya. Their ability to grow through shoot-cuttings plantations under extreme and xeric climatic conditions of cold deserts, makes them ecologically suited and socially accepted for forestry programmes. Willow species in cold deserts may combat desertification and can thrive well in these areas as compared to any other species. *Salix fragilis* L. and *S. alba* L. are under cultivation in the Lahaul valley. However, *S. fragilis* is widely cultivated under the agroforestry and plantation forestry systems. In the Lahaul valley, willow species are used as subsistence resources and for socio-religious purposes. The present study was carried out to examine the vegetation analysis, density, diversity and distribution of willow species, present status and potential willow plantation sites and uses. The results of present study revealed that a higher species density was recorded at middle altitude villages (Jahlma-3,000 m asl and Hinsa-2,700 m asl), except, a higher density of *S. fragilis* was at Khoksar (3,200 m asl) in plantation forestry on south-facing slopes. In forests, *S. fragilis* was planted mainly along the water channels, resulted a low density. The shrubby willow species occurred naturally in the entire Lahaul valley up to an altitude of 3,850 m asl. 81% of households felt the scarcity of willow trees, whereas, 19% of households were satisfied with the willow trees they owned. The majority of willow species were planted in middle altitudes on privately owned irrigated lands. It was rated most potential prospective willow planting site by the farmers. Small size of land-holdings was one of the main constraints for establishing a large number of willow plantations. Commercial aspects of willow species need to be investigated to encourage the farmers to plant more willows further.

Keywords: Willow; Agroforestry; Forestry; Species diversity; Himalaya

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Introduction

Himalayan ecosystems have provided biological resources and ecosystem services that have sustained the livelihood of the Himalayan people for centuries (Saxena et al. 2001). The availability of bio-resources, however, depends on ecosystem health and vitality. Overharvesting and ecosystem degradation deplete ecosystem goods and services (Ramakrishnan et al. 1992, 1996). The increasing threat to biological diversity can cause irreversible environmental damage and calls for immediate remedial measures. The western Himalaya offers unique habitats contributing to its rich biological heritage. Distinctive features of the Himalayan region are its valleys and hills, its undulant topography, altitudinal gradient, slope aspects and a network of rivers and streams (Chawla et al. 2008). The huge environmental variation within a small geographical makes the region an ideal area for ecological and bio-geographical studies (Körner 2000).

The landscape of the Lahaul valley is

predominantly barren (Aswal and Mehrotra 1994; Rawat et al. 2006, 2009a, 2009b, 2010a) with isolated scenic patches of green stands, the oases in the cold desert landscape. The harsh environmental factors that define its life forms and vegetation patterns include scanty rainfall, large snowfalls, early frost, high wind speed, short growing season and long spells of low and fluctuating temperatures (Dhar et al. 1994; Kala 2002; Rawat et al. 2010a). The vegetation distribution is further modified by aspect, with great contrasts between the north and the south-facing slopes (Rawat 2006). Similar to observations made by Slik et al. (2003) in East Kalimantan (Indonesia), species composition, structure and processes in the Lahaul valley are affected by any kind of disturbance as it facilitates changes in resource fluxes and leads to some form of reorganization of the disturbed patch or gap that may be similar or dissimilar to its pre-disturbance state. During the last three to four decades, human population growth and infrastructure development activities have exerted immense pressure on natural resources evident in terms of drastic changes in landscape patterns and processes (Oinam et al. 2005, 2008; Rawat et al. 2010a; Vishvakarma et al. 2011). More and more land is being taken up by agriculture, kitchen gardening and expanding settlements at the cost depletion of the natural grass and willow covered lands. The anthropogenic pressure is likely to increase in future, further impacting on the already scarce bio-resources of the region. Of particular concern is the shrinking of land under willow cultivation. In the Lahaul valley, tree species like *Salix fragilis* L., *S. alba* L., *S. daphnoides* Vill., *Populus nigra* L., *Hippophae rhamnoides* L., *Prunus communis* Huds. and *Pyrus communis* L. have traditionally been cultivated on private land along the margins of crop fields and earthen water channels (locally called *kuhls*). In a large part of the valley, farmers also maintain naturally regenerating bushy woody species, such as willows and poplars, along the margins of terrace crop fields (Rawat et al. 2006). This common practice is referred to as agroforestry in the present study. Willows and poplars have also been planted in private as well as village common lands as a source of fodder, fuelwood and raw material for various domestic uses. This practice is popularly referred as plantation forestry. These plantations also serve to protect the villages from snow slides during winter.

The agroforestry offers the potential to satisfy a diversity of small-scale farmers' needs in temperate and tropical highlands, while providing essential ecological and soil conservation benefits. Woody perennials are known to benefit agro-ecosystems through enhanced nutrient cycling, reduction of soil erosion, amelioration of soil physical properties, conservation of soil-water, microclimate enhancement and increased ecosystem stability (Nair 1984; Nair et al. 1984). Multi-purpose agroforestry trees provide a variety of economic products including timber, fuelwood, fodder, livestock bedding, leaf litter and thatching materials (Nautiyal et al. 1998). Constraints on expansion of competing land uses in highlands and mountainous regions may shift benefit/cost ratios in favour of multipurpose agroforestry systems (Oinam et al. 2005).

Depending on different estimates, between 350 and 500 species of willow (*Salix* spp.) are found worldwide, predominantly in the northern hemisphere (Argus 1999). Although the Indian Himalayan Region is home to 24 willow species (Troup 1921), only 10 (*Salix acmophylla* Boiss., *S. daphnoides* Vill., S. *denticulata* Anderss., *S. flagellaris* Hultén, *S. karelinii* Turcz., *S. lindleyana* Wall., *S. oxycarpa* Anderss., *S. pycnostachya* Anderss., *S. tetrasperma* Roxb. and *S. wallichiana* Anderss.) are reported from the Lahaul valley (Aswal and Mehrotra 1994). *Salix fragilis* L. and *S. alba* L., introduced about 150 years ago from the state of Jammu-Kashmir, are today the major sources of fuelwood and fodder in the region. In addition, they provide raw materials for several domestic utensils and construction purposes and play a vital role in environmental protection by stabilizing the slopes and reducing pressure on natural forests (Anonymous 1995-1996; Singh et al. 1996; Kuniyal et al. 2002; Kuniyal et al. 2004). These hardy species show a wide adaptability to fluctuating climatic conditions and hence are widely cultivated in the agroforestry system of the valley. Cultivated willows are the major multi-purpose woody species in the cold desert upon which the local communities depend. The present study examined the (i) vegetation analysis, density, diversity and distribution of willow species at four sites (ii) present status and potential willow

plantation sites, and (iii) socio-economic-religious values.

1 Material and Methods

1.1 Study area

The Lahaul valley, which is located in the north-western Himalaya, is situated between latitudes 31°44'34" N and 32°59'57" N and longitudes 76°46'29" E and 78°41'34" E. The Lahaul valley system is formed by the river Chenab (also called Chandra-Bhaga). It consists of three sub-valleys: the Chandra, the Bhaga and the Pattan valley (Figure 1). The study was conducted in four villages: village Khoksar (3,200 m a.s.l.) in Chandra valley and Jahlma (3,000 m a.s.l.), Hinsa (2,700 m a.s.l.) and Kuthar (2,600 m a.s.l.) in the Pattan valley. All land under private ownership used for agriculture, kitchen gardens and for residential purposes, including barren land and grassland, of a village is classified as revenue area. The total revenue areas of the Khoksar, Jahlma, Hinsa and Kuthar villages are 11.3, 58.3, 33.3 and 10.7 ha, respectively. Besides the revenue area, Khoksar owns sub-alpine meadows and the other three villages some relict forests under common ownership.

In the Lahaul valley, the warmest and the coldest months of the year are July and January with a mean monthly maximum temperature of 28°C and a mean monthly minimum temperature of minus 13°C, respectively. The average annual rainfall (1991 to 2005) recorded at Khoksar, Jahlma and Hinsa was 685 mm, 176 mm and 446 mm, and snowfall was 530 mm, 332 mm and 272 mm, respectively (Rawat et al. 2009b). The climate of Khoksar and Hinsa is characterised by quite a few rain events during the warm months unlike quite dry Jahlma and the adjacent areas.

Vegetation type varies from temperate to scattered alpine and arctic vegetation. The Lahaul valley supports a patchy vegetation with large open/exposed areas (Figure 2). The Chandra sub-valley is almost devoid of any forest cover except for a few scattered trees of *Betula utilis* D. Don, *Pinus wallichiana* A.B. Jackson, *Juniperus*

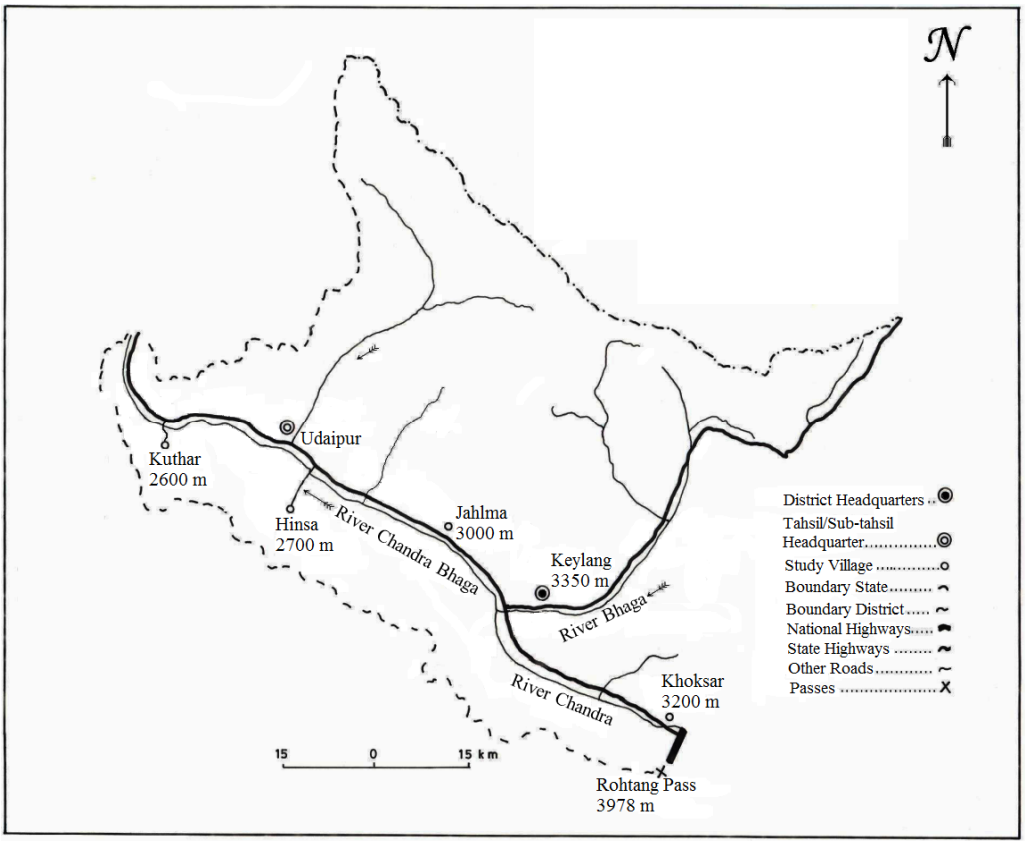

Figure 1 Map of the Lahaul valley illustrating the locations of the study sites Khoksar, Jahlma, Hinsa and Kuthar

communis L., *J. indica* Bertol., *Salix flagellaris, S. lindleyana* and *S. pycnostachya* on north-facing slopes. In the Bhaga sub-valley, a few patches of open forest can be found, with dominance of *Juniperus polycarpos* C. Koch on the south-facing slopes (Aswal and Mehrotra 1994; Rawat 2006; Rawat et al. 2010a). In the Pattan sub-valley, scattered patches of *Pinus wallichiana*, *Abies pindrow* Royle and *Cedrus deodara* (Roxb. ex. D. Don) G. Don occur on the lower reaches and a few scattered trees of *Betula utilis* on the upper reaches of the north-facing slopes. Alpine meadows and grasslands are found above the tree line (4,000 m a.s.l.).

Figure 2 A typical landscape of the Lahaul valley. The dark patches along the settlements and water channels are willows, the scattered plants on the right hand slope are junipers (*Juniperus polycarpos)* and clinging to the steep left slope are a few *Pinus wallichiana* trees

1.2 Vegetation analysis, interviews and questionnaires

Using the transect method (Kershaw 1973), sampling of the tree and shrub vegetation was conducted in agroforestry, forestry and relict patches of natural forests on north- and south-facing slopes within the ambit of the four selected villages during 2002-2005 period. Abundance of willow species at household level was determined by interviews supported with ground measurements.

1.3 Vegetation analysis

Three transects were laid down in each village, starting at the base of the slope and moving upwards, ending at the point beyond which no trees and shrubs were encountered. The distance between the two adjacent transects was 200 m. Quadrats (10 m × 10 m) were laid down using a line-running method (Curtis and McIntosh 1950; Kershaw 1973) covering all three land uses (agroforestry, forestry and natural forests). In total, 180 quadrats were assessed, 60 quadrats for each land use. The species were identified with the help of local flora (Aswal and Mehrotra 1994; Sood et al. 2001). Nomenclature and nativity of the species were based on Anonymous (1883-1970), while endemism was based on the extent of the distribution of the species (Chowdhery and Wadhwa 1984; Aswal and Mehrotra 1994; Dhaliwal and Sharma 1999; Murti 2001; Sood et al. 2001). Information on the altitudinal range and life forms were also noted during data collection.

1.4 Interviews and questionnaires

The head of all 122 households were interviewed using a semi-structured questionnaire seeking details of cultivation and resource availability and requirement. The information obtained through interviews pertained to the uses of willow, the existing management practices, the number of willows already grown, the number of existing willows per household, as well as whether or not the existing willows were sufficient and, in the case that more willows were required, how many were needed per household and at what preferential sites should they be planted. The interviewees were also asked to identify and rank seven categories of potential willow plantation sites (i.e. privately owned irrigated land, wasteland, land along water channels, erosion prone land, agroforestry land where existing uneconomical trees could be replaced by willow, forest land owned by the government or the community). The sites were given scores, 7 for the most preferred site and 1 to the least preferred one by each household that was interviewed. The scores given by different households for a site were added up separately for each of the four villages and the site securing the highest score was designated as the preferred site of the concerned village. Information on indigenous uses of willows was also collected during the household surveys. Five local artisans were interviewed to document the manufacturing of willow products as a source of livelihood.

2 Results

2.1 Density

2.1.1 Agroforestry

The density of *Salix fragilis* in agroforestry systems ranged from 57 plants ha^{-1} on the north-facing slopes of the Kuthar site to 365 plants ha^{-1} on the south-facing slopes of the Jahlma site. The density of *S. fragilis* was 103 plants ha^{-1} at Hinsa and 219 plants ha^{-1} at Jahlma on north-facing slopes, whereas, 102 plants ha^{-1} at Khoksar and 244 plants ha^{-1} at Hinsa on south-facing slopes. This willow species was a major contributor of fodder, fuelwood and other plant-derived materials required by the local farmers. The density of the naturally occurring *Salix acmophylla* (5 plant ha^{-1} at Jahlma and 29 plant ha^{-1} at Kuthar on north facing slopes, whereas, 34 plants ha^{-1} at Jahlma on south facing slopes) and *S. daphnoides* (11 plants ha^{-1} at Hinsa on north facing slopes) was low compared to that of the planted *S. fragilis*.

2.1.2 Plantation forestry

Salix fragilis was also the dominant species in the plantations in village commons. Its highest density was recorded on the south-facing slopes in the village Khoksar (471 plants ha^{-1}) followed by 453 plants ha^{-1} on the north-facing slopes in the village Hinsa, 429 plants ha^{-1} on the south- and 305 plants ha^{-1} on the north-facing slopes in the village Jahlma, and 283 plants ha^{-1} on the south-facing slopes of the village Hinsa. *S. fragilis* was absent from both, the north- and south-facing slopes around the village Kuthar and from the north-facing slopes around Khoksar. *S. acmophylla* was found only in the vicinity of the village Jahlma. The density was 51 plants ha^{-1} on south facing slopes and 53 plants ha^{-1} on north facing slopes.

2.1.3 Forests

In the existing forest management system, the local people are allowed to plant trees for their own use on forest land owned by the Department of the Forests. This arrangement provides direct benefits in the form of availability of fuelwood and fodder to people together with restoration of tree cover on slopes and associated ecosystem services. The land ownership remains with the Department of Forests.

Salix fragilis was less frequent under the forest system compared to the agroforestry and plantation forest systems. In forests, *S. fragilis* was planted mainly along the water channels. It occurred at low densities on the south-facing slopes in the village Jahlma (20 plants ha^{-1}), on north- and south-facing slopes in Hinsa village (6 and 7 plants ha^{-1}, respectively) and on the north-facing slopes around village Kuthar (9 plants ha^{-1}). It was altogether absent in village Khoksar. Among all populations, the shrubby *S. acmophylla* showed the highest density of 865 plants ha^{-1} on the north-facing slopes of Jahlma. *S. acmophylla* was, however, not present in the forest systems of the other three villages. The species *S. denticulata* occurred only in the forests of Hinsa on both, north- and south-facing slopes (59 and 16 plants ha^{-1}, respectively). *S. karelinii* was found only in the forests on the north-facing slopes of Khoksar (296 plants ha^{-1}). The interviews showed that the irrigation needs of the farmers were met by snow and glacial meltwater conveyed through of earthen channels. *S. fragilis*, planted by the farmers in the forests along these channels, benefits from moist soils around this irrigational system.

2.2 Diversity and distribution

The characteristics and importance of the trees *Salix fragilis* and *S. alba* and the 10 shrubby willow species found in the Lahaul valley are given in Table 1. All shrubs occur naturally in the entire Lahaul valley up to an altitude of 3,800 m asl with *Salix karelinii* reaching upto an altitude of 3,850 m asl. *S. fragilis* was identified as the most dominant species within agroforestry and forestry of the villages Khoksar, Jahlma and Hinsa, and *Acer acuminatum* L., *Corylus jacquemontii* L. and *Euonymus fimbriatus* Wall. were the dominant species in agroforestry and forestry of the Kuthar region. Thus, in the latter region all needs for tree-derived products were met by a wide range of species in Kuthar region and only a few plantation species in the other three villages. As a result, the farmers in the latter villages paid more attention to the management of willow species.

It was observed that the growth of the wild willow species was generally far better on the north-facing than on the south-facing slopes. The comparatively dry south-facing slopes supported

Table 1 Diversity and distribution of willow (*Salix*) species in the Lahaul valley

Botanical name	Altitude (m a.s.l.)	Aspect	Nativity	Uses	Status
*Tree					
S. fragilis L.	2,400-3,600	N & S	Europe, Asia borealis	Fuelwood, fodder, timber, agricultural implements, fencing, chewing twigs, rehabilitation	cultivated
S. alba L.	2,400-3,600	N & S	Europe, Asia and Africa borealis	Fuelwood, fodder, timber, agricultural implements, fencing, chewing twigs, rehabilitation	cultivated
*Shrub					
S. acmophylla Boiss.	≤ 3,800	N	Orient, India Orientalis	Fuelwood, fodder, agricultural implements, fencing	wild
S. daphnoides Vill.	≤ 3,800	N	Europe, Asia Borealis	Fuelwood, fodder, agricultural implements, fencing	wild
S. denticulata Anderss.	≤ 3,800	N & S	Himalayan Region	Fuelwood, fodder, baskets	wild
S. flagellaris Hultén	≤ 3,800	N	Himalayan Region	Fuelwood, fodder	wild
S. karelinii Turcz. ex Stschegl.	≤ 3,850	N	Asia Centralis	Fuelwood, fodder	wild
S. lindleyana Wall.	≤ 3,800	N	Himalayan Region	Fuelwood, fodder	wild
S. oxycarpa Anderss.	≤ 3,800	N	Himalayan Region	Fuelwood, fodder	wild
S. pycnostachya Anderss.	≤ 3,800	N	Himalayan Region	Fuelwood, fodder	wild
S. tetrasperma Roxb.	≤ 3,800	N	India Orientalis, Malaya	Fuelwood, fodder, timber, agricultural implements, fencing, rehabilitation	wild
S. wallichiana Anderss.	≤ 3,800	N	Himalayan Region	Fuelwood, fodder, timber, agricultural implements, rehabilitation, fencing	wild

Notes: N=North-facing slope, S= South-facing slope
*Tree willows locally called 'beli', whereas, shrubby willows 'jangli beli'

Cedrus deodara and *Celtis australis* L. at lower altitude in the vicinity of the village Kuthar and *Juniperus polycarpos* at higher altitude in the region of the villages Hinsa and Jahlma.

2.3 Present status and potential willow plantation sites

Although 73% of all households in Jahlma were satisfied with the willows they owned (Table 2), only 2% of Hinsa's households and none of the households in Khoksar and Kuthar were satisfied. Most of the villagers felt scarcity of fuelwood and fodder. Although the inhabitants of the studied villages, with the exception of those of Kuthar, were willing to plant more willows, the establishment of new plantations was hampered by the small sizes of land holdings and the absence of common lands suitable for plantation. Only Jahlma, situated in a wider part of the Lahaul valley, had sufficient land with assured irrigation for plantations. Farmers in Hinsa had the greatest need for additional willows. The numbers of additional willows needed in Jahlma, Kuthar and Khoksar was 978, 804 and 375, respectively.

Farmers rated the potential of prospective planting sites as privately owned irrigated land > wasteland > land along water channels > erosion prone land > agroforestry land (mainly for the replacement of older trees) > forest land owned by the government > communal land. The low preference for new plantations in the agroforestry system was due to the fact that the farmers felt that this system was already saturated with willows. Because of the willow's shading effect on the under-storey crops and increasing scope of income from horticultural plants like apple, farmers only intended to replace existing trees by other willows. Although people have traditional rights to plant trees on governmental forest land and community land, the interviewed farmers ranked such land as the least preferred option.

2.4 Socio-economic-religious values

Until recent times, the kitchen utensils of

native people were commonly made of willow wood (Harcourt 1871). Willow is still used widely for a wide range of purposes including roofing, shelter, fuelwood and fodder, tool handles, domestic utensils, baskets (*kilta*), supports for hops (*Humulus lupulus* L.), poles and for various socio-religious activities (Table 3). Though advent of plastics has reduced use of willow, still it is quite significant for local livelihoods. *Halda* sticks (used as torches that are lit up all around the valley during the *Halda* festival) are still made of willow. In addition, willow plantations provide some protection from glacial erosion, avalanches and landslides.

Table 2 Number of existing (mean ± standard error) and additionally required willow trees in the four study villages of the Lahaul valley (based on the results of a household questionnaire survey)

	Khoksar	Jahlma	Hinsa	Kuthar
Total H	12	41	52	17
Total W	502 ± 8	5,226 ± 19	914 ± 3	98 ± 3
W per H	42	128	18	6
Sufficient*	0	73	2	0
Insufficient*	100	27	98	100
NARW	375	978	1,072	804
NARWH	31	24	21	47

Notes: H = households; W = willow trees; NARW = Number of additionally required willows; NARWH = Number of additionally required willows per household.
* Unit: % household

Table 3 Indigenous uses of willow wood in the Lahaul valley (results from farmers' interviews)

House construction
Roofing Stairs Fencing Gates
Agriculture implements
Ploughs
Domestic items
Hubble-bubble sticks Small washing bats Spindles Baskets (*kilta*) Sticks Spice pots Supporting sticks used in kitchen gardens
Hops cultivation
Poles used to support hops
Items used in religious ceremonies
Biers Halda (a bunch of wood sticks)

3 Discussion

Willow species are used for various domestic and socio-religious purposes in the Lahaul region. Their wood is widely used as fuelwood, probably due to its easy availability, although it has relatively low calorific yield and low specific gravity (Rawat et al. 2009a, 2010b).

Most of the willow species found in the Lahaul valley have their origin in the Himalayan region and neighbouring countries (Aswal and Mehrotra 1994). All bushy willow species are found growing naturally in the Lahaul valley. The endemic willow species are distributed over the entire altitudinal range with species composition varying along the altitudinal gradient (2,400-3,850 m a.s.l.), demonstrating the wide ecological amplitude of the taxa. The endemic willow species are not only well adapted to the cold desert conditions but are also more likely to be resistant to pests and diseases. Willow species introduced from other regions of the Himalaya, such as *Salix fragilis* and *S. alba,* do not exhibit similar resistance to the diseases and pests found in the Lahaul valley (Rawat et al. 2006).

Due to its high altitude, Khoksar is colder than the other villages and extreme cold stress and a hostile climate might be associated with low species richness (Behera and Kushwaha 2007). The high mortality of *S. fragilis* (~55%) due to fungal infection with *Cytospora chrysosperma* (Pers.) Fr. in the year 2003 in the Lahaul valley at altitudes above 3,000 m asl (Rawat et al. 2006) could be another reason for the lower diversity at the Khoksar study site.

The village Kuthar, which is situated at a lower altitude (2,600 m a.s.l.), has well developed mixed forests which meet the requirements of the local people making willow planting not a crucial intervention. Although the area in the ambit of Kuthar is small, it displayed great plant diversity. This corroborates the findings of Grytnes and Vetaas (2002) and Chawla et al. (2008) that the heterogeneity of the habitats at lower altitude supported higher levels of species diversity. The willow species in the agroforestry system on the north-facing slopes of the village Kuthar could be related to lower altitude, better growth conditions and longer growth periods. As a result, the natural regeneration at Kuthar was the best among the studied sites. Kuniyal et al. (2002) also found

increasing bushy woody species richness with decreasing altitude over an elevation gradient of 2,700-3,200 m a.s.l.

The estimated number of additionally required willows differed depending on the location, size, population and the existing tree resources. The need for additional willows for fodder, fuelwood and other requirements was highest at Hinsa corresponding to population size of the village.

Low cash income and inadequate supplies of food, fodder and fuelwood are amongst the most common challenges faced by farmers in the Himalayan region (Ramakrishnan et al. 1992, 1996), especially in the cold desert (Rawat et al. 2006). Willow plantations are not only long term investments with economic benefits; they also improve the environmental quality. As fast growth of willows could be accomplished through an optimized management system of pollarding and irrigation (Rawat et al. 2010b), farmers prefer plantations on their own land with assured irrigation. Because alleviation of water stress is crucial for the survival of willow species under the xeric soil conditions of the cold desert (Vishvakarma et al. 2005), irrigated wasteland and forest land along earthen water channels were the second most preferred sites. However, the practice of planting willows along water channels has come under threat by the *Desert Development Programme* (DOA 2009) encouraging conversion of earthen to cemented canals (thereby reducing percolation around canals that favoured *salix*).

Along with *Salix fragilis* and *S. alba,* seabuckthorn (*Hippophae rhamnoides* L.), a multipurpose shrub species naturally found in the valley along streams, is now also being planted around water channels on community and government lands (Singh and Singh 1998; Kuniyal et al. 2002). Besides its contribution to the stabilization of slopes, there is an increasing demand for sea-buckthorn from the pharmaceutical and nutraceutical industries (Singh and Singh 1998). In the Lahaul valley, private companies were promoting sea-buckthorn to buy its berries and leaves for pharmaceutical and nutraceutical purposes, so farmers were planting sea-buckthorn on around water channels on community and government lands. However, these species has an important value in the life of local people. In the Lahaul valley, the cultivation of willow species in agroforestry and forestry systems is highly successful as it meets, to some extent, the subsistence requirements of the farmers. Periodical lopping and pollarding produce substantial wood and leaf biomass during the lifetime of an intensively managed plantation (Rawat et al. 2006, 2010b). The leaves were given to the cattle as a fodder and used as an animal bedding in the pen. The benefit/cost ratio of agroforestry system in cold desert can be greatly enhanced through improved land management and the use of multiple-purpose trees like *Salix* spp., *Populus* spp. and sea-buckthorn. Tree cover serves to reduce soil erosion and to conserve sloping land, fragile soils, and degraded sites. It contributes to the long-term stability of land resources (Nair 1984). Increasing the availability of fuelwood and fodder on farm land is an often observed response by farmers to increasing resource scarcity (Gilmour and Nurse 1991).

The two non-native willow species *Salix fragilis* and *S. alba* were the main contributors of fuelwood in the studied region. About 70% of Jahlma's fuelwood requirement was met from *S. fragilis* and *S. alba* compared to 19-42% in other three villages (Rawat et al. 2006). The remaining fuelwood requirement was met by locally grown poplar and sea-buckthorn bushes and the wood imported from outside the region. However, some fuelwood is still illegally removed from relict patches of birch (*Betula utilis*) and bushy Juniper (*Juniperus* spp.) located in the vicinity of villages.

The State Forest Department of Himachal Pradesh and the Government of India have initiated schemes, such as the *National Social Forestry Project*, the *Rehabilitation and Development of Forests Scheme*, the *Economic Plantation Scheme* and the *Tree Cover Improvement Scheme*, which focus on the establishment of woody and bushy species in degraded lands (Pandey 1993). The aim of these schemes is to reduce the dependency of local community on relict forest resources and increase the area under plantaion in the valley, thus, such kind of schemes will encourage the plantation of willows and other ecological suitable species to the region. Willow species have high rates of growth and photosynthesis and a high water use efficiency in biomass production (Schaff et al. 2002, 2003) as well as the ability to coppice well, making them

suitable for watershed management (Rawat et al. 2009a, 2010a).

Although large areas at different locations in the Lahaul valley had been designated for afforestation and reforestation programs, such programs have, unfortunately, mostly failed due to the lack of site-specific planning and due to insufficient flexibility within the programme (Anonymous 1995-1996). Site-specific micro-planning, participation of local community, capacity building and skill development of government personnel need to be considered to make such programs successful. A participatory approach through institutional and policy support is needed for developing a new strategies and approaches for the implementation and long-term management of such programmes. Appropriate bio-engineering and biotechnological interventions need to be considered as well.

4 Conclusions

Adequate cover and productivity are crucial for sustainable livelihoods of local people in the Lahaul valley. With a view to sustainable land use planning and management, it is suggested to establish nurseries and arboreta, bushes, grasses and multipurpose tree species (*Salix* spp. and *Populus* spp.) with preference for indigenous species which are ecologically suited to the xeric cold desert environment. The introduction of other ecologically suitable willow species which are well adapted to the harsh climatic conditions of the valley and can survive under prolonged sub-zero conditions as well as withstand high temperature and xeric soil conditions should also be considered. In addition, farmers need to be encouraged to grow multipurpose tree species on their private lands and to earn some income from willow-based small-scale craft industry. Commercial aspects of willows need to be investigated to encourage the farmers to plant more willows further. Capacity building of farmers and value addition of willow based products need to be encouraged. Waste and abandoned land in and around the settlements, if developed for raising willow plantations with the participation of local communities, could be a sustainable approach to encourage the cultivation of willows in the region.

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