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Temporal and Spatial Indigenous Appropriation Management of Agricultural Water in the Eastern Hindu Kush: Examples from Village Kushum, Pakistan

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Abstract: This article aims to analyze the effectiveness of timely control agricultural water management and coping capacity of the hydraulic society for a semi-arid mountain milieu in village Kushum Chitral located in the Northern Pakistan. In order to achieve the objectives of the study, both primary and secondary sources were explored. Primary data was collected through participant observation, unstructured interviews and focused group discussion (FGD) during 2010 to 2018 conducting field work in village Kushum. The FGD was conducted to get information about indigenous allocation device, allocation of water between village sections (eastern and western Kushum), share of neighborhoods and temporal and spatial utilization management mechanisms of irrigation water. Irrigation water management has a strong relationship precipitation, temperature and population growth. Therefore, some secondary data were also used for the analysis such as population, precipitation and temperature. The study also includes a case study on Lafan-dur to strengthen the findings and results. This research result reveals that irrigation water of village Kushum is bifurcated geographically and temporally dynamics. The spatial and temporal management and appropriation of agricultural water are closely associated with agricultural activities and cropping season. The case study Lafan-dur highlights that in contrast to other hydraulic societies, irrigation water of the study area is kept under different property regimes such as private, common and open access. The study also shows that the climate change and demographic development increased water stress in the study area but do not always lead to tragedy of commons. The mountain farmers have capacity, knowledge, and managerial potential to formulate mechanisms for management of irrigation water.

Key words: Agricultural water · Property regimes · Creative adjustment mechanism

INTRODUCTION

For the past few decades (1975-2018), agricultural water management has become the subject of interest and central importance for scientific inquiry in the mountainous belt of the globe [1-10]. Water is becoming scarce not only in rain shadow region but also in the region where precipitation is abundant [11] due to poor water management and governance. Researchers around the world highlighted the importance of sophisticated irrigation water management as an integral strategy to address water scarcity and food insecurity [9]. Water management and zero hunger are of the major objectives of the '2030 Agenda for Sustainable Development Goal and its 17 Goals to Transform our World'. According to Doll & Siebert [12] there is irrigation system in 174 out of 225 countries worldwide. In the global hydrological cycle agriculture is by far the largest consumer of water [13] and seventy percent (2710 km^3) worldwide water withdrawn from river and aquifers are used for irrigation purposes. However, in many developing countries, irrigation represents up to 95 percent of all water withdrawn [14]. During last five decades, the world net cultivated area has increased 12% and the irrigated area has doubled. According to Hunt *et al*. [1] irrigated agriculture is an unusual addition to man's repertoire, unusual social resource and source of power. Irrigation water is a key driver and live blood of mixed mountain agriculture in rain shadow region of the Hindu Kush Karakorum Himalaya.

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In the arid mountain regions of Hindu Kush Karakorum and Himalayas, irrigation water management has distinctive characteristics [1, 15] as compared to other mountain resources management [16, 17]. In general irrigation water governance has a very long history [2] and is embedded in social and cultural institutions based on norms and access strategies. The scientific interaction and relationship of irrigation water to society are coined "socio-hydrology" as a new science [8, 18]. According to Sivakumar [19], socio-hydrology is not a new science at all, but it is existed at least over thirty years. Whereby the co-owners communities perform multiple tasks including establishment and implementation of rule and regulations, allocation of water, operation of the hydraulic works, repair and maintenance of infrastructure, mobilization and administration of resources, and alliance-building and networking [20]. The rules, a combination of individual and collective rights and obligations, form the normative foundation for the collective management of irrigation systems [21].

The agro-pastoral economy of the dwellers of the arid milieu of Hindu Kush heavenly depends on the availability of irrigation water [8, 22]. Agricultural activities and farming are impossible without irrigation. Therefore, irrigation is an indispensable input of mixed mountain agriculture because precipitation is decisively below the agronomic limit for rain-fed cultivation. Moreover, irrigation water is determined by spatiotemporal pattern of precipitation and irrigation water is mainly recharged by precipitation. The rainfed agriculture is very limited and confined to the southern part of Chitral district [3, 15].

In the semi-arid mountainous belt of the Eastern Hindu Kush, irrigation water is the main limiting factor for crop growth and productivity. However, agricultural water is determined by spatiotemporal pattern of precipitation and water is recharged by precipitation in Chitral district. Snowfall of winter season is the potential water source for forthcoming cropping season [10, 15, 23] and climate change embody superfluous stress on irrigation water. However, climate change increases the vulnerability to increasingly severe irrigation water shortages. In order to cope with the irrigation water scarcity the inhabitants of Chitral have developed highly sophisticated irrigation governance and creative adjustment mechanisms. The locally developed indigenous institutions for water governance play a major role in enhancement of the adaptive capacity of local communities [24]. These indigenously formulated and locally developed institutions for water governance system are considered as a mediating strategy in a critical and uncertain environment [25, 26, 27].

The mainstay of economy of the remote rural mountain village of the Chitral district is combined mountain agriculture [28, 29], and more than ninety per cent of the people of the study area are directly or indirectly engaged in agricultural activities for subsistence sustenance. Farming of the study area is exclusively dependent on surface irrigation system and distributed through a network of small irrigation channels. Perennial streams from glacial melt and natural springs are the only source of water for irrigation and drinking. Unlike other hydraulic societies [2, 3, 4, 15, 30] inhabitants of the remote village Kushum have developed a unique creative adjustment mechanism and put irrigation water under temporary dynamic property regimes like private, communal and open access usufruct rights for efficient management and utilization of limited irrigation water. These property use rights and management regimes for irrigation water in the study area have evolved over centuries in response to environmental, cultural, and political imperatives. At village level access to, withdrawal from, and utilization of irrigation water resources are closely associated with property right and ownership regimes. Keeping in view the importance of irrigation for subsistence agriculture and its very long history of successful functioning, an attempt has been made to evaluate the effectiveness of dynamic hydraulic tenure and coping capacity of the mountainous hydraulic society in addressing, mitigating and alleviating with the scarcity of irrigation water in response to climatic change scenarios in a remote semi-arid mountain village of Chitral District.

MATERIALS AND METHODS

In order to achieve the objective of the study, data were collected from both primary and secondary sources. Primary data was collected through participant observation, unstructured interviews and focused group discussion conducting extensive field work in village Kushum during 2010 to 2018. The questionnaire was designed to collect data on water budget and individual share in irrigation water. The system was quite difficult and complicated to understand which is exactly labeled as "the system nobody knows" and "the system nobody sees" by researchers Netting [2] and Verzijl & Quispe [31]. Therefore, focus group discussions (FGDs) were arranged

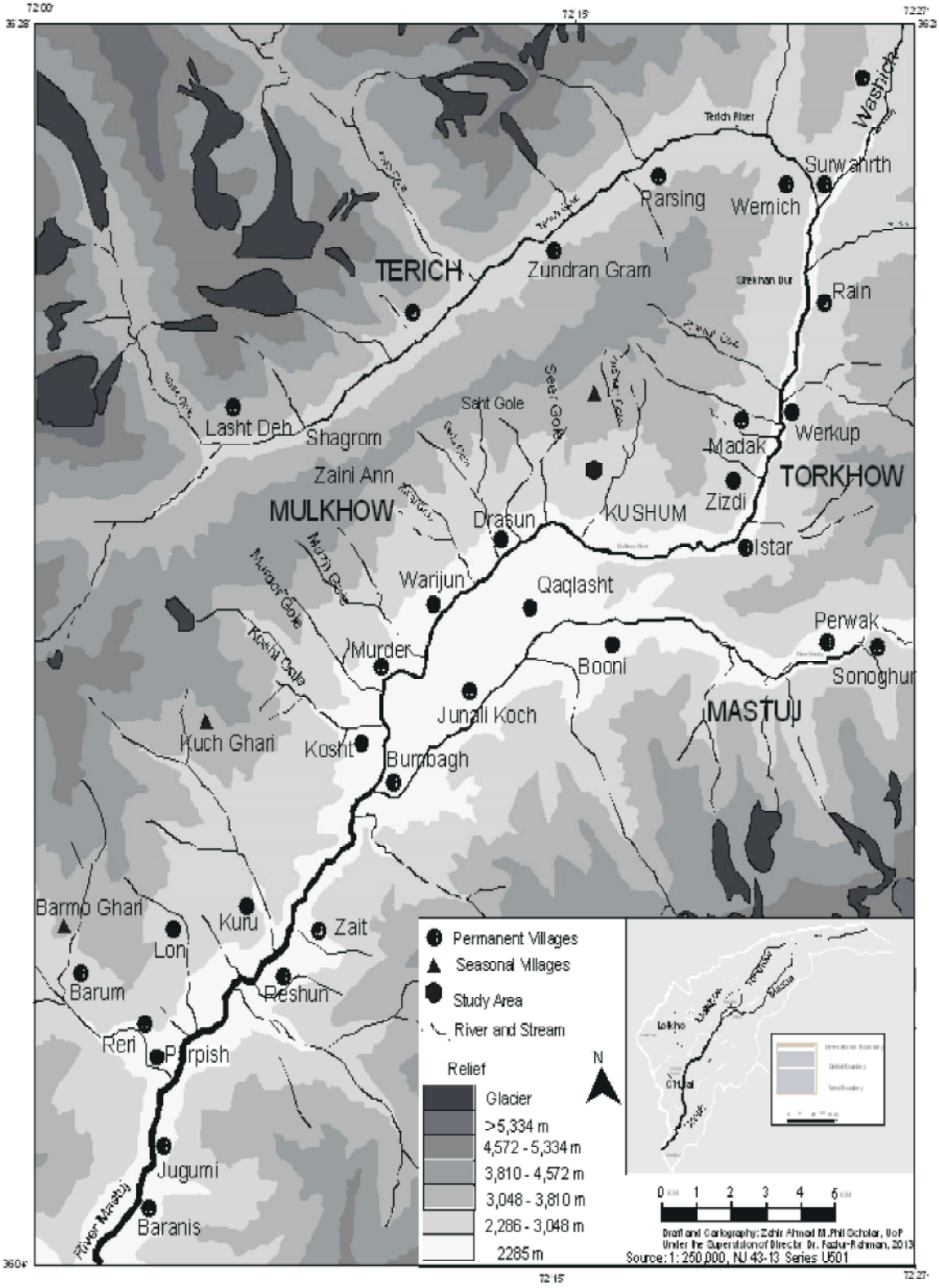
Table I: Village Kushum, Spatially Distributed & Temporally Dynamic Managment of Water, (January to December)

Temporal Distribution Dynamics		Dynamic in Spatially Distribution / Allocation			
		Kushum Nichagh		Kushum Pakhtori	
Date/Month of Irrigation Season	Major Characteristics of irrigation Water with respect to Time and Seasons	Upper	Lower	Upper	Lower
April to Mid-July	Name of Water: Ochi o Ough (watering of crops for proper nourishment during the growing season) Property Right: Communal resource Allocated based on household, Every household has equalshare. No share of migrant household/ tenant land has no share in water but tenant household has share in irrigation water. A household cannot sell his share of water to other	Day water (12 hours) is used for watering of crops	Night water (12 hours) is used for watering of crop	Day water (12 hours) is used for watering of crop	Night water (12 hours) is used for watering of crop
Mid-July to Mid-Sept	Name of water: Padari (Actual share of water according to inheritance and land ratio) Property Right: Private Resource Uneven distribution of water among households Share of migrants household's water is given to tenant Water can be granted to the needy farmer or can be sold	Continuously Eight days & nights water is used for watering of orchard	Specific share of water i.e 48 hours per eight days is allocated for watering of orchard	Both day and night (24 hours) are used to irrigate crops	No water is allocated to this zone due to remoteness and little
Mid-Sept to Nov	Name: Kishmano Ough (Water especially used for cultivation of crops during winter season). Property right is Private. Water can be sold but can be granted only to the household/ farmer of the same village but cannot be granted to the other village's farmer. Reciprocal Exchange Custom/Agreement between upper and lower parts of Kushum and among villages of uppers parts as well	Both day and night (24 hours) water is used for cultivation of winter crops	No Irrigation water due to Reciprocal exchange	Both day and night (24 hours) water is used for cultivation of winter crops	No water during this time period
Nov to Mid-Dec	Name: Kishmano Ough (Water specially used for cultivation of crops during winter season). Property right is Private. Water can be sold but can be granted only to the household/ farmer of the same village but cannot be granted to the other village's farmer. Reciprocal Exchange Custom/Agreement between upper and lower parts of Kushum and among villages of uppers parts as well	No Irrigation water due to Reciprocal exchange	Both day and night (24 hours) water is used for cultivation of winter crops	Irrigation water is channeled to down or lower villages therefore No irrigation water during this time period	Both day and night (24 hours) water is used for cultivation of winter crops
Mid-Dec to March	Name: Hati (Every farmer can use without any restriction) Property Right: Open Access	Due to low temperature, agricultural activities cease and irrigation water is no more needed in the whole village. However, in case of no rainfall, households irrigate their field and orchards to increase soil moisture and preserve it for early spring without following customary laws and rotation rules.			

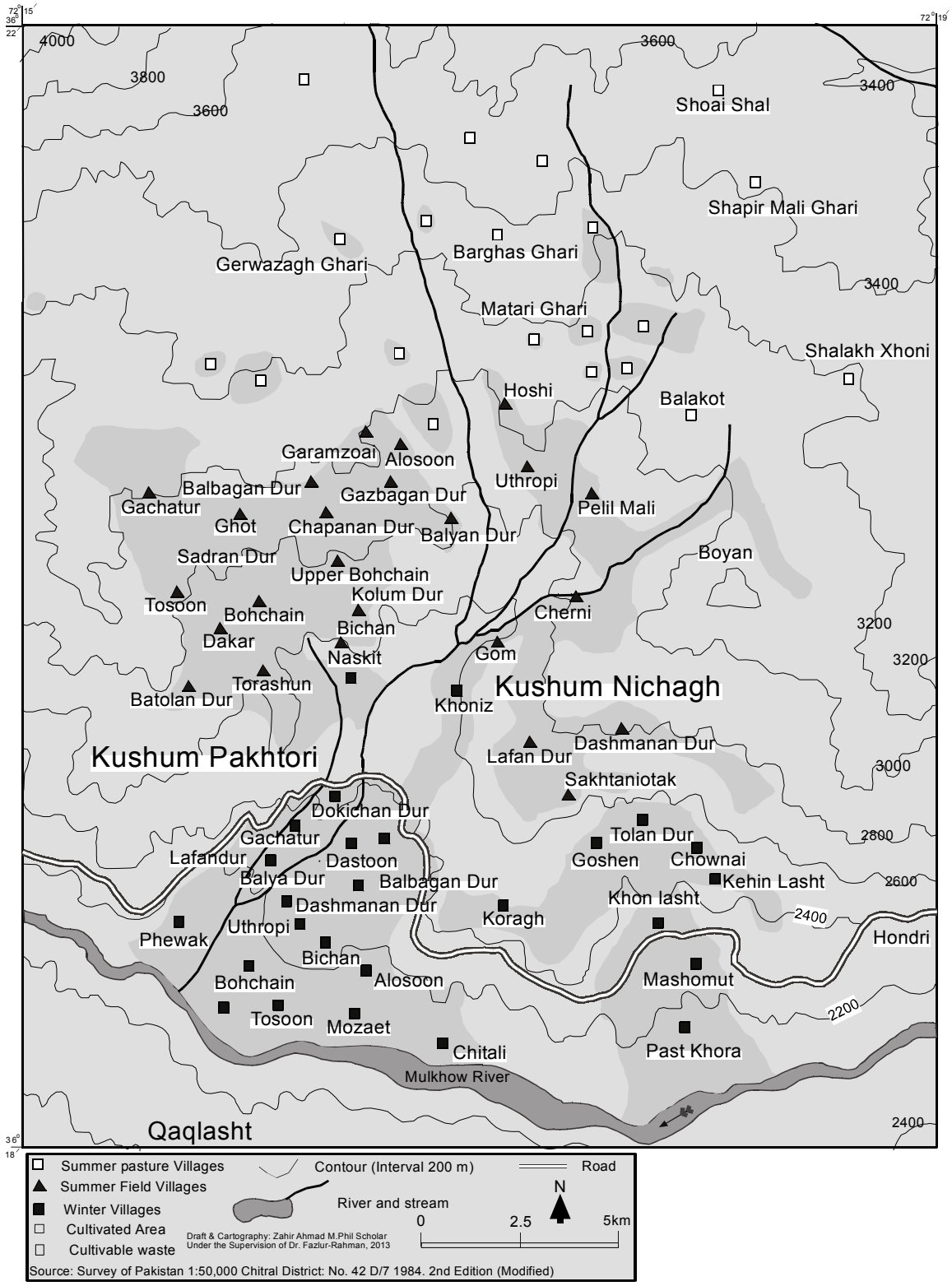
Source: Focus Group Discussion, 2010-17

in both sections of village Kushum. The FGDs were conducted from the village elders and knowledgeable persons to get information about, indigenous water allocation device, share of irrigation water among neighborhoods, temporal and spatial management of irrigation water. Irrigation water management is determined by spatio-temporal pattern of precipitation and temperature. Therefore, climate data of precipitation and temperature for the long term series data (1982 to 2017) was acquired from Pakistan Meteorological Department Peshawar. Moreover, demographic development has a great impact and pressure on resources. Data related to population growth was gathered from Census Report of Chitral District (1961, 1972, 1981, 1998 & 2017).

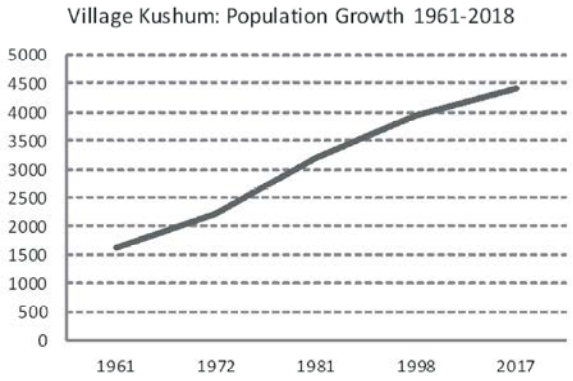
Geography, Demography and Hydrology of Village Kushum: The study area, village Kushum, is located at a distance of about 100 km to the north of Chitral town in Pakistan. It covers considerable vertical extent from the banks of Mulkhow River about 2,052m to the crest of Mulkhow-Terich divide more than 3,660m above mean sea level. Based on allocation of irrigation water, it can be divided into two major zones Kushum Nichagh (Eastern Kushum) and Kushum Pakhtori (Western Kushum). Each section is further divided into two parts based on elevation. These are lower part of Kushum Nichagh and upper part of Kushum Nichagh, lower part of Kushum Pakhtori and upper part of Kushum Pakhtori (Table, I). The study area is located to the right bank of Mulkhow River. On the north Kushum is bounded by Terich valley and to the west Drasun. On the South Booni while Zizdi village is located to the east of Kushum (Map, I; II). Geographically Kushum is located between 36° 18′ 08″ and 36° 22′ 14″ north latitudes and 72°15′ 32″ and 72°19′44″ east longitudes [32].



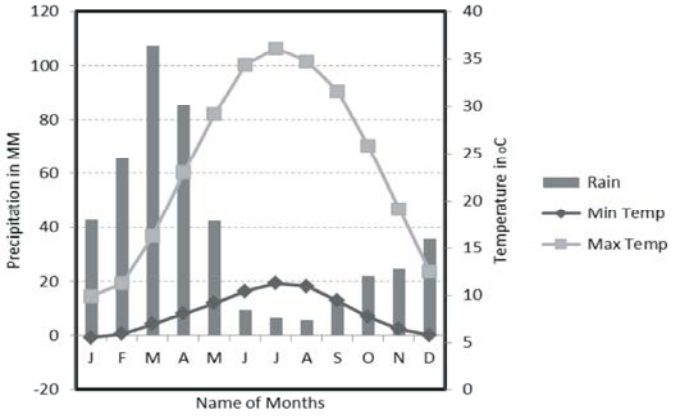
Map I: Location Map of Village Kushum and Surrounding Areas, Chitral Northern Pakistan



Map II: Detail Map of Village Kushum Chitral District Northern Pakistan



Graph I: Population Growth of Village Kushum Chitral District (1961-2018)
Source: GoP, 1962, 1976, 1983, 1999, 2018



Graph, II: Chitral Station, Monthly Mean Minimum & Maximum Temperature (1982-2017) & Precipitation (1966-2017)

Population of the study area is increasing at an explosive rate. According to the census of 1961 the total population of Kushum was 1,629 souls that jumped to 3,194 in 1981[33, 34, 35]. It means that population has been doubled within twenty years. According to the census of 2017, the total population of Kushum was 4412 [36]. It has increased by more than two times during last 56 years (Graph, I). Due to rapid and alarming increase of population, irrigation water management mechanism is considered to be one of the most factors affecting the sustainability of natural resources.

Distance from the ocean and the very abrupt changes in altitude influence the climate which is of the extreme continental type with long cold winters and short hot summers. Dominated by the continental climate, precipitation in Kushum is generally low and concentrated in a few months of the year. Rainfall is often insufficient to meet the water demand of crops in the whole growing period or part of it. Therefore, irrigation is crucial for agriculture. According to the data of nearest meteorological observatory Chitral (at a distance of 100 km) climate of the study area is semi-arid with a mean annual temperature of 16°C and precipitation of 460 mm. Temperature remains high during the whole summer season in lower parts of the study area. A steep rise of temperature is observed from May to July. A rapid fall of temperature is recorded from October to December. July is the hottest month of the summer season in the study area, the mean maximum temperature of thirty years for the same month is 36.12°C and mean minimum temperature is 19.4°C (Graph, II). Winter season starts in November and lasts till April. January is the coldest month of the study area. In this month the temperature drops below freezing point. The mean minimum temperature is -0.7ºC and means maximum is 9.9°C. In January the night time temperature usually falls to below 0°C.

The study area is located at the rain shadow of the Hindu Kush Range and receives the very limited amount of precipitation. Precipitation is inconsistent and unevenly distributed round the year (Graph 1). The total annual rainfall is 460 mm. The study area receives highest amount of precipitation in winter season from December

to April in the form of snow through western disturbances. The average precipitation from December to April amounts to 337mm which makes up of 73% of the average annual precipitation and is important because it firstly, provides moisture to the Rabi growing season, and secondly fed the streams, upon which irrigation is dependent. The rainfall increase in December and the maximum is reached in March when 107 mm rainfall. The summer and autumn rains form only about 27%. Summer and autumn are the driest seasons particularly July to November a very small amount of rainfall take place.

Kushum is known for water scarcity throughout Chitral. Irrigation water in Kushum is determined by the spatiotemporal pattern of precipitation and water is primarily recharged by precipitation. While creating the spatially uneven distribution of water resources, the spatiotemporal pattern of precipitation further reinforces the spatial distribution of water resources by introducing a spatially heterogeneous temporal variation. Water shortages coupled with a growing and large population increases the risk of water scarcity by creating an ever-increasing demand for water in the study area. The main source of irrigation water is springs which provide more than 90% of the irrigation water to the village. There are two springs and they provide water to the study area at constant amount, two *Khorarogh*[1] (six cusecs) round the year. Similar to other region [15, 23], the actual amount of winter snowfall is crucial factor for water availability in the study area. Early snowfall in December and January is highly valued by the villager as the optimal potential water source for the forthcoming crop season. Simultaneously a strong wind following a snowfall event is also essential for transporting the snow and ensuring that it accumulates in sheltered areas and deep gorges. The wind also triggers avalanches, thus causing huge amount of snow to be deposited in deep and plain surface areas, in the form of thick masses which contributes significant amount of water right from April to June. But the volume of water various from March to June depending the amount snow in the spur of the study area. In the month of May, the volume of water reached to its peak level, 10-12 *Khorarogh*. After May, it is shrinking day by day and in July, all the accumulated snow in the spur is fished and only springs provide water for agriculture for the rest of the time.

In order to divert the flow of water from head work to the target fields of the study area, two main channels have been constructed. The length of these channel are quite long i.e. more than 10 km. The nature and structure of both channels are very rough, stony and unlined. Therefore, considerable volume of water, half of the water is dissipated during summer season.

RESULT AND DISCUSSION

This study reveals that Kushum's irrigation water is geographically distributed and temporally dynamic. Geographically, irrigation water of Kushum is bifurcated homogenously between Kushum Nichagh (Eastern Part) and Kushum Pakhtori (Western Part) which is dubbed as water of Nichagh and water of Pakhtori through installation of *Nerwal*[2] (indigenous device for allocation of water) at the top (an altitude of 3,050 meter above mean sea level) of the permanent village in the close proximity of main source of the irrigation water. It ensures to maintain equity and avoid conflicts between Kushum Nichagh and Kushum Pakhtori (Plate, 1). Water of Nichagh is further distributed to upper and lower zones of Kushum Nichagh and water of Pakhtori is also allocated to the upper and lower belt of Kushum Pakhtori.

The management and appropriation of irrigation water between upper and lower zones of Kushum varies from season to season (Table, I). From March to June, day time water is allocated to the upper part of village Kushum and night water to the lower parts of village Kushum. During mid-July to mid-September, both day time and night time water are utilized in upper part of Kushum. However, a fixed amount of water i.e 48 hours at periodic interval of eight days is allocated to the lower part of Kushum Nichagh (LKN). During Mid-September to November, both day and night water is utilized in upper part of village Kushum and even no specific amount of water is allocated to the southern Kushum. From November to mid-December, water is allocated to the hamlets of southern Kushum. From mid-December to March, water is open

[1] *Khorarogh* is local measurement unit of flow of irrigation water in Chitral District Pakistan. It is roughly equal to 3 cusecs. According to Israr-ur-Din (1992; 126), "the discharge of water in a channel is measured in term of the amount needed to run a water mill. This measurement varies from place to place because of size of the mill-stone".
Gologh is smaller unit and it is equal to half of *Khorarogh* (1.5 Cusecs). *Chakhtogh* and *Gospanogh* are further smaller units of flow of irrigation water. Half of *Gologh* is called as *Chakhtogh* (0 .75 Cusecs). However, *Gospanogh* is the smallest unit and 1/10 of *Chakhtogh* is equal to one *Gospanogh* (0.075 Cusecs).

[2] According to Ahmad (2014; 2010) *Nerwal* is an indigenous water distribution device which was established in 8A.D

Plate I: The Picture of *Newal* of Village Kushum Chitral District
(Author's own Photography, 2017)

Plate II: The Picture of *Newal* of Kushum Pakhtori, Chitral District Northern Pakistan
(Author's own Photography, 2017)

access. Nevertheless, this spatial and temporal distribution of irrigation is closely associated with and based on agricultural activities, cropping season, temporally dynamic property regimes of water (Table, I). In addition to these, reciprocal exchange and sharing play a pivotal role in efficient management of irrigation water amongst upper and lower zones in order to cope with water scarcity in arid mountain milieu. However, similar to other hydraulic mountainous societies [1, 37], irrigation water of the study area is managed through highly sophisticated clearly defined, well developed and strictly enforced property regime of water.

For efficient management and utilization of irrigation water among neighbourhoods, it is put on rotation which is locally called *Sorogh*[3]. Neighbourhoods of each zone have their own share in the form of *Sorogh* and practice an intricate system of irrigation management [2, 31] which vary from season to season. The cropping season wise appropriation and management mechanism of agricultural water of both zones (upper and lower Kushum) are described below.

Growing Season (April to Mid-July): At the beginning of irrigation season, irrigation water is managed and controlled by putting it on communal property right. During this time, irrigation water of Kushum Nichagh (KN) and Kushum Pakhtori (KP) are further divided into day time and night time water. During this season, water is needed both parts of village Kushum. Special care is given to minimize the water losses through evaporation. Therefore, day water is allocated to upper section of village Kushum due to proximity of source of irrigation water so that considerable amount of water may be saved and preserved from the losses through seepage, absorption and evaporation during day.

As far as property regime to water is concerned during this period water is kept under communal property right. The major characteristic of this water is that it is distributed based on households. Each and every household has an equal share in irrigation water during this season. However, to access right in irrigation water of a particular neighborhood, it is mandatory to have a house with few members living in it at that particular neighborhood. Otherwise, water share of out-migrant from the neighborhood is suspended during this period.

From April to mid-July, irrigation water is predominantly recharged by ablation of snow, accumulated in the high spur of the study area during a winter snowfall. Similar to other villages of Chitral [4, 15], early snowfall in December and January is highly valued by the villager as the optimal potential water source for the forthcoming crop season. During this season volume of agricultural water remains very high and there is no scarcity of water but cleaning and maintenance of irrigation channel is a difficult task. To ensure the cleaning and maintenance of channel, every household is given equal right to irrigation water in term of volume and duration so that the channel can be maintained properly.

[3] Baig (1997: 158) defines *Sorogh* as "*Sorogh* is a fixed volume of irrigation water with a time limit ranging from 24 hours or more to less than one hour".

Table II: Shareholder Villages of Kushum Nichagh's Irrigation Water (April-June). Source; Focus Group Discussion, 2010-17

			Temporal Dynamic of Irrigation Water								
			Mid-April To Mid- July		Mid-July to Mid Sep		Mid-Sep to November			November to Mid Dec	
Spatial Distribution		Name of shareholder Hamlets	Day Water	Night Water	Day water	Night water	Day water	Night water	Total share in hrs	Day Water	Night Water
I	Upper Villages of Kushum Nichagh	Pelil Mal	12 hr	00	12hr	12hr	24 hrs	24 hrs	48 hrs	In return of exchange of water of lower villagers, the upper villagers give their share to the lower villagers after completing the practices of cultivation.	
		Gom / Cheni	12 hr	00	12hr	12hr	24 hrs	24 hrs	48 hrs		
		Lafan-dur	12 hr	00	12 hr	12 hr	24 hrs	24 hrs	48 hrs		
		Dashmanan Dur	12 hr	00	12 hr	12 hr	24 hrs	24 hrs	48 hrs		
		Sakhtaniotaek	12 hr	00	12 hr	12 hr	24 hrs	24 hrs	48 hrs		
		Kinlasht	12 hr	00	12 hr	12 hr	24 hrs	24 hrs	48 hrs		
		Tholan Dur	12 hr	00	12 hr	12 hr	24 hrs	24 hrs	48 hrs		
		Lot Gadaee	12 hr	00	12 hr	12 hr	24 hrs	24 hrs	48 hrs		
II	Lower Villages of Kushum Nichagh	Koragh	00	12 hrs	A fixed amount of water (48 hours both days and nights) is allocated. 48 hours water with a periodic interval of eight days is allocated for watering of orchard & plants.		As per customary law, reciprocal exchange of irrigation water is practiced therefore during this season lower villagers give their share to the upper villages in return the upper villagers give their share to lower villagers.			48 hrs	48hrs
		Dokichan Dur	00	12 hrs						48 hrs	48hrs
		Gachatur	00	12 hrs						48 hrs	48hrs
		Granzhoi	00	12 hrs						48 hrs	48hrs
		Pewak	00	12 hrs						48 hrs	48hrs
		Dastoon	00	12 hrs						48 hrs	48hrs
		Lafan-dur	00	12 hrs						48 hrs	48hrs
		Dashmanan Dur	00	12 hrs						48 hrs	48hrs
		Balyan Dur	00	12 hrs						48 hrs	48hrs
		Uthropi	00	12 hrs						48 hrs	48hrs

Source; Focus Group Discussion, 2010-17

The detail of shareholder neighborhoods of KN and their share have shown on Table (II). There are eight villages in the upper part of KN and ten villages in Lower part of KN. It has already discussed that day water is allocated to the upper villages and night water is granted to the lower villages of KN.

Mid-July to Mid-September: Irrigation water of the study area is kept under the private property regimes during this irrigation period and it is locally called as *Padari*. The silent feature of this irrigation water is that the ration of migrant household is given to his tenant. The water of this period can be granted to the people of other villagers upon their request and can also be sold (table, I). During this season both day and night water is utilized in upper part of KN, therefore, the ration of each village increased from 12 hours to 24 hours per a periodic cycle of ten days. However, a fixed amount of water i.e 48 hours periodic interval of eight days is allocated to the southern hamlets of KN (table, I). The water of lower neighborhoods during this period is called Golo Sorogh I & II. The share and ration of the neighborhoods of KN's irrigation water are shown on Table (II).

Mid-September to November (Crop Sowing Season in NK): Sowing season of winter crop starts in the upper zones from mid-September and ends in the end of October. During sowing season, much water is needed to the upper zones due to short sowing period. Because late sowing creates low production on one hand while on the other hand it leads to failure of seed germination due to extreme cold weather condition (graph, I). Keeping in view the cold climatic condition of upper zones, the irrigation water is totally allocated to the upper zones from mid-September to end of October (Table, II). This period coincides with the sowing season of the winter crops in Northern Kushum, therefore, both day and night water is used in upper villages and even the fixed share of winter villages' i.e. 48 hours also utilized in the upper villages due to high altitude and very short sowing period of the crop. The specific ration of winter villages is utilized in the summer villages on reciprocal exchange condition as per customary law of irrigation water (Table, I). This type of exchange of water is locally called as *Badaldik*. Moreover, during this season, the share of all villages increased from 24 hours to 48 hours while increasing rotation cycle. Because, land preparation for sowing of winter crop need much water, therefore, the shareholder's villages increase the period of rotation cycle from 10 days to 20 days in order to increase the length of irrigation period and to utilize the irrigation water more economically.

November to Mid-December (Crop Sowing Season in SKN): Sowing of winter crop starts in November at southern Kushum. Therefore, in the early November, the water is channelled down to the lower part of village Kushum for cultivation of winter crops (Table, II). Shareholder hamlets of SKN utilize the agricultural water through turn base.

At the micro level, agricultural water management is highly intricate and vary from one neighborhood to another. Each unit has its own co-owners and independent system of water appropriation. This highly sophisticated system of irrigation water has been formulated in ancient time, more than seven century ago, and these are smoothly functioning still. However, with the passage of time new co-owners are entered due to the demographic development and the share of household is decreasing both in volume and duration. The ration of household are strictly maintained for smooth functioning of the system and avoid from any conflict. In order to highlight the significances of autochthonous management system of irrigation water in response to demographic development a case study from upper Hamlet of Kushum Nichagh is presented below in detail for all three agricultural seasons.

Case Study: Lafan-dur: Lafan-dur is a multi-ethnic hamlet comprising of three different clans Boshay, Lafay, Mosingay. It is summer field hamlet of upper Kushum Nichagh located at an altitude of 2744m above mean sea level. It consists of 24 households and the total population of this village was 204 in 2017. Amongst clans, Boshay is the influential clan of this village, he possesses lion share in both water and land resources. Lafay and Mosingay are distributed widely and possessed limited share in both water and land resources. However, Lafay clan is the pioneer settler of this village, and the name of the village is borrowed from the name of clan Lafay [27].

Similar to the other hamlets of Kushum, irrigation is an indispensable input of agriculture at this hamlet because precipitation is decisively below the agronomic limit for rain-fed cultivation. A highly sophisticated system applies to the allocation of irrigation water. A high degree of organization and control is involved in this practice. Irrigation is the symbols of survival in this semi-arid environment. There is extreme water scarcity in Lafan-dur. The main cause of water scarcity is limited ration and long distance from the irrigation source.

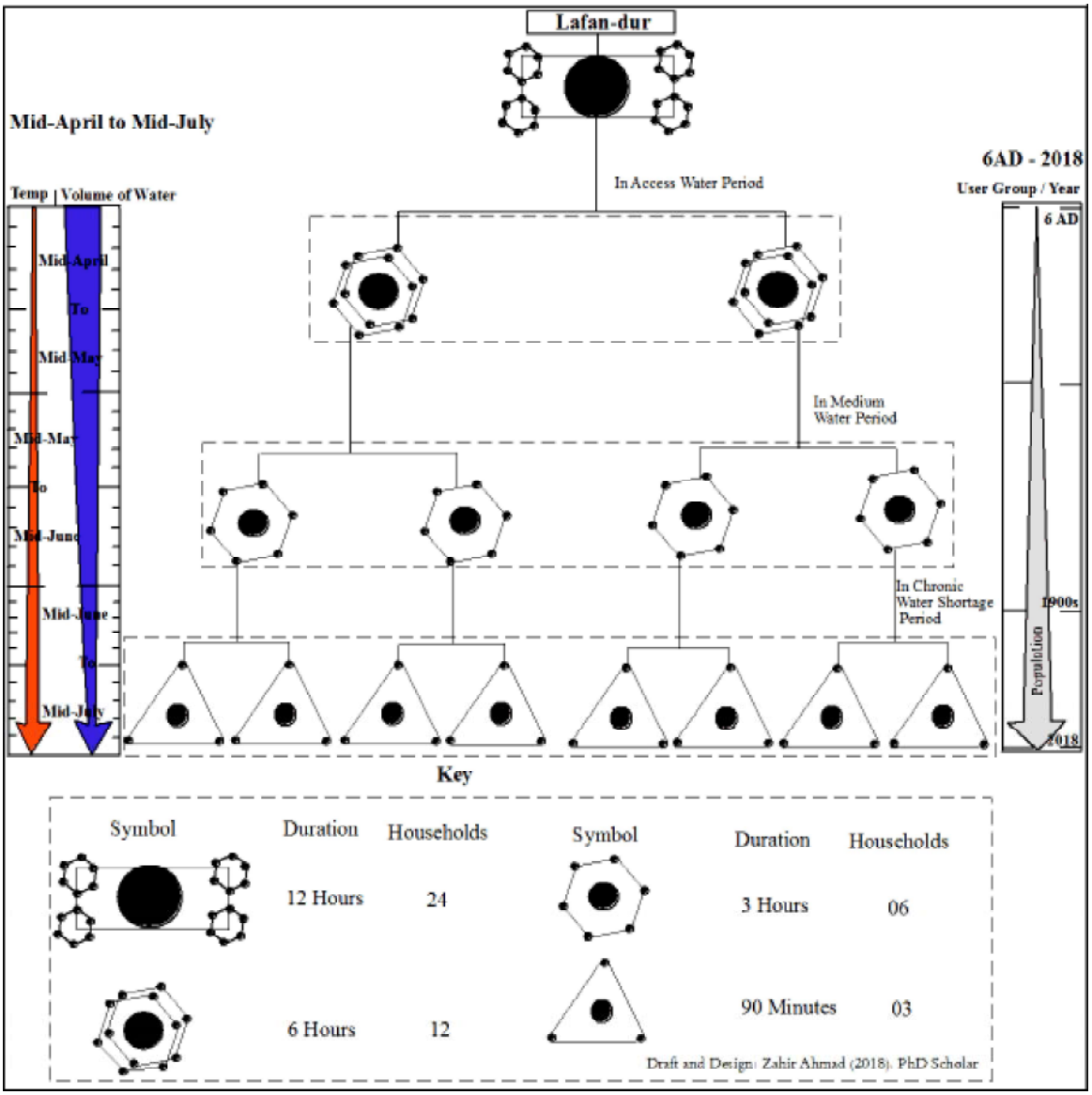
It take water from the water of Kushum Nichagh however, its share is altered from season to season. From April to Mid-July, it receives 12 hours water per eight days. However, its share is increased during Mid-July to Mid-September and it receives 24 hours water in ten days cycle. Due to the reciprocal and mutual exchange of irrigation water, it receives 48 hours water per 20 days. Therefore, management of irrigation water with respect to different irrigation seasons has been discussed below in detail.

April to Mid-July: Management of Water at Household Level: During this season, the share of water of this village is 12 hours per eight days. It consists of 24 households. The principle of allocation of irrigation water is based on the number of households. However, both availability and occupancy of the house (*Koshon-ai-naek*) are the main pre-requisites to have access to irrigation water during this period. Out-migrant households from this hamlet are not entitled with irrigation water during this period due to lack of participation in co-operative activities, mutual help and reciprocal endeavours [38] like cleaning, maintenance of channel. The share of the migrant households are suspended and invalidated during this period only. According to the customary law of *Ochi-o-Ough*, all households have an equal share in irrigation water during this season irrespective of their land size. Both small and large size landholders have an equal share in irrigation water. Moreover, the disintegration of joint family as an independent household could access right in irrigation water equal to other household of the hamlet.

One day water (12 hours) is distributed among 24 households equally. The actual share of each household is 30 minutes. The utilization mechanism exclusively depends on the volume of the water. In access and high runoff period, households combine together and form double hexagonal irrigator group in order to enhance the length of duration of water from 30 minutes to six hours while dividing the water equally amongst twelve households (Fig, I).

The rotation of water with respect to time (morning and evening) is also important because, the volume of water fluctuates from morning to evening time. For instance, in the spring and transition summer season the volume of water increased after 12 p.m because of insulation, a considerable volume of water recharged from the melting of accumulated snow in the spur. In contrary to this, after mid-June, irrigation water is decreased after 10 o' clock because all the accumulated snow in the spur is finished and high insulation accelerates both evaporation and absorption rate result a decrease in volume of the water. Therefore, the shareholders of double hexagonal groups also put the morning and evening water on rotation in respect of time (Fig, 1).

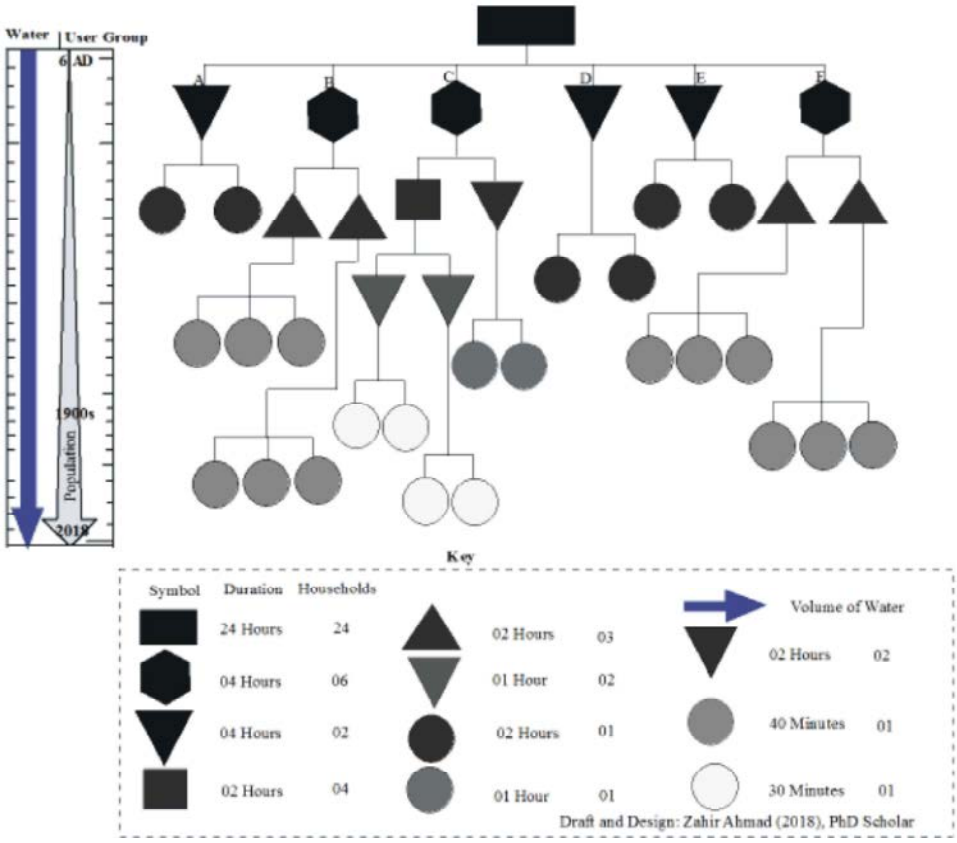
With the change of season, the volume of water shrinks and becomes inadequate to divide into 12 equal parts. Therefore, each double hexagonal group is disintegrated into two single hexagonal groups. The ration of each hexagonal group is three hours. Each member of hexagonal group utilizes the water for three hours (Fig, 1).



Fig, I: Village Lafan-dur, Ration and Utilization Management Mechanism of Communal Irrigation Water (Mid-April to Mid-July)

Paucity of irrigation water prevails with the advent of July when all the accumulated snow in the spur is melted away and then only springs provide limited water for irrigation. In the month of July, the volume of water in the channel is extremely decreased and become too limited to distribute among six shareholders. Then the households adopt another mediating strategy in order to utilize the available limited water more efficiently. They divide the hexagonal group system and form triangle groups. Each member of triangle group utilizes the irrigation water for one and half hours. This strategy is practiced as a creative adjustment mechanism during the drought period.

Mid-July to Mid-September: Creative Adjustment Mechanisms at Household Level: During this time the ration of irrigation water of Lafan-dur is 24 hours in ten days cycle and is distributed equally among six primary user groups that are symbolized as A, B, C, D, E, and F (Fig, II). In the initial stage, about seven or more centuries ago, the population were confined to six households and the then irrigation water was equally distributed among them and the share of each household had irrigation water for four hours in ten days cycle (Fig, II). The descendants then followed the same general principles of management and equity. Today's inheritors



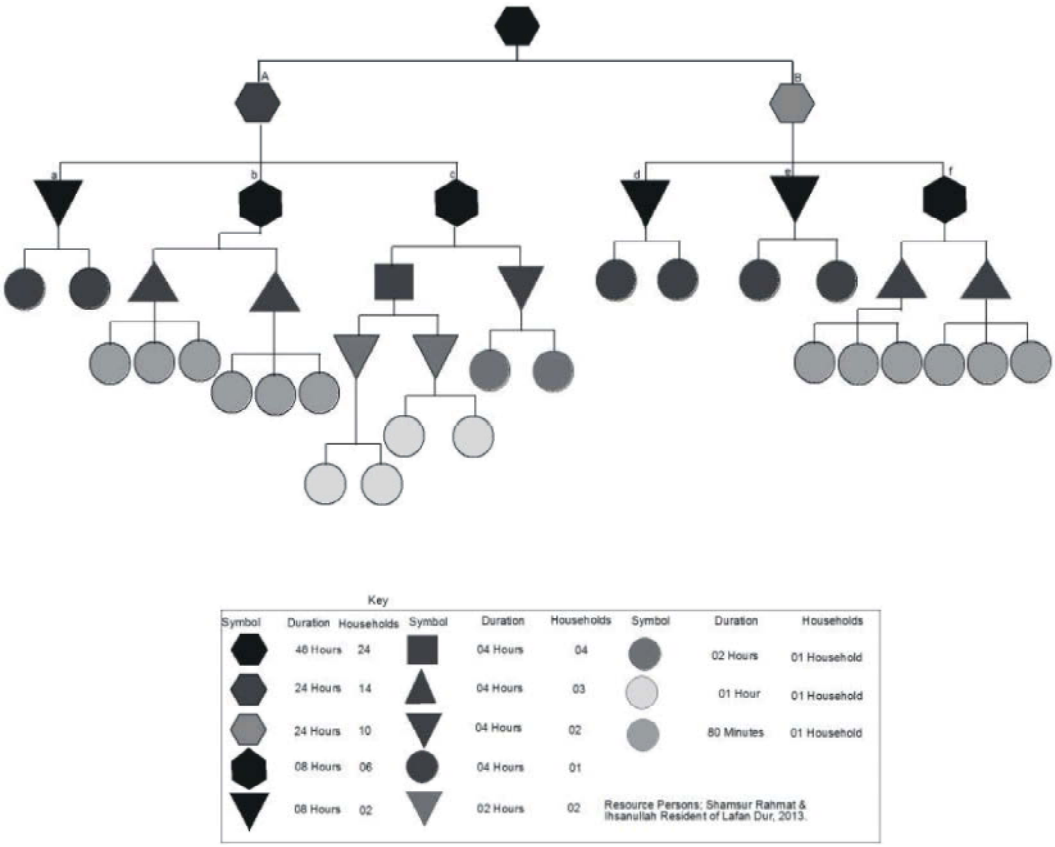
Fig, II: Village Lafan-dur, Ration and Utilization Mechanism of Irrigation Water (Mid-July to Mid-September)

still keep to the old methods without modification, even with the ongoing disintegration of joint families. Each secondary, tertiary or quaternary subgroup takes his share from their respective primary group. For example, according to Fig (II), each group A, D and E has two sub-groups. Each of them has 2 hours water in 10 days cycle. The utilization mechanism of irrigation water is completely different as compared to the individual ration of the possessor. Each and every end user-group does not use his specific ration separately. But each secondary group establishes an irrigation group with his primary group in order to enhance the duration of irrigation period from two hours to four hours (Fig, II).

The allocation of irrigation water of group B and F are very complex due to disintegration of joint family into tertiary user groups. There are six tertiary user groups in each primary group B and F. Each shareholder has irrigation water for 40 minutes per ten days. However, each shareholder merges with his parental group and forms a triangle hydrological user group in order to increase the length of irrigation period from 40 minutes to two hours while dividing the water into three parts homogenously (Fig, II).

The allocation and management of agricultural water of group c is highly intricate because of emergence of quaternary group due to demographic development. There are four quaternary users and two tertiary users in this group. Therefore, the ration and share of end user group varies from tertiary to quaternary. Every end user of tertiary subgroup has one hour (60 minutes) water while each end user of quaternary subgroup has 30 minutes irrigation water per ten days. In chronic reduction period of agricultural water, each shareholder use his own share. But in access runoff period, the members of this group also practice combined irrigation management system in order to enhance the irrigation duration.

Mid-September to November: Coping Strategy for Water of *Kishman*: The ration of village Lafan-dur during this season is 48 hours in 24 days cycle. The water of period locally called as *Kishman* and water of *Kishman* is equally divided among two primary groups i.e. A and B. The primary user groups have been divided into six secondary user groups which are labelled as a,b,c,d,e and f (Fig, III). The share of each secondary user group is eight hours in the irrigation of *Kishman* (Fig, III).



Fig, III: Lafan-dur, Ration and Utilization Mechanism of Water of *Kishman*

The distribution of water of *Kishman* among the end user groups are highly complicated and unevenly distributed. The main cause of uneven distribution of irrigation of *Kishman* is unknown; however, out migration of households and unevenly demographic development might be the factors of uneven distribution.

According to the Figure (III), the allocation and management system of secondary user group a,d and e are identical due to having same number of households. Irrigation water of *Kishman* is equally divided between the shareholders of these groups. Each co-owner has four hours water in 24 days cycle. Unlike to their actual ration, all shareholders of their respective group form a hydrological bond by mutual sharing of their actual share in order to increase the irrigation period from four hours to eight hours.

The secondary user group's b and f have similar irrigation management system and each secondary group has six end shareholders. The ration of each and every end shareholder is identical i.e. 80 minutes (Fig, III). However, three co-owners of each group combine to form triangle group in order to increase the length of irrigation period for proper land preparation.

There are six co-owners in secondary group c. Four hour water is allocated equally among six quinary co-owners while the share of each member of quaternary group is two hours. Similar to other groups, the members of quaternary and quinary group form irrigation group's (Fig, III) for proper management of irrigation water. In this way, irrigators increase the period of irrigation. This creative adjustment mechanism is very important as compared to the actual ration of the co-owner because watering with high volume creates several problems like erosion of fertile soil, wastage of water, etc.

Concluding Remarks: This study highlights that irrigation water of the study area is distributed geographically and temporally dynamic. Geographically, agricultural water is distributed homogenously between eastern and western part of the study area through installation of *Nerwal*. The appropriation of agricultural water between lower and upper belts of the study area is based on agricultural activities and cropping season. The appropriation management mechanism of irrigation water had been formulated in ancient time and is in practice for the last many centuries. The main cause of practicality of

this indigenous water governance system is that it ensures the accountability at all stages of operation and community members are fully involved in the decision making process, which builds ownership and trust in the system. The entitlement and ownership rules are still unwritten and passed from one generation to another through oral narration. All the shareholders have sufficient knowledge and information on this subject.

The property regime and management of irrigation water varies from season to season depending on the availability of the water. It is usually kept under communal ownership in access period, private in the extreme scarcity situation and open access on the off-agricultural season. Generally, in the beginning of agricultural season, every household need water for nourishment of winter crops, the primary source of livelihood of the local people. So, water is kept under communal property regime and equal access right is given to every household in irrigation water during the growth period of winter crop. In the summer season, chronic shortage of water prevails in the study area and agricultural water is kept under private property regime. In the winter season, agricultural season is ceased and water is considered open access property regime. This temporally dynamic property usufruct is the prime mitigating strategy and creative adjustment mechanism to cope with seasonal paucity of irrigation water.

From the micro level case study of agricultural water it is evident that though climate change and population growth increased pressure and stress many folds on irrigation water but do not always lead to tragedy of commons. The mountain farmers do have capacity, knowledge, insight and managerial potential to formulate mechanisms for management of irrigation water (Fig, I). Mountain inhabitants change their coping strategy and utilization mechanism of irrigation water with the change of temperature and water volume and population growth (Fig, I, II, II). This study also shows that the shares of the co-owners are decreasing both in term duration and quantity due to demographic development, disintegration of family and climate change but the autochthonous appropriation mechanism and institution of irrigation water play a pivotal role in sustainable management of irrigation water.

The case study shows highly intricate entitlement and distribution system of irrigation water. It seems very difficult to remember his turn and share and rotation system. Apparently it seems that there is no equity in the allocation of irrigation water among the co-owners in the current distribution system of water for the month from July to December (Fig, II, III). Nevertheless, this distribution was also based on equity but with the passage of time uneven population growth and out-migration of households from the study area totally transformed the system.

Water leakage in irrigation networks is one of the major problem and rational of paucity of water. It is estimated that more than half of the water is lost due to leakage in the canal. It is recommended that leakage of water in irrigation channel should be controlled through canal lining. Moreover, from December to April, considerable volume of water dissipates on daily basis without any utilization. Therefore, it is suggested that pond should be built for conservation of highly valuable irrigation water resources.

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