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KUHL IRRIGATION: A COMMUNITY MANAGEMENT SYSTEM IN COLD DESERT OF THE LAHAUL VALLEY, NORTH WESTERN HIMALAYA, INDIA

SUBHASH C.R. VISHVAKARMA, YASHWANT S. RAWAT, SANTARAM S. OINAM AND JAGDISH C. KUNIYAL [1]

INTRODUCTION

Like other parts of the Himalayan region (Ramakrishnan, 1992; Pandey and Singh, 1984), agriculture is the prime economic activity of the hill people of north western Himalayan zone (Kuniyal et al, 2004a; Singh et al, 1997). Irrigated agriculture is one of the positive indicators to maintain food security in hilly environment. In the cold desert of north western Himalaya, under very scanty and rare rainfall conditions, snow accumulation is the only source of water for irrigation, drinking and other domestic uses. In the past, under extremely xeric, cold and harsh climatic conditions of cold desert of the Lahaul valley, local farmers developed earthen off-take irrigation system which is locally called *kuhl*. This channelizing snowmelt has become the only source of irrigation for ensured crop irrigation and other domestic use. Most of the *kuhls* are constructed by local people by contributing money and human labour which are managed by the villagers themselves. In 1870 Harcourt found extensive irrigation channels in crop fields. He also noticed that water from every available stream was diverted through people made earthen channels to the fields. About 99.5% of the total 2240 ha agricultural land in the cold desert of the Lahaul valley is under the community irrigation system called *kuhl* (Anonymous, 1995). Himachal Pradesh in India is most intensively irrigated state in Indian Himalayan region (Coward, 1990). The Lahaul valley in cold desert of north western Himalaya remains cut off for sometimes (November- June) in a year from other parts of the state due to heavy snow on Rohtang pass (3978 m), the only entry point to the valley.

The present study examines the kuhl system, land use under irrigation, yield pattern under canal irrigation, system of sharing of water among right holders. Attempt is also made to identify problems encoubntered by the farmers in the management of the canals in cold desert environment of the Lahaul valley. The main objectives of the present paper are: (i) to understand the kuhl system, (ii) to

[1] G.B. Pant Institute of Himalayan Environment and Development, Himachal Unit, Mohal-Kullu, 175 126, Himachal Pradesh, India

study the land use pattern under kuhl irrigation, and (iii) to study the system of water sharing among the kuhl users.

MATERIAL AND METHODS

Measurements of main *kuhl* and its branches were done separately. Later length of main *kuhl* and branches were added to find the total length the *kuhl*. Slopes for 100 m length of *kuhl* were measured using abney level. Command area of an individual *kuhl* was estimated under agriculture, forestry, cultivated grasslands and kitchen garden by administering questionnaire. Family heads were asked for the land holding, cropping pattern, and number of cultivated trees on their land. For final estimate of the command area of the individual *kuhl*, summation of all the irrigated land use types such as agriculture, forestry, cultivated grassland and kitchen garden was done. Canal command ratio was calculated after dividing length of *kuhl* by command area of the *kuhl*s. Number of trees under forestry and agroforestry were counted species -wise at village level. Per unit area production of cash crops like potato, pea and hops were measured through crop cutting method. Information of *kuhl* management and water sharing (water allocation to users) were collected after extensive interviews with *mukhiyas* (a nominated head for management of *kuhl* and water sharing) of all the *kuhls* from all the study villages. Crop irrigation is done from 6.00 a.m. to 6.00 p.m. The entire discharge of a *kuhl* from 6.00 a.m. to 6.00 p.m. was considered as one water as per local water sharing terminology.

STUDY AREA AND CLIMATE

Geographical Set-up

The cold desert of Lahaul & Spiti districts extends within 31°44'34" N to 32°59'57" N latitude and 76°46'29" E to 78°41'34" E longitude. The Great Himalayan range in the north and Pir Panjal range of the Lesser Himalaya in the south demarcate the boundaries of the Lahaul valley. The geographical area of the Lahaul & Spiti district is 13,835 km^2 with a total population of 33,224 persons. On average, 2 persons per km^2 inhabit in the Lahaul valley (Census of India, 2001). The Lahaul valley begins from Khoksar in the southeast and ends beyond Kuthar village in the north-west direction. On the north, it is demarcated by Ladakh district of Jammu and Kashmir; while on western and southern side by Chamba and Kullu districts of Himachal Pradesh, respectively. The Lahaul valley is divided into three sub-valleys: Chandra, Bhaga and Chandra-Bhaga sub-valleys after the name of river system. In the Chandra valley, River Chandra flows from east to west direction and meets River Bhaga at Tandi. River beyond Tandi is called Chandra Bhaga. The four study villages- Khoksar (3200 m) in

Chandra sub-valley, Jahlma (3000 m), Hinsa (2700 m) and Kuthar (2600 m) in Chandra-Bhaga sub-valley were selected for study which represent the entire Lahaul valley (**Figure 1**).

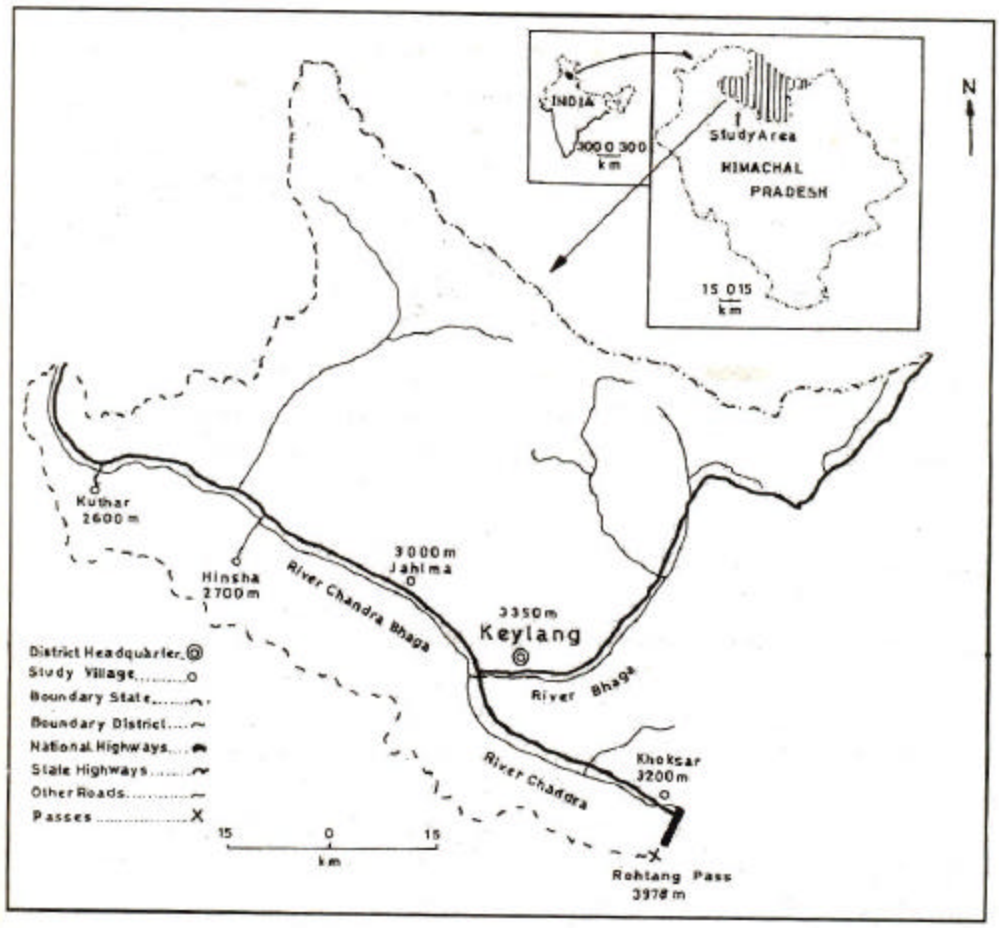

Figure 1: Locations of Study Sites in the Lahaul Valley in Cold Desert of North Western Himalaya

Climate

Climatically, the valley comes under cold arid zone with a very low rainfall and high snowfall, severe and prolonged winters. The region remains cut-off by high mountain ranges after heavy snowfall. The valley receives an average of 25 mm rainfall between June and July and 3000 mm snowfall from November to May. The Lahaul valley remains land-locked from winter to early summer (November to June) due to heavy snow deposit at Rohtang pass (3978 m), the only entry point to the valley. The valley has extremely harsh climatic conditions. During

summer mercury rises upto 27 °C and dips upto 40 °C during winters at Khoksar (**Figure 2**).

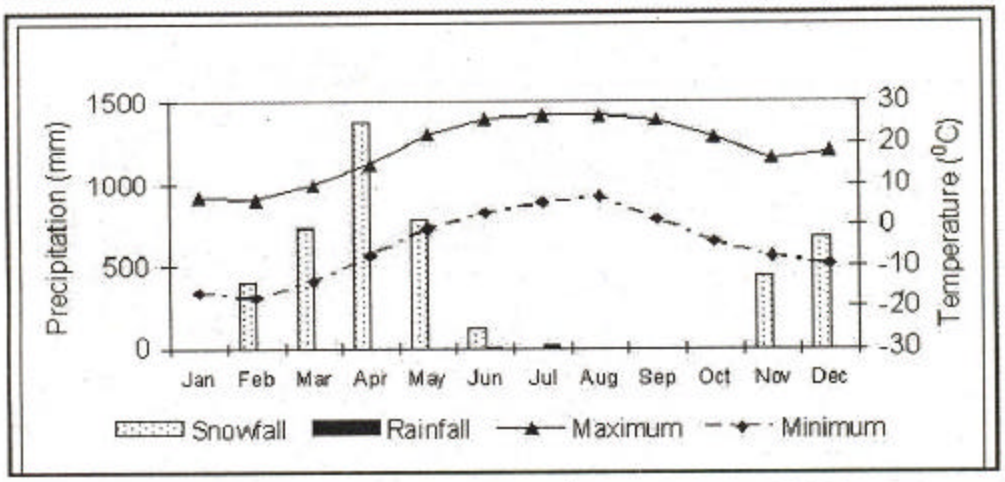

Figure 2: Temperature and Precipitation in Lahaul Valley

Vegetation

There are two types of vegetation zones: (i) temperate zone (2200 m to 3300 m) and (ii) alpine zone (above 3300 m) (Aswal and Mehrotra, 1994). Under temperate zone, maximum tree. Species of different uses like timber, fuel wood and fodder are found. Due to relatively very harsh climatic conditions of Chandra sub-valley, between Khoksar to Tandi, it has relatively poorer vegetation cover than the Chandra Bhaga sub-valley. In Chandra sub-valley, south facing slopes are, more or less, treeless up to Tandi. On lower reaches the north facing slopes, *chiat* (*Pinus wallichiana*) are found in a scanty form and on higher reaches, *bhiy* (*Betula utilis*) are found in a scattered patches (Singh et. al, 1997). North facing slopes have relatively richer bio-diversity and vegetation density as compared to the south facing slopes. *Shur* (*Juniperus macropoda*) is an important tree crop found on southern slopes at present; whereas in past *chiat* was also found in some patches of *shur* forests (Harcourt, 1970). Due to excessive harvesting of these species, they disappeared in course of time from the forests. North facing slopes are covered with patches of tree species like, *diyar* or *kley* (*Cedrus deodara*), *rei* (*Abies pindrow*), *tosh* (*Picea smithiana*) and *chiat* (*Pinus wallichiana*). The area receives high amount of snowfall where glaciers are common. Forest is found in alternate longitudinal patches with glaciers. *Chharma* (*Hippophae rhamnoides* sp. *turkestanica*) is also widely found in the valley particularly in landslide prone zones and close to water sources of Chandra-Bhaga and Bhaga sub-valleys.

Under alpine zone, chief stunted trees of *bhiy*, *chiat* and *Rhododendron campanulatum* are found in a scattered form up to 3600 m which is the highest vegetation limit of the Lahaul valley. Several bushy species like *bithal* (*Juniperus communis*, *J. indica*), *shur*, and *bhiy* are found on rocks, ridges and stony slopes. Several *belly* (*Salix* sp.) species like *S. flegilaris*, *S. lindleyana* and *S. pycnostachya* are found either in pure patches or mixed with *bhiy* as shrubs. Two species of Salix (*S. alba* and *S. fragilis*) are cultivated in agroforestry and village settlements to meet fodder and fuel wood requirement.

People and Villages

The inhabitants of the area are of Indo-Aryan origin and have, more or less, mongoloid features. Largely, they are the followers of Buddhism and Hinduism. People are humorous, soft spoken, simple and unsophisticated. Women are sturdy and self reliant largely performing the agricultural activities with inherited domestic operations. The people are largely attached with the joint family system. The Lahaulis language is a mixture of Tibetans, Hindi, Urdu and Persian (Harcourt, 1870).

From isolated hamlets to conglomerated settlements are the characteristic features of the villages. The houses are made up of stone, timber and earth, with flat roofs. Lower storey is used as cattle shed and first floor for the family if it is two Storey house.

About the System

Agriculture activities start in April, immediately after melting of snow from the fields. In each winter the heavy snow, damages the terraced fields and also causes leaching of soil nutrients. It is observed each year that, this natural process of turning the fertile soil into exhausted ones in the glacial and moraine environment, demands high quantity of organic manure to restore the soil's fertility for satisfactory yields. But the animal population, the main source of organic manure, is very small in this region. The fodder production in the valley it is not enough to support large herds. Even a pair of bullocks for draught power is not owned by single family; they are usually shared by two households. The high demand for manure is therefore met by using night soil that is recycled as traditional farmyard manure (FYM).

Under extremely dry soil conditions, no crop is possible without irrigation. As a result, the villagers on community basis have developed a local irrigation system-- *kuhl* (irrigation channels). The *kuhl* carries the water along the gravitational flow from the high snow bound peaks to the terraced fields downward. This indigenous community based irrigation system is in practice

since time immemorial which ensures a regular supply of water for irrigation throughout the valley. As the water is considered to be a common resource and irrigation has been developed with community effort, no money for irrigation is paid. *Kuhls* remain operational from April to end of the October. In November, *kuhls* are closed at it's origin point. During winter, they are used as path for routine movement of villagers.

RESULTS AND DISCUSSION

Kuhl System

In Khoksar village four *kuhls* (Janksha, Pomokuhl, Ghanka and Chantha) have been constructed. In Jahlma there are two *kuhls* (Groni and Kalpader). In Hinsa and Kuthar, each village has one kuhl each (**Table 1**). In Khoksar, Pompkuhl is the main *kuhl* and all these 16 households have the equal water right. However,

Table 1: Average Number of Dependent Families, Canal Command Ratio and Land Area under *Kuhl* Irrigation in the Cold Desert of the Lahaul Valley, North Western Himalaya

Attributes	Villages			
	Khoksar* (3200 m) n = 4	Jahlma (3000 m) n = 2	Hinsa (2700 m) n = 1	Kuthar (2600 m) n = 1
Number of dependent families	10.8	27.5	52.0	17.0
Number of branches of kuhl	3.8	9.0	4.0	3.0
Status	Earthen	Earthen	Earthen	Earthen
Length of kuhl (km)				
• Main *Kuhl*	0.33	0.37	0.26	0.15
• Branches	0.55	1.47	1.80	0.65
• Total	0.88	1.84	2.06	0.80
Slope of kuhl per 100 m distance	5° - 6°	5°	5°	5°
Area under per kuhl irrigation (ha	2.72	28.13	32.53	10.31
Canal command ratio (km/ha)	0.32	0.07	0.06	0.08

*** The village has one government *kuhl*, which is exclusively used by the Department of Forests for irrigating of 0.24 ha forestry land; hence not included in the table.**

other *kuhls* were constructed later for irrigating cash crops like pea and potato as well as, willow plantations on newly acquired lands. On an average, each *kuhl* of the Khoksar has command area of about 2.72 ha of land (agriculture, forestry, grassland and kitchen garden) with very high canal command ratio of 0.32 km per ha, the highest in the valley. In Jahlma village, two *kuhls* irrigated an average area of 28.13 ha of command area where average canal command ratio was 0.07 km per ha. The highest command area was in Hinsa village. In Kuthar, command area was 10.31 ha of land. In Jahlma, Hinsa and Kuthar villages, there is not much difference in the canal command ratio. However, in Khoksar village, canal command ratio was very high. Studies on hill irrigation systems often make comment about the length of the conveyance canals. The length of conveyance canal per irrigated area, or per irrigator, is a better indicator of operation and maintenance facing new challenges in irrigation development in cold desert environment. Canal ratio as high as one kilometre per irrigated hectare has been noted by Ambler (1989) in Sumatra, but the ratio is usually much shorter in most canals.

Under extreme xeric conditions and in the absence of rainfall in the Lahaul valley, availability of soil moisture is a necessity during crop months. Innovative farmers learnt to rearrange the water resources from snow melts to gravitational off-take water channels upto agriculture fields. As a result, water channel (*kuhl*) system came into the existence in the land locked Lahaul valley. *Kuhls* have been constructed by the local people with the contribution of the users since time immemorial. The contribution was in terms of cash and as well as labours. The valley has very sloppy mountains, moraine conditions, scree and stony outcrops. Sometimes *kuhls* pass through narrow and steep gorge of about 90° slopes after cutting the rocks and in some place erecting the stone walls as in case of Garoni *kuhl* along Jahlmanal stream near Jahlma. At origin point of the *kuhl* after 10 metre distance, *kuhl*'s wall facing toward stream side is kept opened as a scope door upto a length of 30 cm to pass entire *kuhl*'s water back to the stream again when *kuhl* does not remains in use. During operation of *kuhl,* this door is closed with a gunny bag filled with sand. The older *kuhls* do not have history or record about construction year and construction cost. The senior citizens of the valley say that, Balti people (people of Baltistan) were hired. The Baltis had skill of stone cutting and digging kuhls through gorges. Tiwari and Gupta (2003) found that *Baltis* were hired by the *Dards* rulers of Leh for construction of canal system for irrigation. *Dard* rulers occupied the Leh region even before *Namgyal* dynasty which was established around a thousand year back (Ghani, 1999) *Baltis* were experts in designing and making the canal and tunnel systems for irrigation. Sometimes *kuhl* passes through a stone wall and use of hume-pipes in case of scree. Falling pebbles cover humpipes and later pipe comes under pebbles and water flows from the pipe like in a small tunnel.

Traditional *kuhls* in the valley were of earthen. Under the Desert Development Programme (DDP) from Department of Rural Development, Govt. of India, the state government provides fund for cementing a very few *kuhls*. Irrigation development is taking place in one or two modes; (a) development of community irrigation systems (b) the development of agency operated systems (Coward, 1980). This is also true in case of the Lahaul valley. All the older *kuhls* in the valley had been constructed with the community participation. These *kuhls* are also managed by the decision makers from the community and water is shared among the right holders. Nowadays, state government also constructs new *kuhls* on public demand where community effort fails because of long distance of water sources and high cost of engineering works, like stone wall construction, hume-pipes, rock cutting along the gorge. The government constructs the *kuhl* and does repair work. However, the responsibility for regular management's like cleaning the canal and water sharing has been given to the farmers. The state government has constructed 26 new *kuhls* in different parts of the Lahaul valley with 1031 ha of command area. In other parts of the Himachal Pradesh, many *kuhls* have been constructed with the community efforts, or some system are constructed by the government, after completion of the construction, they are handed over to the local people for their use and management. Baker (1994) studied historical background of *kuhl* system in the Kangra valley. He found that the majority of the *kuhls* were constructed by the community work of the villagers in 17^{th} and 18^{th} century except a few *kuhls* which were supported by the Katoch kings of the Kangra area. Thirty nine *kuhls* which divert the water from the River Neugal, irrigated approximately 5,000 ha of land which is distributed in 240 hamlets located in 85 km^2 Neugal basin. Coward (1990) found that management and repairing of all *kuhls* were the job of the users including the *kuhls* financed by the Katochs. *Kuhl* management by the local community makes a *kuhl* system more viable and sustainable without any dispute in the community.

In Khoksar village, average per *kuhl* command area is 2.72 ha. At Kuthar it is 10.31 ha in Jahlma 28.13 ha and in Hinsa 32.53 ha the largest command area in the study villages (**Figure 3**). At the valley level, about 62.2 % land was under agriculture, 5.3 % under forestry, 31.1 % under cultivated grassland and 1.4 % under kitchen garden for vegetables. Though command area of the *kuhl* varies from one village to another but agriculture area is around 60 % of total cropped area in their villages. Cultivated grassland was second major land use type in all villages for secured fodder for lean period during severe winter months.

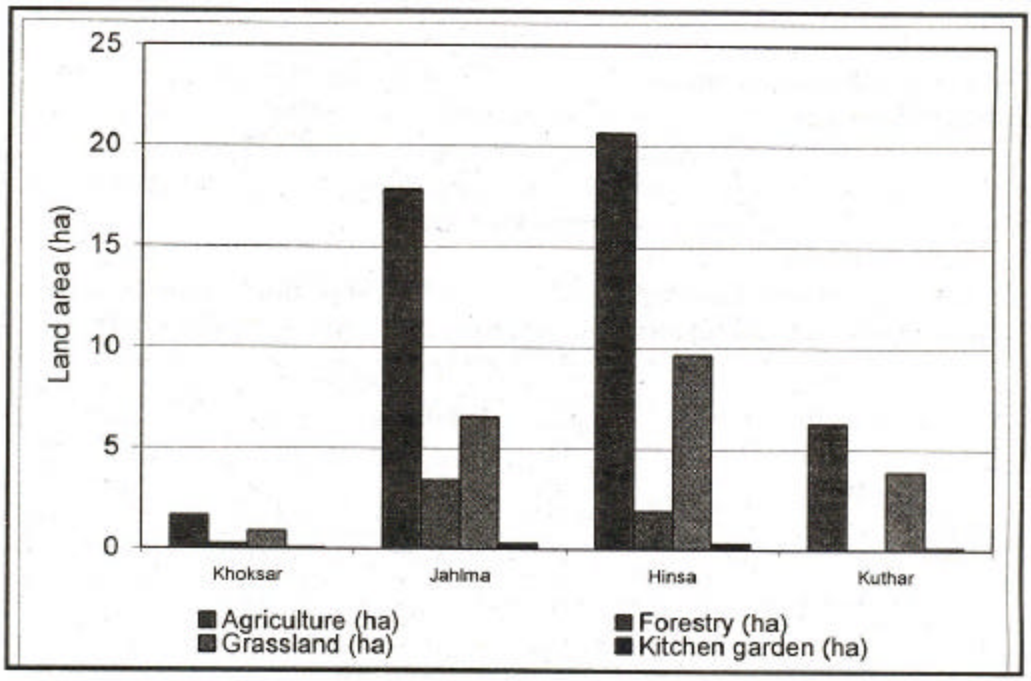

Figure 3: Land Use Types and Average Land under Kuhl Irrigation in Cold Deserts of the Lahaul Valley

Land Use Types under Irrigation

In all those four villages, 60.88 to 63.53 % land of the total area is devoted to agriculture (**Table 2**). In the land locked area of the Lahaul valley, agriculture was the prime source of revenue generation and food security to the farmers. In Khoksar, cash crops like potato and pea and in Jahlma potato, pea and hops are cultivated in more than 95% of the total land. Traditional food crops like barley, buckwheat, wheat, beans, vegetables (beet roots, cabbage, carrot cauliflower, pumpkin, radish, spinach, tomato and turnip) and medicinal herbs like *Saussurea lappa* and *Inula recemosa* are cultivated relatively in a smaller area to conserve the seed banks. In Hinsa village, cash crops like potato and peas are cultivated in about 70% of the total agriculture land. Traditional crops are cultivated on the rest of the land. Climatic conditions such as warmer climate and longer growth period upto the end of October at Hinsa and Kuthar villages permit second cropping immediately after a harvest of pea and potato. Traditionally buckwheat and mustarded are cultivated as second crop after a harvest of pea and potato and farmers need regular water supply from May to the end of the October. In the same way, at Kuthar village, farmers cultivate traditional crops only on major area of land except pea and potato on small scale. Kuthar is at a very far distance village from south eastern corner of the Lahaul valley; cash crops cultivated by the villagers are not picked up either by the traders or by the Lahaul Potato Society- a farmer's co-operative society- during harvesting season located at

Manali, outside the Lahaul valley. An irrigation frequency for agriculture varies for crops to crops. However, on an average, in Khoksar and Jahlma villages, 3.67 times irrigation for one crop was needed. In Hinsa village, 3.50 and in Kuthar village 4.00 times irrigation is required for good harvest. Flood irrigation is a prevailing form of irrigation for maximum crop yield.

Table 2: Irrigated and Through *Kuhl* in Cold Desert of the Lahaul Valley, North Western Himalaya (values in parenthesis are % of the total)

Land area (ha)	Villages			
	Khoksar n=12	**Jahlma n=41**	**Hinsa n=52**	**Kuthar n=17**
• Agriculture	6.63 (60.88)	35.63 (63.31)	20.66 (63.53)	6.28 (60.89)
• Forestry	0.54 (9.92)	6.88 (12.22)	1.91 (5.87)	0.01 (0.10)
• Grassland	3.65 (33.52)	13.16 (23.38)	9.64 (29.64)	3.91 (37.89)
• Kitchen garden	0.07 (2.57)	0.61 (1.08)	0.31 (0.95)	0.12 (1.16)
Total	10.89 (100.00)	56.28 (100.00)	32.52 (100.00)	10.32 (100.00)
Per household land holding (ha)	0.91	1.37	0.63	0.61
***n= number of household studied**				

Grasslands ranked second after agriculture land use ranging from 23.38 to 37.89% of the total land (**Table 2**). In the cold desert, fodder is a scarce commodity and grasslands are cultivated for hay which remains the source of fodder during lean period of extreme winters in the valley. These grasslands are the home of several high value medicinal plants like *Aconitum heterophyllum, Angelica glauca, Dactylorhiza hatageria* and *Ephedra gerardiana* (Kuniyal et al, 2004b). For high forage yield, regular irrigation was done. Irrigation frequency for grasses is more at Jahlma (5.72 times in one growing season) followed by Hinsa (4.04 times) and Khoksar (3.83 times) and is lowest in Kuthar village (3.17 times). Till October, animals are stall-fed and pasturing is not allowed. When fields are without any crop, immediately after harvest of second crop in the end of October, animals are allowed to graze on them.

Willow around villages for fuel wood and fodder are cultivated in the Jahlma (12.22% of the total land), Khoksar (9.92%) and Hinsa (5.87%) villages (**Table 2**). In Kuthar village, broad leaved and coniferous forest resources are available and farmers harvest fodder from the neighbouring forests and no more attention is given for willow plantation. In Kuthar village, only 0.10% of the total land is under forestry. Every Lahauli family has a kitchen garden to grow a variety of

green vegetables. Land under kitchen garden ranges from 0.95 (Hinsa) to 2.57% (Khoksar) of the total land area in study villages. Kitchen garden needs more care and irrigations. In Jahlma and Hinsa villages, 8 times watering was done in kitchen gardens whereas at Khoksar and Kuthar villages, 7 times irrigation is given to vegetables.

Under agroforestry and forestry system in Khoksar village, willow (*Salix* sp.) and poplar (*Populus* sp.) are raised for fodder, fuel wood and timber (**Table 3**). Willow is most important species and about 97.48% of total trees are found under agroforestry system. Like other parts of the Himachal Pradesh, agroforestry was important source of fodder and fuel wood (Vishvakarma et al, 1998). In Jahlma village willow is also most important species and about 70.70% of the total trees are of willow. *Hippophae* sp. is second important species found on the margin of the agricultural fields, particularly, along the streams or water channels (Kuniyal et al, 2002). Apple is now being grown in the Jahlma and Hinsa villages where as in Kuthar apple is already an established cash crop. Here, poplar, plum, apricot and walnuts are also cultivated but in smaller numbers. In Hinsa village, willow was most important species and 96.41% of the total trees are of willow. Poplar, apple and walnuts are also found relatively in small numbers. In Kuthar village, trees under forestry and agroforestry are very few (415 trees) as compared to the highest number of 14,698 trees of Jahlma village. Apple is most important tree under agroforestry and forestry system followed by willow. Hazel nut is maintained for its better quality nuts basically for home consumption. In Khoksar, Jahlma and Hinsa villages, emphasis is given for cultivation of fodder and fuel wood trees; more than 90% of the total trees planted in these villages belonged to this category. However, in Kuthar village more emphasis is given to fruit trees because fodder can easily be available from the surrounding forests of this village.

The highest number of trees are in Jahlma (14, 698 trees) followed by Khoksar (2, 575 trees) and Hinsa (948 trees) and is in the lowest number in Kuthar village totalling as much as 415 trees (**Table 3**). Trees are regularly irrigated through *kuhls*. On the slopes, flood irrigation is not possible so the farmers make shallow *kuhl* across the slopes adjacent to the trees. Water runs through shallow *kuhls* making soil wet through seepage. Overflow of the *kuhls* irrigate the slopes under trees to maintain continuous level of moisture till the next irrigation comes. Average irrigation frequencies vary from 7.06 times in one growing season at Jahlma, followed by 4.96 times at Hinsa, 4.83 times at Khoksar and 4.29 times at Kuthar village. Extremely xeric conditions prevalent in village Jahlma requires more and frequent irrigation to maintain trees as compared to other three villages.

Table 3: Village Wise *kuhl* Irrigated Trees under Agroforestry/Forestry Systems in Cold Desert of the Lahaul Valley, North Western Himalaya (values in parentheses are % of the total trees)

Trees	Villages			
	Khoksar n=12	Jahlma n=41	Hinsa n=52	Kuthar n=17
Fuel wood/fodder				
Salix sp.(willow)	2510 (97.48)	10392 (70.70)	914 (96.41)	98 (23.61)
Populus sp. (poplar)	65 (2.52)	522 (3.55)	12 (1.27)	4 (0.96)
Hippophae rhamnoides (sea buckthorn)	-	2700 (18.37)	-	-
Fleshy Fruits				
Pyrus malus (apple)	-	1042 (7.09)	16 (1.69)	280 (67.47)
Prunus communus (plum)	-	26 (0.18)	-	-
Prunus armeniaca (apricot)	-	16 (0.11)	-	3 (0.72)
Pyrus sp. (pears)	-	-	-	2 (0.48)
Nuts				
Juglance regia (walnut)	-	-	6 (0.63)	10 (2.41)
Corylus avellana (hazel nut)	-	-	-	18 (4.34)
Total	2575 (100)	14698 (100)	948 (100)	415 (100)
- = absent in the village				

Development of forestry and agroforestry is dependent basically on two factors: (i) scarcity/ availability of fodder resources in the village, and (ii) availability of land for plantation. Both in Khoksar and Jahlma villages, fodder resources are very scarce. Farmers in Jahlma plant willow on large scale around the village settlements. However, under similar conditions due to lack of lands, the farmers at Khoksar can not plant trees beyond a certain limits due to narrow valley and high slopes. In Hinsa village, farmers get fodder and grasses from neighbouring forests along with willow plantation. So they do not plant more willow trees inspite of availability of land. In Kuthar village farmers lop broad leaved trees from forests and they do not pay more attention toward willow plantation. Willow is a second tree crop after apple under agroforestry system.

Yield Pattern of Cash Crops under Kuhl Irrigation

Ensured crop irrigation results in good harvest under extremely xeric environment. Per hectare yield of cash crops such as pea and hops is better at Jahlma village as compared to Hinsa, Kuthar and Khoksar villages (**Figure 4**). However, yield of potato is the best (33.22 MT/ha) at Khoksar village. The lowest yield of potato was 10.74 MT/ha at Kuthar village. The climatic

conditions of Hinsa and Kuthar villages are more suitable for good yield. Because of better agricultural practices, superior seed input, timely cropping and better soil and water managements, farmers of Jahlma and Khoksar villages reap better harvest than the other two former villages. Pea is harvested from mid July to mid August exclusively for green vegetables. Harvest of hops is treated as a community work for which farmers support each others. Harvesting of hop is done by mid August. Potato is harvested relatively late and is sold through Lahaul Potato Society (LPS), a farmers' co-operative society that sells most of the produce in different parts of the country. Each year, the LPS ensures the initial supply of provisions and other essentials to the farmers in lieu of potatoes before the onset of winter and closing of the Rohtang pass. Under ensured *kuhl* irrigation conditions, cash crops economy has changed the socio-economic status of the people. Kuniyal et. al (2004a) in their study found that monetary efficiency of the cash crops is more than two times higher at Khoksar as compared to traditional crops.

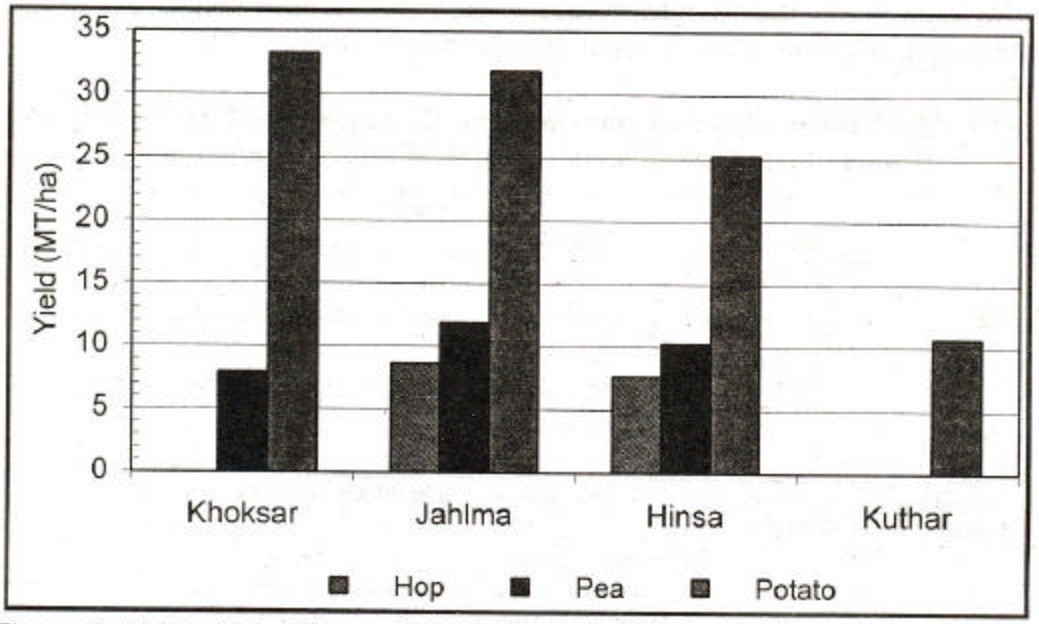

Figure 4: Yield of Cash Crops in Cold Dersert of the Lahaul Valley under Khul Irrigation

Water Sharing

Irrigation in a day is normally done from 6.00 a.m. to 6.00 p.m. (**Table 4**). Water is a right of every individual in the valley but only a right holder of a *kuhl* gets water from a particular *kuhl*. Here, entire discharge of main *kuhl* from 6.00 a.m. to 6.00 p.m. is called one-water. In Khoksar and Kuthar villages, one–water is used by one farmer. In Jahlma village discharge of the main *kuhl* is divided in two equal shares, thus two farmers simultaneously use one half-water. In Hinsa

village, water of main *kuhl* is divided into 4 equal shares and simultaneously four farmers irrigate the land each using one quarter-water. For a distribution of water from the main *kuhl* to the branches, there is no water regulation structure and engineering work available in the valley. In Jahlma, the main *kuhl* is equally divided into two first order branches at one place and water equally flows in both of them. In the same way water of the main *kuhl* has been divided into four equal first order branches at one place. Dani and Siddqi (1989) in their studies in Pakistan found propositional weir (*Chaukhat*), like Sumatran *penaro* (Coward, 1985) and Nepalese *saacho* (Martin and Yoder, 1988) with four proportionate inlets. Irrigation is done in day time; in years of shortage of water, the same farmer can irrigate his crop in the night after 6.00 p.m. also. In nights if water can not be used for irrigation, third order branches diver water to nearby streams. There are no as such storage facilities of water during night so that it could be used in a day time. Dani and Siddqi (1989) found that in Pakistan, farmers had developed reservoir for storage of water at a stage of third order branches and use the same in day time. Night storage system are found in Ladak area in India and in supper Mustang area of Nepal. (Baskota and Chalise, 2000)

Table 4: Mechanism of Water Sharing and Management of *Kuhls* in Cold Desert of the Lahaul Valley, North Western Himalaya

Attributes	Villages			
	Khoksar	Jahlma	Hinsa	Kuthar
A. Water sharing				
1. Roster (days)	17	14	9	No roster
2. Available water for irrigation	One-water[A]	One half-water	One quarter-water	One-water
3. Irrigation duration	6.00 a.m. to 6.00 p.m.	6.00 a.m. to 6.00 p.m. In case of water shortage in *kuhl*, farmers irrigate crops in night also	6.00 a.m. to 6.00 p.m. In case of water shortage in *kuhl*, farmers irrigate crops in night also	6.00 a.m. to 6.00 p.m. --
4. Basis of water sharing	House holds	Land holding size	Land holding size	When ever required
5. Amount of water available	I water	1/2 to 1/8 share of *kuhl*'s water. 3-4 households of small landholdings are clubbed together in 1/2 share of water in one day for	1/4 to 1/16 share of *kuhl*'s water. 3-4 households of small landholdings are clubbed together in 1/4 share of water in one day for	Farmers of small landholdings, in one day several farmers irrigate the crop

		irrigation	irrigation	
B. Management				
1. Main *kuhl*	Nowadays initial cleaning and repairing of the *kuhl* given to contractors. Regular cleaning is done by the users.	Nowadays initial cleaning and repairing of the *kuhl* given to contractors. Regular cleaning is done by the users.	Farmers provide 5 man power for initial cleaning and ongoing repairing of the *kuhl*	Farmers provide 5 man power for initial cleaning and ongoing repairing of the *kuhl*
2. Branches	Users living along the branch regularly clean and maintain themselves.	Users living along the branch regularly clean and maintain themselves.	Users living along the branch regularly clean and maintain themselves.	Users living along the branch regularly clean and maintain themselves.

[a]One-water = Entire discharge of the main *kuhl* where water distribution starts from 6.00 a.m. to 6.00 p.m.

There is no separate share of water for irrigation of agriculture, forestry, grassland and kitchen garden. Water share is also not done on the basis of location of the lands. If a farmer has land on different locations he has to irrigate the land during his turn in any part of the command area. However, if there is surplus water in once share, he can share mutually his water with other farmer; in return he would get the same amount of water from the receiver's share. In a family, water is divided with a ratio of the inheritance of the land. Suppose a father has one half-water in his share and his property is divided into his two sons. Both the sons shall get one quarter-water in their share. In the same way, if some one sale his lands to other person, his water share for that part of the land shall also goes to the new owner of the land. Relatively in larger villages like Jahlma and Hinsa, 3-4 marginal farmers' irrigation is clubbed in one half-water or one quarter-water for Jahlma and Hinsa villages, respectively. Sharing is done in such a way that no single farmers in the village could suffer crop damages due to lack of irrigation water. In Jahlma and Hinsa villages, 2-3 families have more than one day water in their share because of either higher landholding or higher amount of contribution paid by their ancestors at the time of construction of the *kuhls*. More than one day water of the *kuhl* can be also possible by purchasing new land area from other right holder of the same *kuhl*. In Khoksar village, turn of the same farmer comes after 17 days, in Jahlma this turn comes after 14 days

and in Hinsa 9 days. In Kuthar village no roster has been made because of relatively smaller landholding size (0.61 ha per household) and lesser numbers of users (total 17 users), when water is needed farmers could use it after waiting a few hours.

Water sharing in all the villages shows three distinct distribution patterns among right holders: (i) water sharing is on the basis of numbers of households in the village as in Khoksar irrespective of the land holding size. This practice was a common feature in the small villages, (ii) water sharing basis on land holding size in a larger villages like Jahlma and Hinsa, and (iii) there is absence of any water sharing mechanism, when farmers need water they can take it after mutual negotiations. This system is possible fit only where land holding is very small and water users are less in number such as in Kuthar village.

Kuhl Management

Management of main *kuhl* is done through participation of labour by its users. Initial cleaning and repairing of the *kuhl* is done before starting cropping season in the month of April every year. Every household provides 5 man days per year for cleaning, repairing of the damaged part of the main *kuhl* and regular repairing and removal of stones, pebbles and sediments, etc. (**Table 4**). Repairing work is supervised by a nominated member among the *kuhl* users itself called *mukhiya* (in Hindi) or *lapha* (in Lahauli). *Mukhiya* is a senior *kuhl* user who has adequate knowledge for *kuhl* management and water sharing from it. He is nominated for a period of one year. In a few villages, like Rapring near Jahlma, *mukhiya* is hereditary; a gesture provided by the Fate *kuhl* (synonym Rapring *kuhl*) users. Fate *kuhl* was constructed by grand father of the present day's *mukhiya* Mr. Shiv Chand Thakur of Rapring village. Later, other members of the Rapring village joined the initial cleaning and regular repairing of the *kuhl*. Nowadays, about 50% native population reside out of the valley for jobs. Senior citizens are residing in the villages; every household in Khoksar and Jahlma villages hires two agricultural labourers. So job for initial cleaning and repairing in Jahlma and Khoksar villages is given to Nepalese contractors. Expenditure for the contact is met by a combined contribution of the users in accordance with ratio of their water share. Regular vigilance of the main *kuhl* is done by the villagers as per instruction of the *Mukhiya* from the man power provided to him on turn basis out of the total users. All the branches of the *kuhls* are repaired and maintained by such contribution of the users along the branches.

In the cold desert environment, management of *kuhl* is difficult job. Several options regarding management problems are asked from the farmers. The responses from different villages are also found different (**Table 5**). However, in

all the four villages, damages due to landslides, deposition of mud, pebbles and gravels etc., and damages at an origin site of *kuhl* due to floods and destruction by animals are common problems. In Khoksar and Kuthar villages, households being very few in a smaller command area the people could not observe seepage from *kuhl* any more as a problem. In the villages like Jahlma and Hinsa, per household landholding and number of users of *kuhls* are more than the Khoksar and Kuthar villages, and people acknowledged the seepage as a major problem and favoured to design these with concrete. Moreover, in Jahlma and Hinsa villages, total length of the *kuhls* are also long as compared to Khoksar and Kuthar villages (**Table 1**) so seepage losses is very high upto 50 % of the total intake in the *kuhl* at its origin point. The state government provided funds for minor repairing of *kuhls* to all the study villages. For reducing the seepage loss from lengthy *kuhls*, concrete lining is one of the best options. Under DDP some parts of a few *kuhls* have also been cement plastered.

Table 5: Problems in K*uhl* Management in Cold Desert of the Lahaul Valley, North Western Himalaya (values in parentheses are % of the total respondents)

Attributes	Villages			
	Khoksar n=6	Jahlma n=18	Hinsa n=26	Kuthar n=9
Problems in management				
Seepage	-	11 (61)	13 (50)	2 (22)
Landslide	4 (67)	6 (33)	2 (8)	9 (100)
Mud, gravel and pebble deposition	5 (83)	17 (94)	25 (96)	9 (100)
Flood	6 (100)	17 (94)	5 (19)	9 (100)
Animal destruction	5 (83)	4 (22)	13 (50)	-
Role of government				
Granting money	6 (100)	18 (100)	26 (100)	9 (100)
Causes of lesser amount of water				
Less snowfall from last 6-7 years	5 (83)	18 (100)	10 (38)	-
Receding glacier	-	15 (83)	12 (46)	6 (67)
Climate change	4 (67)	5 (28)	11 (42)	6 (66)
Increase in agriculture area	-	-	2 (8)	2 (22)
Lesser rainfall	-	-	8 (31)	8 (89)
Remedial measures				
Plantation	1 (17)	14 (78)	21 (81)	2 (22)
Cementing of kuhl	-	-	22 (85)	4 (44)
Can't say	1 (17)	5 (28)	4 (15)	5 (56)

n = Number of family interviewed, - = indicates no any respons

It is felt by the farmers in the entire valley that the amount of the water is reducing in the streams and subsequently also in the *kuhls*. When learned and experienced senior citizens are asked its reasons, continuous reduction in snowfall from the recent last 6-7 years, receding of glaciers and changes in climate are identified as the major causes. The unpublished work of the principal author showed that there is a rise of 2.47 °C in annual maximum temperature and reduction of 115.9 cm in annual snowfall in the 10^{th} decade of 20^{th} century as compared to the 9^{th} decade of the same century at Tandi (12 km far from Jahlma). Similar trend is also noticed in the Kullu valley where 1.1 °C rise in maximum temperature and 0.35 °C in minimum temperature is noted in the 10^{th} decade of the 20^{th} century as compared to the 9^{th} decade of the same century. Snowfall comes late and melts at much faster rates so when more water for irrigation is needed, shortage of water in the stream is obviously visible.

Increase in irrigated area and reduction in rainfall and subsequently more requirement of water are recognised as the major reasons by respondents in Hinsa and Kuthar villages. Successive cropping of the second crop after harvest of cash crops like pea and potato is also one of the causes of more demand of water. Remedial measures suggested by the people, includes massive plantation in the valley and cementing of *kuhls* to reduce seepage losses. From all the four villages there is a category of respondents who could say "can't say" such category ranges from 15% in Hinsa to 56% in Kuthar villages.

CONCLUSION

Kuhl system is a unique traditional irrigation system which is suitable to the local climatic condition under the cold desert environment. Seepage losses from *kuhl* could be a serious problem with an increase in water demand for more cultivation and simultaneously amount of water availability is also reducing in the streams. Better water conservation technique like concrete lining of *kuhl* is one of the best options to minimise water losses from the system. Moreover, massive plantation work around the villages is needed to stabilise slopes, reduce impact of climatic changes and increase greenery with a better use of aforesaid water management practices.

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