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RESEARCH PAPER

Assessment of ecosystem services of oak forests, Tangir valley, district Diamer, Pakistan

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Key Message: The study identified ecosystem services (provisioning, regulatory, supporting and cultural services) in Tangir valley, district Diamer, Gilgit Baltistan. Forest community recognized provisioning services as the most important because of its tangible benefits compared to other intangible services (regulatory, supporting and cultural services).

Abstract: Socio-cultural assessment is an extensively used method to quantify ecosystem services (ES). Present study investigated socio-economic importance of ES and measured carbon sequestration potential as regulatory ES in seven villages (Sheikhou, Jaglote, Glai, Adrkali, Shumari, Shabinal and Sobokot) of Tangir valley, district Diamer, Gilgit Baltistan. Questionnaires and interview based social survey was conducted to explore provisioning, regulatory, supporting and cultural ES. Further, forest attributes data was collected from 29 inventory plots in pure stand of *Quercus ilex*. Results showed that the provisioning services are comprised of fuel wood, fodder, grazing, food, leaf litter, fresh water and timber. In group discussion, community members gave top rank to the fodder (for their livestock) followed by fuel wood and litter collection. The highest correlation was shown between timber and monthly income ($R^2 = 0.42$) whereas lowest was ($R^2 = 0.09$) for NTFPs and fuel wood. Whereas negative correlation was perceived for agriculture, leaf litter, grazing, fodder and range land with R^2 (0.31, 0.18, 0.17, 0.15 and 0.11), respectively. Local communities were less aware about regulatory and supporting services as these ES are taken as far-granted. Forest inventory showed that mean above ground biomass and carbon stocks were 72.46 and 34.06 t/ha, respectively. Similarly, total biomass and carbon stocks were 90.22 and 42.40 t/ha, respectively. Regarding cultural services, the area has great potential for eco-tourism due to outstanding landscape, scenic beauty and biodiversity. Present study suggests further in-depth evaluation of ecosystem services provided by *Quercus* forests on the regional scales.

Key words: Carbon sequestration, Ecosystem services, Fuel wood, Tangir valley

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Introduction

Appraisal based on social and cultural aspects is one of most extensively used approaches to evaluate ecosystem services and has emerged as a vital tool to quantify contribution of ecological services to human prosperity (Iniesta-Arandia et al., 2014; Scholte et al., 2015; Dorji et al., 2019). Functional values of ecological systems can be recognized and quantified through detailed monetary valuation which may be integrated with quantifying biophysical attributes for assessment of ecosystem services (Kubiszewski et al., 2013; Baral et al., 2014; Viirret et al., 2019). In the context of human wellbeing, evaluation of ecosystem services may be divided into two major parts; one that quantifies tangible benefits or direct services (it may include food, forest produce, hydrology etc) whereas the other quantifies intangible benefits or indirect services (it may include recreational values, ecotourism, socio-cultural values, spiritual attachments etc). Assessment of aforesaid two types of ecosystem services help in recognition and understanding of local community, dwellers and shareholders (Smith & Sullivan, 2014; van Oort et al., 2015).

Evaluation of ecological services based on socio-cultural values are considered as central and core part of all direct and indirect services because they show relation of societies with ecosystem. Such as provisioning services can be assessed on how much materialistic output from ecological systems (timber, wild food, medicines, minor and raw products, fresh water) are utilized by mankind (Kalaba et al., 2013; Kandziora et al., 2013). Similarly, regulatory services are linked with socio-cultural aspects in the way that pollution free air or soil is utilized by human beings and it also includes that to what extent ecosystems protect the local community from extreme events such as floods or diseases (Bogdan et al., 2016). Further, regulatory services also play an important role in carbon sequestration (Onaindia et al., 2013), regulation of microclimate, soil water plant relationships, pollination and bio-control through sustainable food web (Harrison et al., 2014). Likewise, ecological systems also support hundreds of species and act as a genetic pool for biodiversity hot-spots; all such services fall under habitat supporting services (Bastian, 2013) which have significant impact on human life. Lastly, one of the powerful non-biological aspects of human survival is the cultural services provided by ecological system such as maintenance of mental and physical health; heritage, art and design preservation; tourism and spending their free time in outstanding beautiful natural landscapes (Iniesta-Arandia et al., 2014; Plieninger et al., 2014). Such precious ecosystem services should be documented and evaluated in order to understand their economic, social and cultural aspects for socially equitable management decisions (Scholte et al., 2015; Nordstrom et al., 2019).

In the context of ecosystem services; Quercus Forests (Oak species) are valued throughout the world; particularly in Asia, Europe and America (Johnson et al., 2009; Schweitzer et al., 2019). Forests of *Quercus* species provide different ecosystem services such as wood industries drive timber from these forests, biological energy in terms of *Quercus* biomass, Oak forests support biodiversity and also various recreational and local cultural services. Quercus forests can be managed sustainably for multiple ecosystem services to meet various emerging socio-cultural expectations (Gustafsson et al., 2012; Schwenk et al., 2012). At the local scale, requirement of forest management for multiple uses can be met by Quercus production forests and secondly it may help in adaptation of objects of management to hotter climates at northern aspects (Lof et al., 2012). In Pakistan, unfortunately, clearing of forest and forest degradation has reached to its alarming rates (Ahmed et al., 2015). Illegal cutting of trees and land use change has drastically reduced forest areas specifically coniferous forests (of which Oak forest is a part) which ultimately has influenced various direct and indirect impacts on socio-cultural aspects of local livelihood (Qamer et al., 2016). Such unwise utilization and continued deforestation of oak forest threaten livelihood of forest dwellers because they are dependent on forest products such as fodder, timber, firewood, wild fruits, nuts and wild mushrooms (Shahbaz et al., 2011; Zeb et al., 2019). Moreover, serious economic crises are faced by the forest communities because enterprises of timber or non-timber forest produce provide little amount (return) from sale of forest produce; although communities are actual custodians of natural resources.

Present research focused on Quercus forests in district Diamer as the territory holds the last remains of coniferous forest in the northern regions of Gilgit in Pakistan (Khan et al., 2015a). Quercus forests are found at the lower elevations, depression and transitional zones of Sub-tropical Chirpine Forests (*Pinus roxburghii*) and Moist Temperate Forests (*Pinus wallichiana*, *Abies pindrow*, *Picea smithiana* and junipers species.). At higher elevations, Quercus forests are also intermingled with *Betula utilis* species. It is utmost important to protect Diamer forests which not only provide sustainable livelihood and human well being but also provide various regulatory ecosystem services such as construction of proposed hydropower dams (Khan et al., 2015a). Similarly, various provisioning services such as non-timber forest produce (medicines, wild food and fruits and nuts etc) are also extracted from Diamer forests. Oak forest is highly browsed and also lopped as fodder for the cattle in winter being the only green fodder available at this time to local communities. In assessment of ecosystem services, there are big knowledge gaps such as lack of data on regulatory, cultural and supporting ES; many aspects are still unexplored and not quantified fully so far (Power, 2010; Lienhoop et al., 2015; Shedayi et al., 2019). Moreover, in Pakistan, limited studies are available on ecosystem services such as livestock and range resources, forest resources and fisheries contribution to the local livelihood (Chandio et al., 2015; Nazir et al., 2015; Shedayi et al., 2019). Till date, there was no study published on the ecosystem services of oak forests in the entire Karakoram region. The main objectives of present research were; to identify various types of ecosystem services and its socio-economic importance and to measure carbon sequestration potential as a regulatory ecosystem service. To address research objectives, two research questions were formulated: i) how much indigenous knowledge of the local community contributes to ecosystem services assessment and what is the awareness level of local people and ii) to what extent socio-economic variables explain community dependency on provisioning ecosystem services.

Based on study objectives hypothesis of the study was:

H_0 = There is no statistically significant relationship between socio-economic status of community and provisioning ecosystem services.

H_1= There is no statistically significant relationship between socio-economic status of community and provisioning ecosystem services.

Materials and Methods

Present study assessed various ecosystem services with its socio-economic importance through questionnaires and estimated carbon stocks as regulatory ecosystem service through forest inventory.

Study area

This study was conducted in Tangir Valley, where oak forests dominate the elevation belt between 1455m and 3812 m above sea level (Fig. 1). The total area of the tract is about 28000 square miles out of which 848 (5, 42,720 acres =217088 hectares) is covered by private forest in Diamer district out of which about 49% is unproductive forests. While total forest cover including private forest cover constitutes 30% of the Diamer district. There are four forest ranges at Chilas Division, Chilas, Thore, Thak/ Babusar and Gunner in Chilas Forest Division, and three forest ranges at Tangir, Darel and Khanbari in Darel/Tangir Forest division. Pakistan Forest Institute prepared land cover data for whole Pakistan in 2012 which shows the following for district Diamer (Table 1).

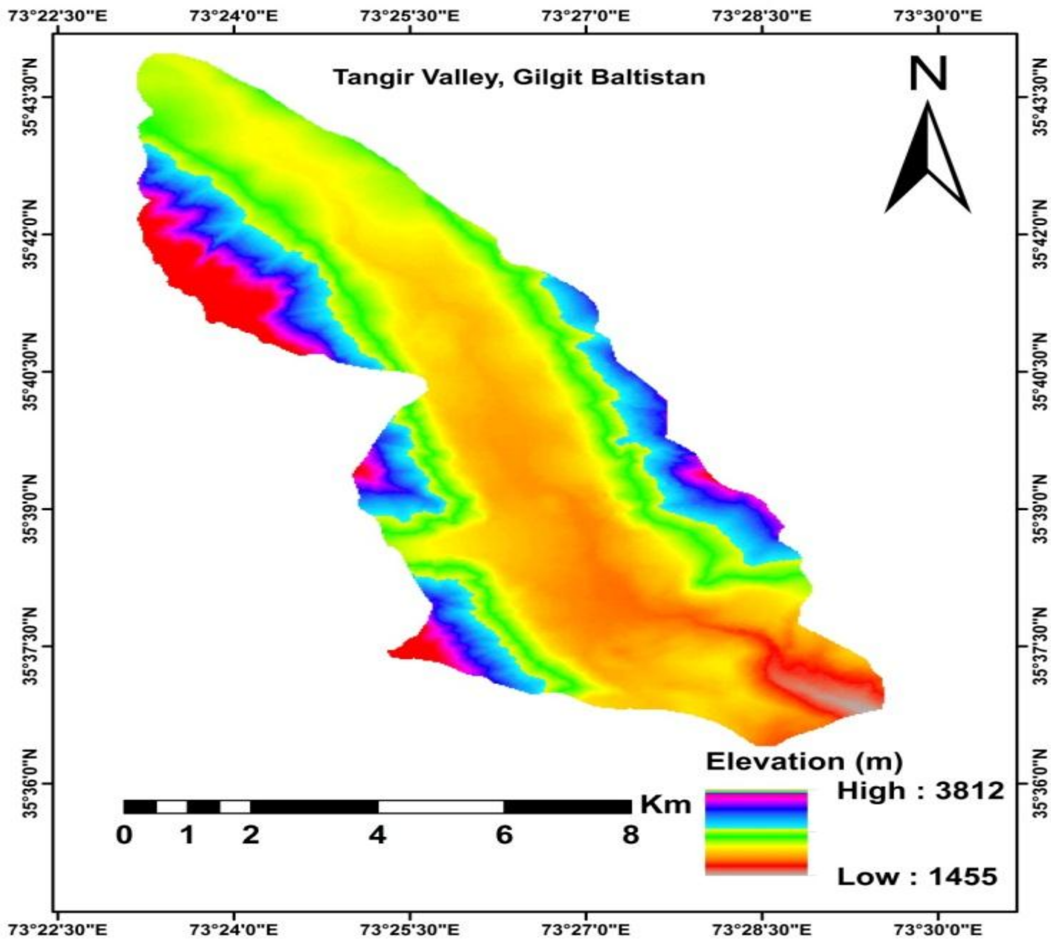

Fig. 1 Study area map

Table 1 Land use map of district Diamer

S.No.	Land cover class	Area (ha)	Percentage
1	Alpine pastures	136222	19.54
2	Sub-alpine	3429	0.49
3	Dry temperate	185760	26.65
4	Oak	56317	08.08
5	Other land cover	315,376	45.24
	Total	697,104	100.00

(Source: Bukhari et al., 2012).

Questionnaire and interview based survey

Questionnaire based survey was conducted in seven villages of Quercus forest in Tangir valley of district Diamer. Ecosystem services were evaluated in the selected seven villages which include Sheikhou, Jaglote, Glai, Adrkali, Shumari, Shabinal and Sobokot in Tangir valley. Selection of villages was based on socio-economic condition and their dependency on forest for direct or indirect services. The communities were selected based on their location (within or adjacent to forest) because such communities are fully or partially dependent on ecosystem services for their livelihood. Same culture, sharing same resources and family status were the similarities in all communities however dependency on forest and water resources were different due to their geographical location (i.e residence near to forest, away from forest, near to markets, livelihood subsistence). Based on the resources and time available, 40 respondents were selected randomly in the selected villages and an additional pretesting of questionnaire in one village. Some of the important explanatory variables to assess ecosystem service include socio-demographic (household, family, source of income, income, land) and dependency on forests for domestic and economic benefits

(Sinha & Mishra, 2015). Further, separate questions of all major categories of ecosystem services were included such as provisioning, regulatory, supporting and cultural aspects (Battisti et al., 2020). Such information include timber, utilization of fuel wood, type of fuel wood preferred, eco-tourism, livestock number, intensity of grazing, wild fruits, wild mushrooms and ethno-botanical benefits. After the collection of data it was transferred on the computer.

Socio-economic characteristics and ecosystem services were measured with the help of (links cale) questionnaire. As most of selected communities were less literate therefore they haven't full information or awareness regarding ecosystem services except provisioning ES. Therefore, closed ended questions were formulated and respondents had to answer in three or five options (coded). For socio-economic information was acquired in five options (codes) whereas ecosystem services information was acquired in three point scale. However, some questions regarding supporting and cultural ES, respondents shared their indigenous knowledge through discussion.The analysis was made through percentage and averages, because most of the data were quantitative in nature.

On the other hand, interviews were also conducted in the local residency (called Hujras) of community members. Discussions were made regarding various ecosystem services in layman language (shina local language) and each community discussion lasted in one hour duration. Interviews were conducted with the local community in order to understand their attitude, awareness and problems which are linked to their livelihood and ecosystem services. Many seful indigenous information was acquired during face-to-face interviews and documented specifically for supporting and cultural ecosystem services (and some indirect regulatory services as well). This was an open discussion without any predefined questions and almost all available community members described their field rich experience regarding indirect ES such as diseases control, soil erosion, fresh air and water , percolation, sub-surface flow (streams) etc. Similar discussion was also conducted with the forest officials and other local market members. Thus the interview was purely purposive in nature because only relevant persons were interviewed. After the interview; main discussion comments were noted and highlighted for further qualitative and quantitative analysis (Maharana et al., 2000; Sinha & Mishra, 2015). Statistical analysis includes descriptive statistics (frequency, percentages etc) and correlation and regression between explanatory variables and tangible benefits (specially provisioning ecosystem services).

Field inventory for regulatory ecosystem services

Regulatory eco-services were assessed by forest inventory in the pure stands of *Quercus ilex* forest in Tangir Valley. Random sampling technique was used and forest attributes data was collected from 29 inventory plots (Ali et al., 2018). As per standard sampling procedure followed in forest management planning, a fixed-area method was adopted with 0.1 hectare plot size of circular shape (17.84 m radius). Layout of sample plots was done with the help of GPS receiver, measuring tape, ranging rods and clinometer. GPS receiver received geographic coordinates of the plots and similarly measurement within plots was done by measuring tape and ranging rods. Clinometer was used for slope measurement as terrain was mountainous and proper plot layout needed slope corrected measurement. Basic tree growth was assessed which include diameter at breast height and total height of all trees within each sample plot (Inoue et al., 2019; Imran et al., 2020). Tree diameter was acquired by using diameter tape while tree height was calculated by using Haga Altimeter (this instrument used trigonometric principles to calculate tree height). Further, tree volume and biomass was calculated by using allometric equations developed by Pakistan Forest Institute, Peshawar. Allometric equations were actually regression equations developed from tree diameter and height data. Onwards, it was expanded to plot wise by summing all tree biomass within plot and further plot wise estimate was extrapolated into per hectare by using plot expansion factor (in this study plot expansion factor was 10 as plot size was 0.1 hectare). Lastly, biomass was converted into carbon stocks (regulatory services) by multiplying biomass with 0.47 as this conversion is recommended by Intergovernmental Panel on Climate Change (IPCC) (Malhi et al., 2004).

Results and Discussion

Description of study sites

During the field survey of Tangir Valley information was collected from the seven villages mentioned in Table 2. Results showed that the source of income of the people were agriculture, governmental jobs, own business, farming, private services, livestock and forest use (fuel wood and forest products). The number of livestock was recorded from the selected seven villages which are adjacent to the oak forest (Table 2). The livestock are a very important source of income as well as fulfilling the dairy requirements of rural society. The meat and milk are very important products from the livestock and the by products are cow dung as well as it is used in many other sources. Results showed that major livestock types were cows, goats and minor livestock consists of donkeys, oxes, sheep, horses and buffaloes . The highest number of livestock was 2200 in juglote villages which comprised of 1500 goats, 300 cows and 200 donkeys and horses. Whereas the lowest number of livestock was 430 in shumari villages which consist of 100 cows, 80 sheeps and donkeys and 250 goats. Overall, communities of all the seven villages have considerable numbers of livestocks (range from 430 to 2200). The total number of livestock in the study area was 9880 with 6500 goats and 1750 cows, while the remainder was counted as others.

Socio-demographic details

The respondents were asked about their education status summarized in Table 3. Most of the respondents were not highly qualified. Out of 40 respondents, 19 % were illiterate, 23 % answered below matric, 21 % were Matriculate, 21 % replied Intermediate and 16 % of the respondents answered Graduate. The respondents were asked about their occupation. Results show that out of 40 respondents, 22.5% respondents answered agriculture/farmer, 20% respondents replied Govt job, 22.5% respondents replied that they were doing private services, 15% respondents were business and 20% respondents replied other than occupation as mentioned above. The respondents were interviewed about their monthly income and their responses are summarized in Table 3. The respondents were required to select among various ranges of income, 40% of the respondents had income below fifteen thousands, 37% respondents income fell within the range of 16,000-30,000. 10% respondents replied that their income lies within the 31,000-50,000 range and 13% replied that they had income more than 50,000. Overall, most of respondents (83%) have less than fifty thousand income which depicts that the majority population has "middle class" socio-economic status.

Level of dependence on forest produce

The respondents were also asked about their dependency on forests regarding their fuel wood consumption. The respondents were required to select one of three points "dependency" scale. The three points scale included "low", "medium" and "high" dependency. The results showed that most of the respondents have high dependency on the fuel wood. Table 4 showed that 12.5% of the respondents replied low dependency on fuel wood, 25% replied "medium" dependency on the forests for fuel wood and 62.5% replied that they are highly dependent on forest for their fuel wood consumption.

The respondents were asked about grazing dependency for their livestock. The respondents were required to show their dependency in one of three level i.e. Low, Medium and High dependence. Most of the respondents replied that they are highly dependent on the forests regarding grazing of animals; most of such respondents have livestock. Table 4 showed that 25% of the respondents had low grazing dependency, 30% of the respondents replied "medium dependence", 45% replied "high dependency" on forests for grazing. The respondents were asked questions about how they are dependent on forests for NTFPs. Most of the respondents do not depend on forests for NTFPs from the forests. Table 4 shows that 62.5 % of the respondents replied "low use", 25% replied "medium use" of NTFPs, 12.5% respondents answered "high use" of NTFPs.

Table 2 Description of villages, source of income and livestock

Village	Altitude (m)	Source of income	Livestock	Livestock type
Shumari	1890	Livestock, forest, agriculture, business, Govt. employees	430	Goat 250 Cow 100 Others 80
Juglote	1950	Livestock, forest, agriculture, business, Govt. emplyees	2200	Goat 1500 Cow 300 Others 200
Gali	1910	Livestock, forest, agriculture, business	1450	Goat 1000 Cow 300 Others 150
Darkali	1859	Livestock, forest, agriculture, business, Govt employees	1800	Goat 1100 Cow 350 Others 450
Sheikhou	1645	Liv stock, forest, agriculture, business, Govt. employees	900	Goat 600 Cow 200 Others 100
Shabinal	1950	Livestock, forest, agriculture, business, Govt employees	1600	Goat 1400 Cow 200
Sobokot	2150	Livestock, forest, agriculture	1500	Goat 900 Cow 300 Others 300

Table 3 Details of occupation, monthly income and education of the respondents

Attributes	Frequency	Percentage
	Occupation	
Agriculture/farmer	9	22.5
Govt job	8	20
Private services	9	22.5
Business	6	15
Others	8	20
	Monthly Income (PKR)	
<15000	16	40
16000-30000	15	37
31000-50000	4	10
>50000	5	13
	Education	
Illiterate	28	19
Below matric	35	23
Matric	31	21
Intermediate	32	21
Graduate	24	16

Focal group discussion regarding forest dependency

In the group discussion the community of seven villages participated and expressed their feelings about the ranking of ecosystem services provided by the oak forest. The priorities were different among the need and use of services by the community as shown in Table 5. Many of the community members were given top rank to the fodder which is used by their livestock in the winter season, however they ranked second priority to the fuelwood which is not only a very good source of income but also primary energy source. However the growth rate of oak is very slow and the regeneration rate is very low. The third priority is different among the different villages while some villagers were given timber and litter. Oak wood is used as a timber by users in the ares where conifers are not available, the main reason behind oak trees as timber due to its local and free of cost availability.

Table 4 Community dependence on forestry products

Dependence	Fuel wood		Grazing		NTFPs	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Low	5	12.5	10	25	25	62.5
Medium	10	25	12	30	10	25
High	25	62.5	18	45	5	12.5
Total	40	100	40	100	40	100

NTFPs = Non-timber forest products

Ecosystem services categories

Following categories of ecological services were assessed; seven types of provisioning services, regulating and supporting (eight services) and two cultural services.

Provisioning services

The respondents were asked regarding provisioning ecosystem services provided by oak forests. Results showed that provisioning services consisted of fuel wood, fodder, grazing, food, leaf litter, fresh water and timber (Table 6). Fuel wood was the most important ecosystem service that was obtained from forests and it was measured as the number/volume of fuel wood extracted from oak forests. Fodder was the second most important ecosystem service followed by grazing, food, litter and fresh water on third, fourth, fifth and sixth important ecosystem services respectively. Food consists of berries, wild fruits, mushrooms and wild vegetation whereas leaf litter was used as farm manure. Fresh water was used for domestic and agriculture purposes mostly. Timber was considered the least important ecosystem derived from oak forest in the study area as a small portion of the population harvested timber from oak forest. All of the provisioning ecosystem services have great socio-economic values in community livelihood. Overall, discussion sessions preferred tangible services (provisioning) compared to non-tangible services which included regulatory and cultural services. This preference is given because communities' livelihood mainly depends upon tangible benefits they derived from forests.

Regulating and habitat services

Local communities and forest dwellers were less aware regarding indirect regulatory and supporting services because normally local people don't note and visualize such non-tangible ecological services (Table 7). A small portion of respondents who have higher education identified various regulatory services such as *Quercus* forest help in recharge of ground water, provides silt free purified water, store carbon emissions from atmosphere by photosynthesis and protection of soil from erosion. However, most of villagers agreed that forest has a variety of wildlife and *Quercus* forest clearing is a threat to the existence of animals and birds. Most of respondents believed that due to illicit cutting and degradation of forest has caused dryness of many perennial and seasonal springs. Many regulatory services (such as fresh air regulation, disease regulation and soil protection) were assumed free services granted by nature and taught to be forever available and that's why these were unknown and taken as for granted (Table 7).

Table 5 Focal group discussion regarding forest dependency

Location	First	Second	Third
Sheikhou	Fodder	Fuel wood	Litter
Juglote	Fresh water	Fuel wood	Litter
Shumari	Fodder	Water	Timber
Gali	Fodder	Water	Litter
Darkali	Fodder	Fuel wood	Timber
Shabinal	Fuel wood	Fodder	Litter
Sobokot	Fodder	Water	Litter

Table 6 Details of provisioning ecosystem services in Tangir

ES identified locally	Description	Indicator of ES
Fuel wood	Fuel wood by cutting Quercus trees	Cord feet of collected fuel wood
Fodder	Livestock forage derived from Quercus forests	Quantity of forage and number of palatable species
Grazing	Grazing areas associated with Quercus forests	Number of grazing animals
Food	Quercus forest wild fruits and edible mushrooms	Quantity of wild food
Leaf litter	Crop manure was prepared from collected forest litter	Forest litter quantity
Fresh Water	Fresh water used in farmlands and for domestic purposes	Watershed areas and number of rivers/streams
Timber	Exploitable size timber obtained from Quercus forests	Per hectare timber harvested
Associated community values for all above-mentioned was “socio-economical for livelihood”		

ES = Ecosystem services

Cultural services

Tangir valley forest has outstanding landscape, scenic beauty, unique geological formation and supports biodiversity of high national importance (Table 8). The location of Tangir valley Forests provides a unique opportunity for tourists and local residents. Number of visitors is at its peak; the normally an average of 10,000 visitors come to the forest area, specifically pastures, lakes. Due to its outstanding landscape, people from Tangir and outside areas come to the area for the scenery, landscape, lakes, mountains and wildlife watching. The bird’s legal hunting and tracking could be practical intervention for tourism. The natural resources have a great potential for development of eco-tourism in the area; however lack of facilities have limited eco-tourism enhancement and improvement.

Table 7 Details of regulating ecosystem services in Tangir valley

ES identified locally	Description	Indicator of ES
Regulation of fresh air	Oxygen is provided by trees during photosynthesis	Leaf area index and bio-indicators of pollution
Storage of carbon emissions	Biomass of trees is developed by storing carbon from atmosphere and help in climate regulation	Total carbon stocks per unit area
Deep percolation	Soil plant water relationship ensure deep drainage of water and maintain sub-surface flow and recharge	Water quantity available round the year
Regulation of natural extreme events	Forest trees provide buffer against many natural calamities (windstorm, mass flow, floods)	Annual extreme events
Purification of fresh water	Silt free and pure water are availale in streams within *Quercus* forests	Pollution and water quality
Control of disease	Purified water and fresh air ensure protection from diseases	Affected people by contaminated water and air
Protection of soil	Top soil (fertility) and nutrients are protected by dense vegetation and ensure to maintain biogeochemical cycles	Soil degradation and landslides incidences per year
Home for Wildlife	Quercus forests provide shelter and food to biodiversity	Status and distribution of biodiversity
Associated community values for regulatory and habitat services were environmental conservation, human wellbeing and co-existence		

ES= Ecosystem services

Carbon sequestration potential

Results showed that mean elevation of Tangir valley was 1899 m ± - 98.56. The elevation ranged from 1644 to 2149 m (Table 9). The maximum elevation was recorded as 2149, while the minimum elevation was 1644m. It was observed that forest density at higher elevation was maximum because of limited accessibility and minimum anthropogenic activities such as livestock grazing, browsing, tree cutting and exploitation of forest for Non-Timber Forest Produce. On the other hands, forest density was gradually decreased at lower elevation due to social pressure and deforestation for fuel wood consumption. The vegetation structure was observed on four slopes of different aspects (north, west, east and south). The south-, east- and west-facing slopes have low density (spare vegetation) whereas on the north-facing aspect, vegetation density becomes higher. Overall the slope of the area ranges from gentle to very steep slope, most of the area having medium slope followed by steep slopes at some places. Slope factor also affected forest density. However, slope-vegetation relationship was not quantified as it was beyond the scope of the present study. Champion et al. (1965); Ahmed et al. (2006) identified various forest types based on altitude as one of the important factor during field campaigns and observational surveys. Their study reported *Quercus* forests at lower temperate forest (from 1350 to 2550 meters) and also sub-tropical forests (from 500 to 1350 meters). Similarly, *Quercus* communities are reported between 1950 to 2150 meters altitude (Ahmed el al., 2006).

Height ranges from 5.33 m at 7 cm diameter to 7.6 m at 35.26 cm. The mean height was recorded as 9.61 m ± 4.79 (Table 9). Sheikh (1993) reported the height of the Quercus from 2 m to 12 m. Tree height is the function of diameter and the height (m) of a tree has a direct relation with its diameter (cm). Tree height increases with the increase in diameter (Ahmad et al., 2014). In present study, it was found that the height of the tree increases with the increase in stem diameter. In present research, stem density range from 150 to 440 trees/ha and mean density was 255± 76 trees per ha in Pure Oak Forest (Table 9) which were similar to the range of 80±8.16 to 510 ± 42 trees per ha while the average tree height was 5.47 ± 0.76 m (Khan et al., 2015b). Similarly, stem density range of *Quercus ilex* was reported from 207 to 388 trees per hectare whereas its mean stem density was 295 trees per hectare (Haq et al., 2017).

Table 8 Details of cultural ecosystem services in Tangir valley

ES identified locally	Description	Indicator of ES
Aesthetic service	Visitors and local people enjoy unique landscape and scenic aesthetics of Quercus forest	Visitor frequency and feedback
Eco-tourism and recreational values	Quercus forest has also significant valued for ecotourism for local and outsider visitors	Recreational sites and average visitors per year
Associated community values for cultural services were wellbeing and socio-economic benefits		

ES= Ecosystem services

Table 9 Mean DBH, mean height, stem number of *Quercus* forest plots

Plot No.	Latitude	Longitude	Elevation (m)	Mean DBH	Mean height (m)	Stem No.	Stem No./ha
1.	3235722	1275386	1895	29.50	6.85	26	260
2.	3235724	1275377	1926	27.50	6.57	30	300
3.	3235213	1275339	1947	31.16	7.09	17	170
4.	3237373	1275231	1881	35.24	7.67	21	210
5.	3237712	1275323	1925	20.41	95.57	22	220
6.	3238032	1275637	2149	27.96	6.63	18	180
7.	3236060	1275547	1876	30.69	7.02	34	340
8.	3235696	1275	1898	35.28	7.68	18	180
9.	3235545	1275606	1909	31.76	7.18	36	360
10.	3235383	1275771	1927	22.13	5.80	15	150
11.	3235499	1275989	1898	21.47	5.71	15	150
12.	3235390	1276466	1843	22.29	5.83	17	170
13.	3235361	1276806	1852	26.68	6.45	27	270
14.	3235171	1277271	1858	23.48	6.00	30	300
15.	3235296	1278106	1850	21.54	5.72	34	340
16.	3236247	1277424	1871	18.78	5.33	26	260
17.	3236288	1276761	1859	31.29	7.11	17	170
18.	3236445	1276471	1827	32.42	7.27	44	140
19.	3239356	1273089	1644	27.82	6.61	22	220
20.	3233507	1281174	1933	25.20	6.24	18	180
21.	3233271	1281397	1948	26.05	6.36	22	220

22.	3233266	1281846	1980	32.14	7.23	32	320
23.	3232956	1282016	2037	32.93	7.34	29	290
24.	3234984	1280221	1890	27.12	6.51	24	240

DBH = Diameter at breast height

Biomass and carbon stocks

Summary and plot wise details of AGB, BGB, AGC, BGC, total biomass and total carbon stocks have been presented in Table 10. The mean above ground biomass of oak forest was 72.46 ±36.62 t/ha whereas the mean above ground carbon was 34.06 t/ha. Similarly, below ground biomass was 17.76 t/ha and below ground carbon was 8.35 t/ha. The total biomass was 90.22 t/ha and the total carbon 42.40 t/ha. The minimum above ground biomass was 25.09 t/ha and the maximum was 181.17 t/ha whereas minimum above ground carbon was 11.79 t/ha and the maximum above ground carbon was 85.15 t/ha. Regarding below ground carbon, the maximum, minimum and mean values were 22.14 t/ha, 1.67 t/ha and 8.35 t/ha, respectively. The mean value of total biomass was 90.22 ± 46.61 t/ha and the minimum total biomass was 29.65 t/ha. Similarly, the maximum total biomass was 228.27 t/ha. The mean value of total carbon t/ha was 42.40± 21.91 t/ha while the highest and lowest carbon stock was determined as 13.94 t/ha and 107.29 t/ha respectively. Ahmed et al. (2015) reported mean tree biomass, carbon stocks was 51.61 and 25.80 tons per hectare, respectively. Oubrahim et al. (2015) estimated the aboveground biomass of oak stands (38.1-170.2 t/ha) whereas Boulmane (2010) reported that tree biomass range from 34 to 183 t/ha for *Quercus ilex* stands. Similarly, in another study Ali et al. (2020) estimated above ground biomass and carbon stocks in all major forest types of Khyber Pakhtunkhwa and the study reported that mean AGB was 34.27 ± 6.51 t/ha and mean AGC was 34.58 ± 6.39 t/ha in oak (*Quercus ilex)* forests. *Quercus ilex* was also reported as one of the dominant broadleaved species in dry temperate forests of Khyber Pakhtunkhwa (Ali et al., 2020). One of the major outcomes of the present study was that *Quercus* forests of Tangir valley may be considered a carbon sink as potential for future climate mitigation project. However, social pressure such as fuel wood collection, timber for domestic uses and unscientific forest management may be some basic barriers to such type of management (Baskent, 2020).

Multiple linear regression between socio-economic condition and provisioning ecosystem service

Correlation matrix was developed in order to understand the relationship of socio-economic conditions (monthly income) and provisioning ecosystem services. Dependent variable was respondent's family income, while the explanatory variables were leaf litter, fuelwood, range land, fodder, timber, grazing, NTFPs, agriculture. Results showed that timber, agriculture, fuel wood, range lands, grazing have negative correlation with family income whereas fodder, NTFPs and leaf litter have negative correlation (Table 11). Highest correlation was shown between timber and monthly income (R = -0.42) whereas lowest correlation was observed in NTFPs and fuel wood (R^2 = 0.09). Regarding other variables, coefficient of correlation was -0.31, 0.18, -0.17, 0.15 and -0.11 for agriculture, leaf litter, grazing, fodder and range land respectively. Moreover, the relationship of two variables (timber and NTFPs) was significant (at the 0.05 level) whereas the relationship of rest variables remained insignificant (P-value is greater than 0.05). According to Table 12, the overall coefficient of correlation of multiple regression model was 0.32 with the standard error estimate of 0.94. Similarly, the unsubsidized coefficients were -0.23, -0.54, -.03, -.02, 0.11, 0.10, -0.14 and 0.21 for agriculture, timber, rangeland, fuel wood, fodder, NTFPs, grazing and leaf litter, respectively.

Table 10 Summary of regulatory services (biomass and carbon stocks of *Quercus* forest)

Plot No	AGB	AGC	BGB	BGC	TB	TC	CO_2e
1.	76.00	35.72	22.04	10.36	98.04	46.08	168.65
2.	75.46	35.47	19.62	9.22	95.08	44.69	163.55
3.	121.12	56.93	31.49	14.80	152.61	71.73	262.52
4.	84.55	39.74	21.98	10.33	106.54	50.07	183.27
5.	24.82	11.66	6.45	3.03	31.27	14.70	53.79
6.	30.85	14.50	8.02	3.77	38.87	18.27	66.86
7.	42.97	20.20	11.17	5.25	54.14	25.45	93.14
8.	74.81	35.16	19.45	9.14	94.27	44.31	162.16
9.	113.64	53.41	29.55	13.89	143.18	67.30	246.31
10.	90.06	42.33	23.42	11.01	113.47	53.33	195.20
11.	118.55	55.72	30.82	14.49	149.37	70.20	256.94
12.	26.09	12.26	3.56	1.67	29.65	13.94	51.00
13.	26.62	12.51	7.72	3.63	34.34	16.14	59.06
14.	32.24	15.15	4.39	2.07	36.63	17.22	63.02
15.	74.95	35.23	10.22	4.80	85.16	40.03	146.50

16.	69.14	32.49	8.45	3.97	77.59	36.47	133.46
17.	61.46	28.88	7.51	3.53	68.97	32.41	118.63
18.	35.81	16.83	9.31	4.38	45.12	21.21	77.62
19.	54.70	25.71	14.22	6.68	68.92	32.39	118.55
20.	181.17	85.15	47.10	22.14	228.27	107.29	392.68
21.	64.60	30.36	16.80	7.89	81.40	38.26	140.02
22.	50.80	23.88	13.21	6.21	64.01	30.08	110.10
23.	66.96	31.47	17.41	8.18	84.37	39.65	145.13
24.	44.02	20.69	11.45	5.38	55.47	26.07	95.42
25.	52.98	24.90	13.77	6.47	66.76	31.38	114.83
26.	115.39	54.23	30.00	14.10	145.39	68.34	250.11
27.	116.23	54.63	30.22	14.20	146.45	68.83	251.93
28.	104.77	49.24	27.24	12.80	132.01	62.04	227.08
29.	70.33	33.06	18.29	8.59	88.62	41.65	152.45
Mean	72.45	34.05	17.75	8.34	90.21	42.40	155.17

AGB = Above ground biomass; AGC= Above ground carbon; BGB = Below ground biomass; BGC = Below ground carbon; TB = Total biomass; TC = Total carbon; CO_2e = Carbon dioxide eqvivalent

Table 11 Correlation between monthly income and livelihood variables

Monthly Income		Agriculture	Timber	Range land	Fuel wood	Fodder	NTFPs	Grazing	Leaf litter
Monthly Income	1.000	-.317	-.424	-.106	-.092	.158	.096	-.178	.187
Agriculture	-.317	1.000	.196	.000	-.215	-.258	-.249	.091	.076
Timber	-.424	.196	1.000	.205	.140	.023	-.002	-.026	-.039
Range Land	-.106	.000	.205	1.000	.036	-.035	-.202	-.195	-.040
Fuel wood	-.092	-.215	.140	.036	1.000	-.157	-.113	.233	-.003
Fodder	.158	-.258	.023	-.035	-.157	1.000	.040	.014	-.025
NTFPs	.096	-.249	-.002	-.202	-.113	.040	1.000	-.029	-.329
Grazing	-.178	.091	-.026	-.195	.233	.014	-.029	1.000	-.203
Leaf Litter	.187	.076	-.039	-.040	-.003	-.025	-.329	-.203	1.000

Table 12 Multiple linear regression between monthly income and livelihood variables

Coefficients					
Model	Unstandardized Coefficients	Standardized Coefficients	t	Sig.	
	B	Std. Error	Beta		
(Constant)	2.816	1.393		2.022	.052
Agriculture	-.239	.215	-.199	-1.113	.274
Timber	-.542	.234	-.375	-2.320	.027
Range land	-.033	.228	-.023	-.142	.888
Fuel wood	-.023	.175	-.022	-.130	.897
Fodder	.111	.157	.114	.705	.486
NTFPs	.107	.196	.094	.544	.048
Grazing	-.141	.182	-.128	-.776	.443
Leaf litter	.217	.184	.194	1.181	.246
Model Summary					
	R	R square	Adjusted R square	Std. error of the estimate	
	0.55	0.32	0.13	0.94	
ANOVA					
Regression	Sum of squares	d.f.	Mean square	F	Sig.
Residual	12.465	8	1.558	1.760	.124a
Total	27.435	31	.885		
Regression	39.900	39			

Dependent Variable: Monthly Income

Predictors: (Constant), leaf litter, fuel wood, range land, fodder, timber, grazing, NTFPs, agriculture.

d.f. = Degree of freedom; Std. error = Standard error

Conclusion

The local community was highly dependent on forest for fuel wood, fodder, grazing, litter. Most of the respondents earned their income from the forest because most of them were illiterate due to which they don't work outside their village. Therefore, it is recommended to develop multipurpose trees to support local livelihood and to minimize pressure on pure oak forest. Regarding ecosystem services, awareness is very necessary which is very low in the study area so it is recommended to create awareness about ecosystem services with involvement of forest communities, civil society and other stakeholders. The local people of the study area have valuable knowledge and authentic information about ecosystem services. Since they are very important to provide how the demands of the local people can be fulfilled, which provide efficient quantification of ecosystem services. Regarding carbon sequestration potential of *Quercus ilex forests*, it is recommended that carbon stocks can be enhanced by protection and raising new forested lands will be vital for climate mitigation. It is recommended that the tourism department should take practical steps under short and long term plans for the tourism promotion in the area. Livestock is one of the important factors in community subsistence therefore controlled grazing will not only contribute to the local economy but will also lead to optimal utilization of grazing sites. The people of the area have limited opportunities regarding income generation and livelihoods which mostly include livestock rearing and small scale business conducted locally. Promoting NTFPs enterprises on small scales may contribute to their income generation.

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