Draft Report

08 Economic Feasibility of Willow Removal from Wular Lake, Jammu & Kashmir

THE ECONOMICS OF ECOSYSTEMS AND BIODIVERSITY-INDIA INITIATIVE

WETLANDS

Ministry of Environment, Forest and Climate Change
Government of India

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- The Economics of Ecosystems and Biodiversity - India Initiative (TII)
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- Himachal Pradesh Forest Ecosystem Services Project
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Submitted to: GIZ/Ministry of Environment, Forests and Climate Change

Government of India

Submitted by: Wildlife Trust of India

THE ECONOMICS OF ECOSYSTEMS AND BIODIVERSITY-INDIA INITIATIVE

The Economics of Ecosystems and Biodiversity – India Initiative (TII) aims at making the values of biodiversity and linked ecosystem services explicit for consideration and mainstreaming into developmental planning. TII targets action at the policy making levels, the business decision level and awareness of citizens. TII has prioritized its focus on three ecosystems - forests, inland wetlands, and coastal and marine ecosystems - to ensure that tangible outcomes can be integrated into policy and planning for these ecosystems based on recommendations emerging from TII.

In addition to the existing knowledge, TII envisions establishing new policy-relevant evidences for ecosystems values and their relation to human well-being through field-based primary case studies in each of the three ecosystems. In response to an open call for proposals for conducting field-based case studies in the context of relevant policy or management challenges for conservation and the sustainable use of biodiversity and ecosystem services, over 200 proposals were received. A Scientific and Technical Advisory Group (STAG), comprising eminent ecologists and economists, appraised the proposals and recommended 14 case studies for commissioning under TII.

These studies in forests deal with issues such as hidden ecosystem services of forests, conflicts between humans and wildlife, and the economic consequences of species decline. In wetlands, the studies draw lessons on water resources management, community stewardship and equity, and the economics of hydrological regime changes. In coastal and marine ecosystems, the studies explore the opportunities and economic efficiency of interventions such as eco-labelling, seasonal fishing bans, mangrove regeneration, and the challenge of bycatch in marine fisheries.

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KEY MESSAGES

Wular lake is integral to the hydrological system of the Kashmir valley. Drainage of associated marshes, agriculture, increased siltation and plantation of willows to supply wood to sports and timber industries have reduced the lake size and increased the flood risk. A revised plan by the State Government suggests that despite high costs of dredging and permanent loss of carbon dioxide sequestration from willow removal, restoring the lake is still worthwhile.

FINDINGS

- The impact of willow removal on siltation rates was difficult to establish. Willow roots act as a soil binder, hence their removal could lead to an increase in soil erosion.
- Loss of carbon sequestration benefits from the removal of willow trees is **₹8.09 million** (**US$ 134,667**) per year.
- Willow removal and dredging would improve the holdingcapacity of Wular Lake, saving **₹1.05 billion** (**US$ 17.5m**) on flood damage.
- One-time sale of willows will fetch **₹142.43 millio**n (**US$ 2.4m**).
- Lake restoration will increase hydropower generation, yielding **₹69.6 million** (**US$ 1.1m**) per year.
- Per year, fish production will amount to **₹3.1 million** (**US$ 51,666**) and use of aquatic plants will earn **₹5.6 million** (**US$ 93,333**).

RECOMMENDATIONS

- Willows should be removed from Wular fringes to restore hydrological functioning of the wetland complex.
- Wular tourism has to be developed in order to generate revenue.
- Funds realised from sale of willow wood should be ploughed back into wetland management.
- Willow removal may increase spread of invasive species such as alligator weed and azolla. To avoid costs of de-weeding, a plan to mitigate this threat should be part of the existing management.

Photo: WTI Library

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EXECUTIVE SUMMARY

Economic Feasibility of Willow Removal from Wular Lake

The Wular Lake is located in the Kashmir Valley, J&K, India. With an area of 130 km_2, it is the largest fresh water lake in India. Wular is intricately linked with the hydrological regime of the valley, since all the water draining from the valley upstream via River Jhelum has to pass through it. Therefore, this lake, along with its associated marshes, plays an important function in water regulation, absorbing water during peak flows and discharging this excess water in lean times. Apart from this regulating function, the lake provides various services, provisioning and cultural in nature. Wular Lake was listed as a Ramsar site in 1992 for the congregation of bird species, especially the migratory waterfowl, in winter.

The lake has shrunk in size from 213 km^2 in 1911 to 130 km^2, which is almost half. This shrinkage has been attributed to drainage of the associated marshes, an increase in areas under cultivation, siltation and subsequent plantation of willows since 1912 to meet the fuelwood needs of the local people. The changes in the lake character, (size, volume, water quality and biota) have adversely affected the lake function. In a bid to restore it, the state government had a plan formulated by Wetlands International in 2007. This holistic plan recommends the setting up of a Wular Conservation and Management Authority (WUCMA) under the Department of Wildlife Protection, to oversee the conservation and management of Wular Lake, in addition to monitoring other actions, including augmentation of lake capacity by dredging and excavation at specified points subsequent to the removal of willows, along with their rootstock. The plan also recommended catchment area treatments to reduce siltation rates, especially in the immediate catchment of Madhumati and Erin rivers, and enhancement of livelihoods, with an emphasis on the development of tourism. This plan was not implemented and instead, a whittled down version was accepted in the form of a Revised Action Plan, which reduced the scope of work significantly. Under this plan, the main activities were excavation and removal of willows from an area of 7.4 km^2, and the dredging of over 2 million m^3 of silt.

The two activities, felling 5.6 lakh trees and removing silt from 2 million m^3, are bound to have detrimental impacts, both on the ecology and processes of the lake. The impact is long term, impairing ecological function, the food chain and perhaps the livelihood of people, which largely comes from fish and vegetable based product harvests. There are doubts about whether the removal of willows would increase suspended particulate matter and silt, since willow roots are known to bind loose particles. The removal of trees would also mean a permanent loss of carbon dioxide sequestration potential. The removal of trees could also cause losses to biodiversity, and being a Ramsar site, avifauna is quite an important component of the lake.

On the positive side, these activities would help increase the lake's volumetric capacity, thus helping in water regulation. More water would be available, and there would be better flood control, since water flowing through various rivers and channels bring higher flow, and the lake needs to have greater absorption capacity. The increased water availability would also potentially lead to higher availability of water during lean seasons for the three downstream power stations and more power generation. The suggested plan thus has both costs and benefits.

Therefore, we undertook a cost-benefit analysis of the revised plan and projected to the original plan, to assess if it made economic sense to remove the willows from the lake. We assessed costs and benefit flows through four categories of stakeholders: the government, public, individuals and business and industry. Most data was obtained from government departments. However, some data collection for bird richness was carried out first-hand. We also undertook questionnaire surveys to gather information on income generated by locals from fishing and harvesting of vegetation products like water chestnut (*Trapa sp*) and lotus root (*Nelumbo sp*). We also evaluated the travel costs for tourists visiting Wular. We could not assess ecological costs and benefits and have thus left out ecological services from our analysis.

The results indicate overwhelming economic benefits of willow removal and dredging to improve the volumetric capacity, in terms of costs saved on flood damage, increase in power generation, improvement in livelihoods by more fish and water chestnut becoming available and the one-time gain from the sale of willow. The main costs come from the loss of sequestration benefits and the cost of silt removal.

We are unable to assess the impact on siltation rates, since removal of willows allows for free silt particles to float in the water, which may settle down where flows are reduced. However, removal of willows is also expected to improve flows to carry higher silt loads into the river on its exit.

The main recommendation from the report is that the removal of willows is financially beneficial, and should be carried out in a timely fashion for full benefits to accrue. Slippages shall result in reduced benefits.

In the time available for the project, it was not possible to assess the costs and benefits of these activities on the ecological services of the lake. It is strongly recommended that a monitoring programme is put into place to study the effects of interventions on the ecology of the lake. Any additional de-silting activities undertaken in the lake must be preceded by proper environmental impact assessments. For this to happen, WUCMA must be strengthened and all forthcoming activities in Wular must be undertaken under one umbrella organisation. This is especially important because Wular Lake has multiple government agencies who hold stakes in the lake.

Willow clearance will open up a significant area of the lake and the possibility of invasive species colonising such areas is high. Species like *Azolla* and the alligator weed in the lake have already been reported and its advance must be monitored closely and thwarted. If these are left unchecked, de-weeding may become a major expense in future years and thus, a plan must be prepared now for its mitigation.

The study also found negligible amounts of tourism activity and recommends that ways to improve tourism must be found, as it would have a compounding affect on the importance of the lake and thus its maintenance.

1. Background

Wular is a shallow lake, (5.8m: Max. depth), situated about 40 km northwest of the capital city of Srinagar (34o 20' N; 70o 42' E), in the state of Jammu and Kashmir, India. Its expanse of nearly 130-189 km_2 and altitude of 1,530m makes it amongst the largest high-altitude freshwater lakes in Asia, and certainly the largest freshwater lake in India. It is about 16 km long and 7.6 km wide.

The Valley of Kashmir, within which the lake is located, is surrounded by high mountain ranges. The watersheds drain into the valley, which slopes south to north at a mean altitude of about 1700m (in Srinagar). The Jhelum river, which is the main river flowing through and across the valley, has its origins in Verinag, a spring in the south. From there, the Jhelum, fed by a host of perennial streams, flows into Wular from the southeastern side and after making a U pin, exits the lake, flowing down Baramulla and eventually through Pakistan to fall into the Indus.

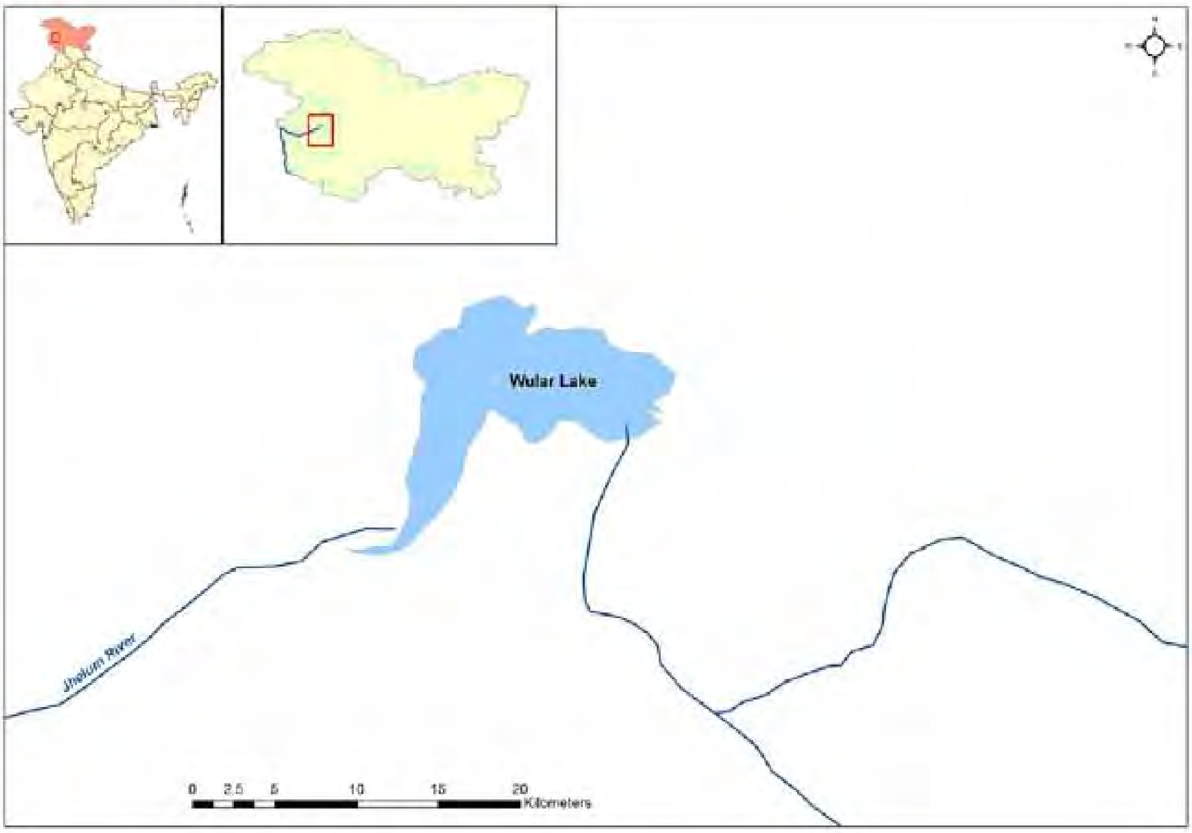
Thus, most of the water that the valley receives passes through Wular Lake via the river Jhelum.

The catchments of Wular Lake are essentially linked with the entire Jhelum Basin, which extends to an area of 12,777 km^2 comprising 24 watersheds (Wetland International 2007). The basin can be broadly classified into the following three sub catchments:

- Wular upstream sub catchment, comprising 14 watersheds of River Jhelum prior to its entry into Wular, extending to 8,627 km^2
- Wular direct sub catchment, comprising 6 watersheds directly draining into Wular, extending to 1,144 km^2
- Wular downstream sub catchment, comprising 3 watersheds of River Jhelum below Wular, extending to 3,006 km^2

Therefore, Wular Lake, along with its associated marshes and wetlands, has been performing a significant function of regulating the water regime of the valley by absorbing water during peak periods (summers) and releasing it during lows (winters). This regulation also helps in flood control by absorbing excess water and

Figure 1: Location of Wular Lake



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preventing fast runoffs. This role has been recognised since historical times and thus, the lake has been subjected to periodic interventions.

Wular also contributes immensely to local economies. Over 60% of fish for the Kashmir valley comes from Wular, which supports about 8000 fisher families. Besides, Wular provides two important plant resources impacting the local economy: the water chestnut, (*Trapa sp.*) and the lotus root (*Nelumbo sp.*), consumed by the denizens of the valley with cherish through the winters. Although the lake has potential for tourism, this has really not taken off, possibly due to its distance from Srinagar and also its appeal, infrastructure and projection.

Despite its values, the lake has witnessed massive shrinkage over the last century, with its area and surrounding marshes reducing from about 215 km^2 in 1911 to about 176 km^2 in 2007 (Wetlands International 2007).This includes associated settlements, plantations and agriculture, in addition to the open water area and marshes. Most gains have occurred in agriculture, which has increased by over 43 km^2, mainly at the expense of the marshes, reduced by over 54 km^2 (see Table 1; Wetland International 2007).

Estimates of the lake area vary vastly with different authors. The recent demarcation within the third line of defence gives an area of 130 km^2 and a periphery of 83 km for the lake (WUCMA pers. comm. 2015).

This shrinkage, mainly on account of loss of marshland within the main lake and associated marshland near the lake and factors like the changes in land use in the catchment, siltation, etc, has impaired the lake's natural functions and ecosystem services. Both the state and the central governments are now keen to restore the lake.

Table 1: Changes in land use in Wular Lake

Land use categories	Area Km^2		Net Change in land use
	1911	2007	
Water	91.20	75.23	-16.06
Marsh	66.45	11.48	-54.97
Plantation	0.66	27.30	26.64
Agriculture	0.38	44.25	43.87
Settlements	0.43	0.95	0.52
	159.21	159.21	
Associated Marshes	58.67	17.67	
Total	217.88	176.88	-41.00

Reproduced from Wetland International (2007)

1.1. Problem Statement

With such a profound effect on the hydrological regimes of the valley, it is natural that this lake has been subjected to periodic interventions. The earliest documented intervention was related to floods in the valley. In the days of king Avantivarman in the 10th century, his minister Suya used his ingenuity to get people to help in dredging near the outflow area of the lake, by throwing gold coins in the flooded area and asking people to find them. In the 15th century, King Zain-ul- abuddin, as a welfare measure, raised an island in the lake to afford shelter to fishermen from the high waves that are common in the lake.

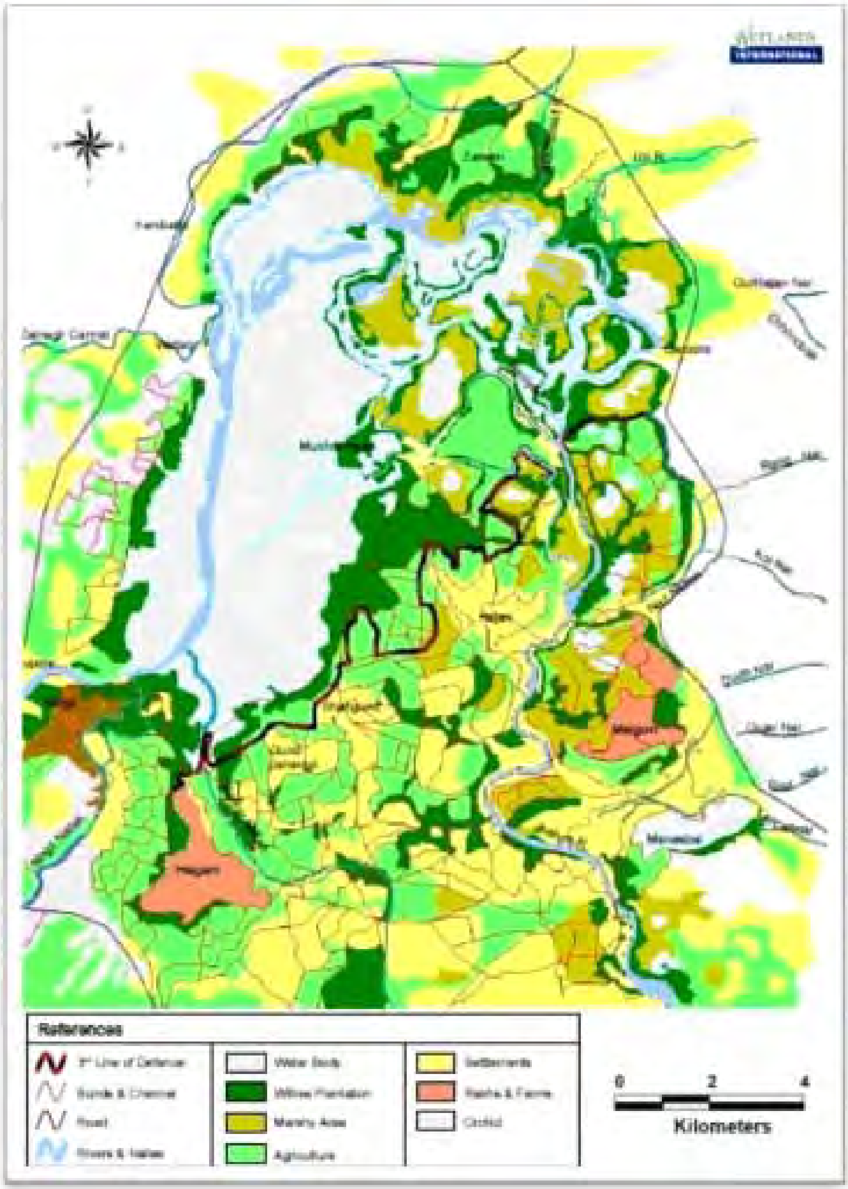
However, a more direct and impacting intervention was made at the beginning of the 20th century by the then ruler of J&K, who ordered dredging of the river downstream of the lake to allow flood waters to drain out quicker. The dredging equipment was powered by a specially commissioned hydel power station in 1907, which later became the first power generation unit to supply power to the city of Srinagar. However, the slurry that was dug up was used up in the reclamation of a part of the lake to allow local farmers to cultivate paddy, thus initiating damaging changes to the land use of the lake.

Over a period of several decades, the swamps which surrounded the lake were dried up for agriculture and these have now become large areas of permanent cultivation. At the same time, the state ordered willows to be planted within the lake area to provide firewood supply to people. Major plantations were undertaken in 1916, such as the famous Ningli plantations. The plantations continued to emerge, the most recent one being in 2002.The plantations have now grown and regenerated to cover over 27 km^2 of the lake.

The lake has also suffered from siltation due to eroded catchments, especially areas directly north of the lake in the River Madhumati. River Erin catchments bring immense quantities of silt into the lake. Additionally, the Jhelum also deposits a large amount of silt into the lake and the shoals formed as a result, especially at the entrance, now impede upon the natural flow of the river. The volumetric capacity and as a result, the absorption capacity of the lake, is now much reduced.

With settlements growing around the lake, direct discharge of solid and liquid wastes into the lake has depleted its water quality, creating a major health hazard not only for the populace, but also for the lake ecosystem.

Figure 2: Land Use of Wular



Courtesy WI

Considering the ecological, economic, cultural and hydrological importance of the Wular Lake, the government had a detailed Conservation and Management Action Plan prepared for its restoration (Wetlands International 2007). Recommendations of this detailed plan are diverse and far-reaching, but mainly centre around three aspects: a) strategies within the lake b) strategies in the catchment to arrest soil loss and silt load and c) improving local livelihoods and generating capital for the conservation of the lake. It suggests implementation of the plan alongside the River Jhelum Conservation Plan. The action plan also recommends setting up of a Wular Development Authority, under the Department of Wildlife Protection.

The recommendations pertaining directly to the lake are to increase the volumetric capacity of the lake to restore and improve lake function. The proposals in this plan seek to (i) remove 35.5 million cubic meters

(Mm^3) of silt from designated areas and (ii) clear willow trees from a 27 km^2 area, felling about 2.1 million trees, along with their rootstock. This plan, prepared in 2007, had a total outlay of ₹386.39 crore and was to be completed in five years.

This plan could not be initiated but instead, a revised plan with an outlay of ₹120 crore over four years was initiated in the year 2012. The revised plan cuts down the scope of the activities envisaged in the original action plan (Wetlands

International 2007) both in terms of the magnitude and areas of work. For instance, several activities related to catchment area treatment have been left out, as have various activities related to livelihoods and tourism. Dredging has been reduced to cover only a 1.65 km^2 area. The removal of willows has also been reduced from 27 km2 (approximately 2.1 million trees) to 7.4 km2 (5.6 lakh trees). Besides, activities like solid waste management have also been included.

Table 2: Difference in the scope of work between two plans (within lake)

	Revised Plan (1)	Original Plan (2)
Willow Plantations (area)	7.4 km^2	27.1 km^2
Number of trees	5.6 lakh	21 lakh
De-silting	2.0 Mm^3	26.54 Mm^3
De-silting from plantation areas	0.717 Mm^3	11.20 Mm^3

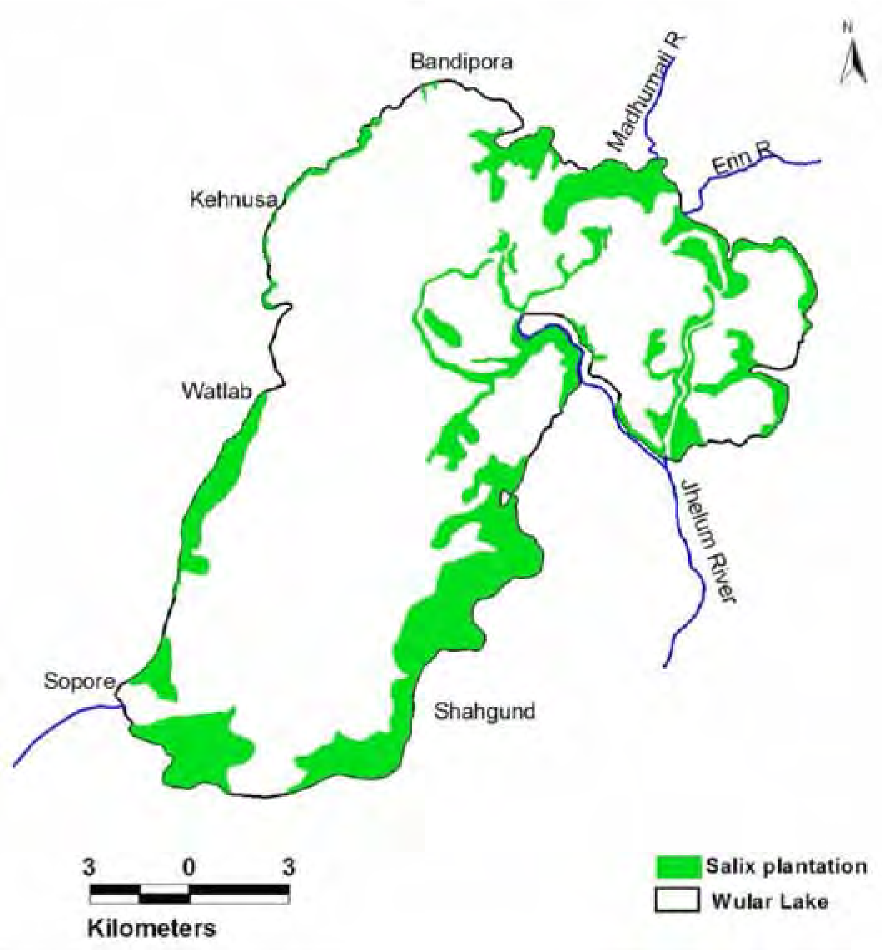
Ostensibly, the completion of these activities is expected to result in an increase in the retention capacity of the lake, which will restore, to some extent, its function of regulating the hydrological regime of the valley. In addition, there will be revenue earned from the sale of the wood that is removed. However, will there be any short and long-term effects of these activities on the lake, its basic character, its ecology and the services it provides?

Willow (*Salix sp*) is a commonly occurring tree in the valley and due to its superior growth and productivity (Christersson et al. 1993; Wilkinson, 1999). Due to ease of vegetative propagation, it is a tree of choice for plantations, (Grey and Sotir 1996) and hence commonly used as firewood in Kashmir. Recently however, it is also used for packaging and the sports industry (Kashmir willow cricket bats).

The willow shows great tolerance to moisture and can thus grow easily in saturated soils (Aronsson and Perttu 2001; Kuzovkina et al. 2004). Willows have a fibrous root system that has the capacity to bind soils (Grey and Sotir 1996). Willows show high levels of evapo-transpiration and have the ability to accumulate high levels of toxic metals (Ebbs et al. 2003; Klang-Westin and Eriksson 2003). Willows have the ability to sequester carbon. Several species of passerines inhabit

Willows within the Wular Lake

Figure 3: Location of Salix plantations in Wular Lake.



and nest in the willows. The willows are also used by several species of lepidopterons for laying eggs and pupa formation.

While there are obvious benefits in the removal of willow to clear a significant area of the lake, which along with excavation and dredging will improve the volumetric capacity of the lake, there are concerns. These concerns range from what would be the nature of ecological responses to the removal of the willows, to its fallout on natural processes and services. Wular is a Ramsar site, and there is concern about how the avifauna would respond to willow removal and dredging. There are also concerns about hydrological regime and whether there would be any significant impacts on sedimentation rates, since water flow has a cascading impact on the ecology, provisioning and regulating services of the lake.

Thus, it is important to understand the pros and cons of willow removal. A cost-benefit analysis is one of the ways of assessing the impact of this activity.

The Economic Evaluation of Biodiversity (TEEB) provides a way to conduct a cost-benefit analysis based on economic valuations of commodities, services and goods. We have used the TEEB framework to evaluate the economic feasibility of managing Wular Lake.

1.2. Limitations

This cost-benefit analysis is primarily based on the valuations of data obtained from various government departments. However, we collected primary data mainly through questionnaire surveys, to assess yields of fish and vegetable products. We were unable to assess ecological effects and their valuations due to paucity of time. Therefore, we have not included any valuations of costs and benefits of the ecology of the lake in the analysis.

2. Wular: a Profile

2.1. Location

The Wular Lake is situated in the districts of Baramulla and Bandipora in the state of Jammu and Kashmir. The lake is located about 40 km southwest of Srinagar, the capital city (34o 17’ 45” to 34o 25’ 30”N and 74o 31’ 40” to 74o 40’ 15” E) and adjoins two main towns, Bandipora towards the north and Sopore towards the southwest. However, several smaller settlements (31), mainly engaged in the extraction of fish, trapa and other produce of the lake for their livelihoods, live close to the lake. The lake is about 16 km long and about 7.6 km wide and covers an area of about 170 km_2 during peak capacity. This has now been revised to 130 km_2 after the demarcation of the third line of defence towards its eastern side. Wular is a shallow lake with an average depth of about 5.8m and is situated at 1570m.

The inter-montane basin of Kashmir, within which Wular is located, was developed during the Neogene-Quarternary period (Burchfiel *et al.* 1992, Burbank *et al.* 1996). According to Kulkarni and Khan (2014). The presence of a distinct planar surface in the region around Wular is suggestive of major structural control over its formation. Its surface at 1550-1600 m was probably developed as a result of faulting along the Jhelum-Madhumati lineament, which subsequently was subjected to rapid depositionary episodes during the upliftment of the Himalayan region.

The geo-chemistry of the water in and around Wular Lake also supports intense erosion of structurally weaker and chemically susceptible formations of its catchments (Kulkarni and Khan 2014).

2.2. Catchment, Drainage and Water

Wular and its associated wetlands form a part of the River Jhelum basin, which extends over 12,777 km^2. The basin is bowl-shaped and is surrounded by high mountain ranges, except for the Jhelum gorge in the southwest, allowing drainage out of the valley. In the north is the great Himalayan range, separating the basin from the trans-Himalayan region of Ladakh. Towards the south is the Pirpanjal range, separating the valley from the north Indian plains. The high altitude of the ranges allows glacial formations, the primary water source of the valley.

Over 5.4 million people live in the Jhelum basin in 34 towns and over 2800 villages, exerting pressure on the natural resources. As a result, the catchments are degrading, causing soil erosion. The silt is carried by the numerous tributaries of the Jhelum into the water bodies in the valley, including Wular, causing siltation of the water bodies.

Apart from the Jhelum, two other important rivers flowing from the north contribute to Wular. These are the Madhumati and Erin. The Wular catchment covers an area of about 1200 km^2 and accounts for about 7.6% of the valley (Hassan et al. 2015). Hassan et al. (2015) further concludes that the changes in land cover and land use in the Wular catchment such as agricultural land, built up areas, and horticultural land, are responsible for the deterioration of the water quality of the lake. They hold the agricultural fields responsible for draining maximum fertilisers into the lake, resulting in the growth of micro-organisms that deplete the dissolved oxygen content in the water.

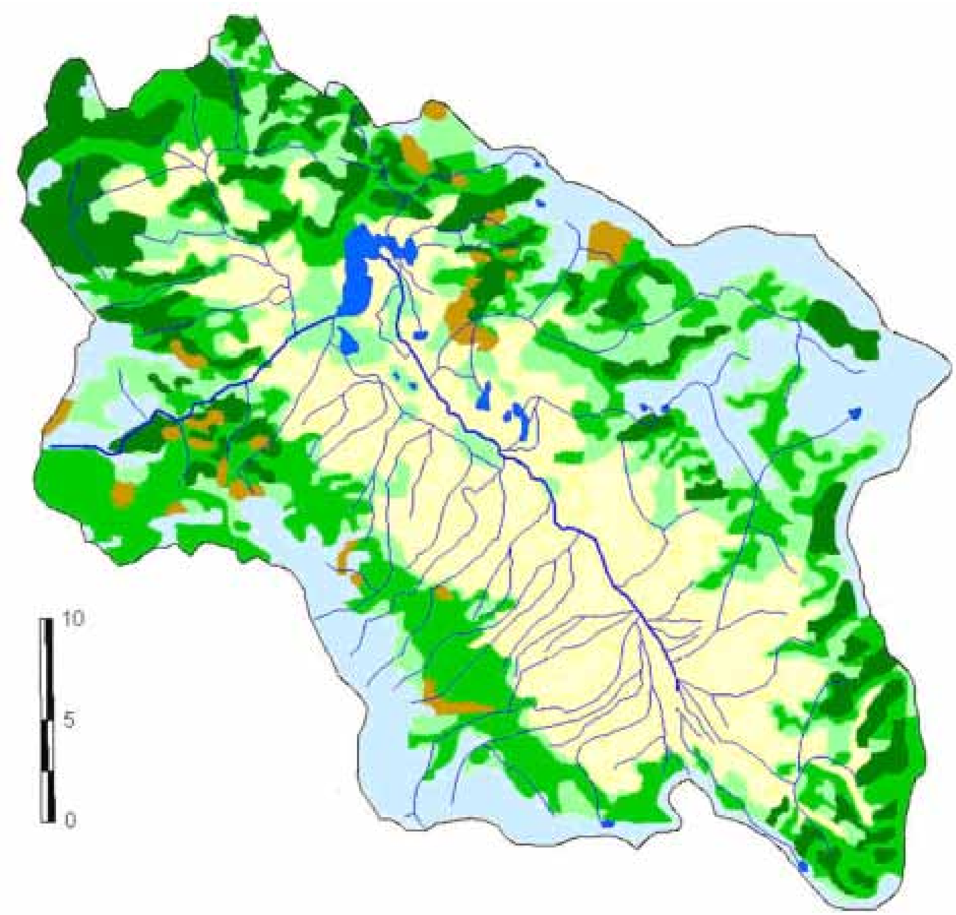
The Wular catchment is characterised by a dendritic drainage pattern. The total number of streams is 2,708. The lake volume is 371.825 x 10^6 m^3 (max volume) to 187.735 x 10^6 m^3 (min volume) (Bhatt and Pandit 2015). Its inflow varies between 1030 and 43,314 cusecs, while the outflow ranges between 870 and 31,800 cusecs, although Wetlands International (2007) indicates that at Sopore, the net outflows from Wular were higher than the inflows. The annual silt deposition during the decade 1970-1980 indicated an average value of 3331 acre/ft/year (Kulkarni and Khan 2014). This is likely to have grown substantially in the last three decades, as land use changed more rapidly post 1980s.

According to Wetlands International (2007), Jhelum river is the main contributor of water inflow into Wular, accounting for about 88%, the rest being brought in by the streams of the catchments and precipitation. Jhelum accounts for a majority of the outflow (96%).

Table 3: Features of the Wular Lake (Bhat and Pandita 2015)

Feature	Value
Maximum area	61.6 km^2
Minimum area	12.4 km^2
Average area	31.41 km^2
Max volume	371.825 x 10^6 m^3
Min volume	187.735 x 10^6 m^3
Elevation	1580 m
Length	16 km
Breadth	7.6 km
Maximum Depth	5.8 m

Figure 4: Drainage map of Wular Lake



Source: *Wetland International 2007*

2.3. Climate

The valley of Kashmir falls in the northern extreme of the tropical circulation. Rains in the period of June-September in the valley occur due to southwesterly monsoon winds and constitute about 25% of annual rainfall. The winters, from December through April, receive precipitation mostly in the form of snow, due to the westerlies of the Mediterranean origin moving into the region. Thunderstorms and rains occur at the end of winter season. The months of October through December, and a small period before June, are normally the driest months of the year. Normal annual rainfall in the main valley, over the catchment with an altitude range of 1600-1900 meters, is 600 to 900 mm, whereas in areas at an altitude of 2500 m, the mountains receive 1200 to 2500 mm of precipitation. Local disturbances also generate an appreciable precipitation in the area. Bandipore rain gauge station, which is in proximity to Wular Lake, has witnessed an annual rainfall of 589-3264 mm, with the number of rainy days from 46-82 from 1980 to 1998.

Average temperatures at Srinagar vary from a few degrees above zero during winter to well above 20oC from July to August. During 1994 to 2004, the mean maximum and minimum temperature at Srinagar has been recorded as 20oC and 4oC respectively. The humidity values reach a maximum of 90% in winters and a maximum of 80% in early summers.

2.4. Hydrology

Wular Lake is an important link of the hydrographic system in Kashmir valley and lies in the water course of River Jhelum, which flows through it. The Jhelum River rises from the spring of Verinag in the district of Anantnag, on the southeastern side of Pir Panjal mountains and flows in the northwesterly direction towards Wular at an average elevation of 1676.40 meters. The river Jhelum, along its course up to Wular, is joined by many significant perennial tributaries and other streams. While rivers *Sandaran, Bringi, Arapat Khul, Lidder, Arapal,* outflows of Dal lake, Manasbal Lake and River Sindh join Wular along its right bank, rivers *Vishow, Romshi, Sasar, Rambiara, Doodganga, Shaliganga* and *Sukhnag* join it along its left bank. The Jhelum enters Wular Lake towards the southeast of the lake at Banayari, and exits from the lake upstream of Sopore town in Baramulla district. Nallah Erin and Madhumati flow into the lake in its upstream reaches towards the northeastern side, whereas Nallah Ningli joins River Jhelum immediately after its departure from the lake. Thus, Ningli Nallah does not contribute any inflow to the lake. Thereafter, the River Jhelum passes through Sopore town and is joined by River Pohru along its right bank near Doabgah. The river then continues to flow, passing Baramulla town and Uri town, with Chandanwari Nallah joining it along its right bank and Nallah Boniyar and Nallah Hajipeer joining along its left bank.

River Jhelum, being the main river draining the valley of Kashmir, is at the lowest ebb of the valley. It has many important cities, towns and villages located along its banks. In 1977, Wular Lake was reported to have a water spread of 112.61 km2 at an elevation of 1576.425m. Its dead storage is reported to be 19.74 million cubic meters. The maximum and minimum depths recorded are 6.10m and 1.00m respectively.

2.5. Catchment Areas

The total contributory catchment area of the lake can broadly be classified into two inter basin catchments; the one being drained through River Jhelum has been termed an "indirect catchment" and the other, which is drained by Nallah Madhumati, Erin and areas which contribute direct runoff to Wular Lake along its periphery, has been termed as a "direct catchment". This classification is more on the basis of inter- basin transfer of flow into the lake, rather than any other aspect. For all practical purposes, the Jhelum catchment constitutes the major part of the Wular Contributory catchment.

2.6. Lake Water Flow

The flow data with respect to River Jhelum, obtained from the department of irrigation and flood control, as collected from various sources:

a. Monthly mean discharges of River Jhelum at Baramulla from 1922 to 1993
b. Monthly mean discharges of River Jhelum at Sopore from 1985 to 2003
c. Monthly mean discharges of River Jhelum at Asham from 1990-2003
d. Monthly mean discharges of Nallah Madhumati from 1990-2003

Wular with willow plantations and a part of the direct catchment

Figure 5: Drainage of the Jhelum Basin

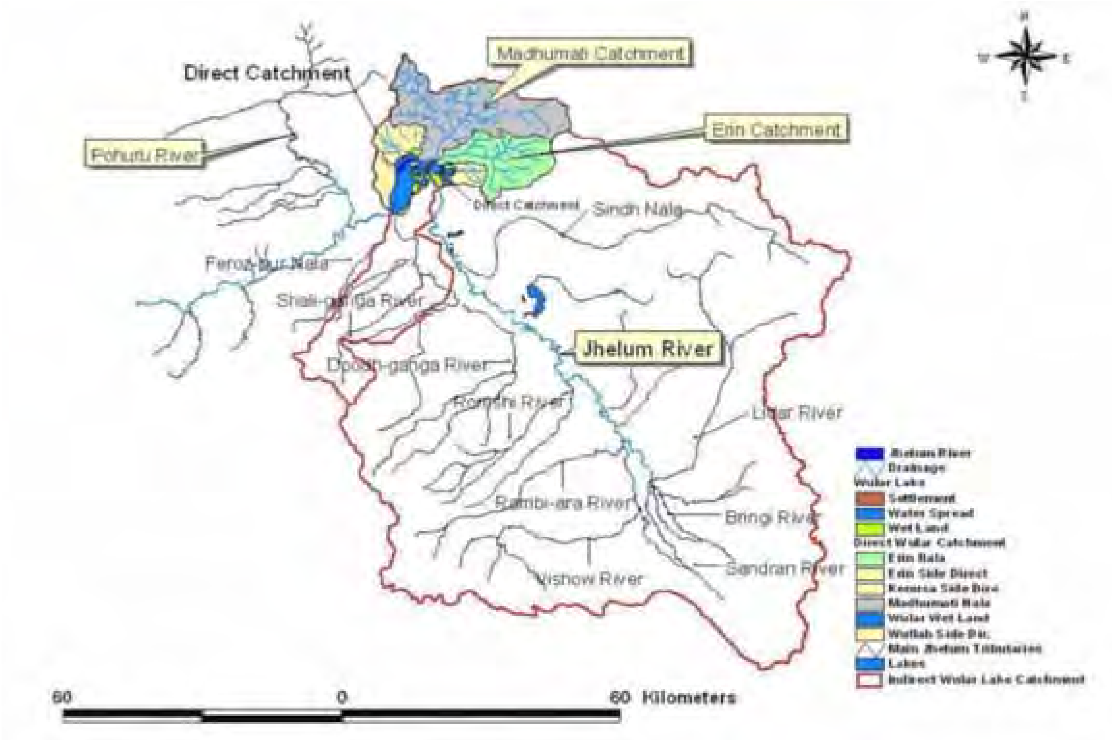
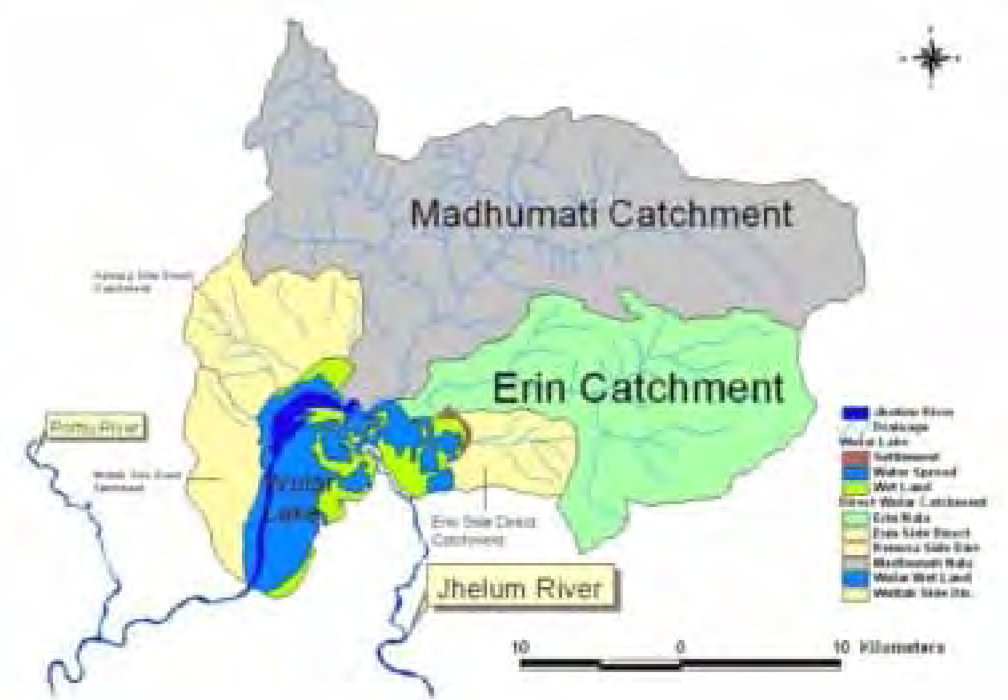


Figure 6: Direct Catchment of Wular Lake



e. Monthly mean discharges of Erin Nallah from 1990-2003

The hydraulic analysis of this data has been done by taking the concurrent period (1990-2003) as the hydro period for determining the lake water budget.

2.7. Inflow

The inflows into Wular are from four principal sources: the Jhelum (indirect catchcment), Madhumati and Erin (direct catchments), other catchments draining directly into Wular (Kunoosa and Watlab) and the springs within the lake.

To provide the monthly mean discharges of the river in m^3 per second (cumecs), the inflow into the lake from River Jhelum, which drains the indirect catchment of Wular Lake (8689.67 km^2) up to the lake inlet, has been worked out on the basis of recorded discharges of river Jhelum at Asham, by the P&D Division of Irrigation and Flood Control Department for the years 1990 to 2003 (14 years). This has further been extrapolated to get the flows of River Jhelum at Wular inlet on a pro rata basis of catchment areas, which up to Asham, is 8627.32 km^2. This gives a conversion multiple of 1.0072 for additional flow contribution from Asham to Wular inlet. No other river joins Jhelum in this reach.

The annual mean inflow volume into Wular Lake, calculated in Table 5, is 7262.49 million cubic meters (cumec) per year.

The volume of water contributed from other catchments draining directly into Wular, evaluated on the basis of mean yearly rainfall recorded at Bandipore, during the period from 1995 to 1998, is 824.75 mm. The rainfall in other catchments, Kunoosa and Watlab, spanning 146.17 km2, and a wetland area of 100.54 km2, excluding evaporation losses, contributes an annual volume of 200.98 million m^3.

The total annual volume contributed to Wular

Table 4: Catchment of Wular

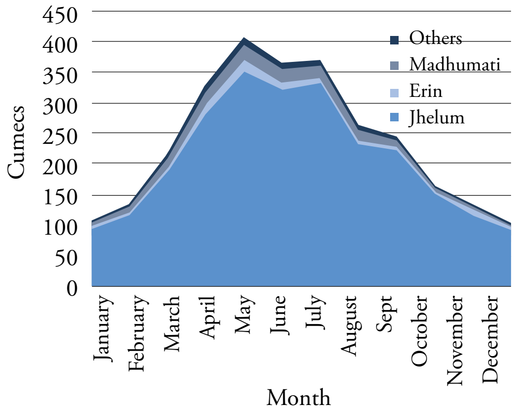
Catchment	Area in K m^2
A. Indirect (drained by River Jhelum up to Wular inlet) up-Ca tchm ent	
Jhelum up to outfall in Wular	8689.67
B. Direct (draining into Wular)	
Nallah Erin	214.16
Nallah Madhumati	436.36
Sub-total 'B'	650.52
C. Wular Lake Expanse	100.54
D. Other Area (draining into Wular)	
Kunoosa	71.64
Erin adjacent area	34.27
Watlab side	40.26
Sub-total 'D'	146.17
Grand Total	9586.90

Table 5: Monthly inflow into Wular Lake from various sources

	Jhelum	Erin	Madhumati	Others	Total
January	94.81	3.11	5.21	2.4	105.53
February	115.92	4.14	9.36	4.32	133.74
March	185.6	6.57	16.56	7.64	216.37
April	282.65	13.53	22.29	10.28	328.75
May	351.73	19.34	25.1	11.57	407.74
June	321.51	11.91	22.25	10.6	366.27
July	333.66	8.69	19.1	8.81	370.26
August	232.59	6.75	17.07	7.87	264.28
Sept	223.4	4.08	11.95	5.51	244.94
October	152.4	3.08	6.01	2.77	164.26
November	117.02	2.76	5.64	2.6	128.02
December	93.33	2.92	4.39	2.02	102.66

Source: *Irrigation and Flood Control Department, J&K Govt.*

Figure 7: Mean monthly inflow into Wular from various sources



from rivers, nallahs and other catchments are given in Table 6.

The combined Hydrograph is plotted and given hereunder. (Figure 8)

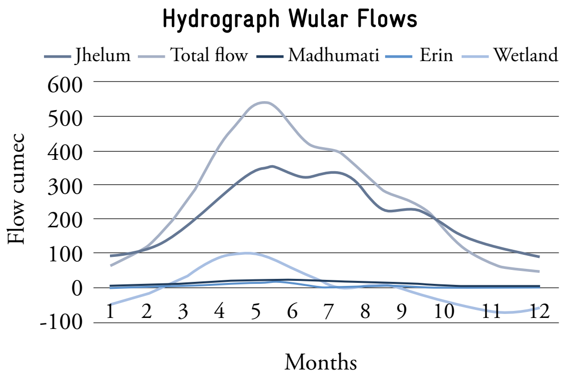
The total annual volume of water flowing into Wular Lake amounts to 7,463.46 million cubic meters (Mm³), and a month-wise breakup is provided in Table 7.

2.8. Outflow

The outflows from Wular Lake have been evaluated on the basis of recorded flows of River Jhelum at the gauge station in Sopore, maintained by the Irrigation & Flood Control Department from the years 1990 to 2003.

These outflows have been worked out on pro rata basis by taking the monthly mean flows of River Jhelum at Sopore, where River Jhelum has a catchment area of 10,455 km^2, and deriving the outflows for Wular outlet, where the river has a catchment area of 10,221 km^2.

Figure 8: Combined Wular Flows



The monthly mean values are shown in Figure 9.

In the reach of the river between Wular outlet and Sopore, Jhelum is joined by the Ningli Nallah. The above extrapolation of flows is seen to also match the values if alternatively, Ningli flows are subtracted from Sopore flows. The flows of Ningli Nallah, which drains a catchment area of 635.72 km^2 up to its outfall in River Jhelum, immediately after the later outflows from Wular Lake, have been obtained from Power

Table 6: Inflows into Wular from various sources (Total inflow volumes /year)

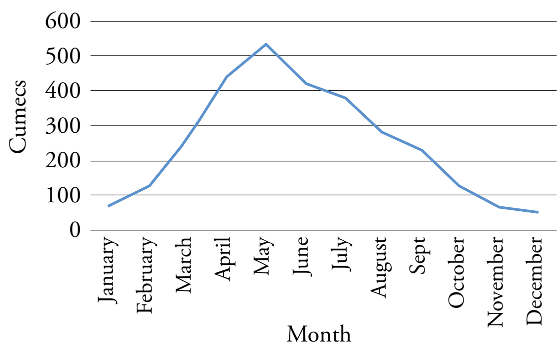
Source	Volume (in million m³)
Jhelum	6596.73
Madhumati	435.89
Erin	229.87
Kunoosa	58.36
Watlab	32.79
Erin adjacent	27.92
Lake surface	81.91
Total	7463.47

Table 7: Total Monthly mean inflow volumes to Wular Lake (1990 to 2003)

Month	Volume (Mm³)	Month	Volume (Mm³)	Month	Volume (Mm³)
Jan	282.66	May	1092.10	Sep	634.9
Feb	323.52	Jun	952.33	Oct	439.97
Mar	579.53	July	991.69	Nov	331.83
Apr	852.12	Aug	707.85	Dec	274.96

Source: *Irrigation and Flood Control Department, J&K Govt.*

Figure 9: Mean monthly values of outflow from Wular through Jhelum



Development Department for the years 1996 to 2000. These have been evaluated for the hydro period (1990-2003) on the basis of pro rata comparison of Jhelum flows at Sopore and Ningli flows during the period 1996-2000.

The annual outflow volume of Wular Lake through Jhelum is thus 7883.83 million cubic meters per year.

2.9. Lake Water Uses

The lake water is used for irrigation and water supply. A major irrigation canal called Zainagir canal off takes from Madhumati Nallah near Sonarwani. This canal is designed to carry 10 cumecs flow. However, at present, this is utilised to an extent of only 7 cumecs during irrigation season. The tail end of this canal used to be augmented by a lift station at Watlab, which would directly pump lake water to the canal for augmentation. However, this practice has now been stopped. The Zainagir canal irrigates an agriculture area between Bandipore and Watlab and onwards up to Seer in Zainagir block.

A 4 MGD lift water supply installation at Watlab draws its raw water requirements from the lake to meet the drinking water needs of Sopore town and villages between Watlab and Sopore. There is another rural water supply scheme at Tarzoo. Sopore also utilises 0.17 MGD of lake water for its raw water requirements.

The abstraction from the lake for water supply, irrigation and evaporation have been evaluated on the basis of 4.17 MGD for water supply around the year, and 7 cumecs for irrigation for the months of April through August and November.

The evaporation has been evaluated from a formula derived for Dal Lake, using annual mean values of relative humidity and temperatures as observed at Bandipore, to get annual mean rate of evaporation. The monthly mean values have been apportioned on the analogy by using the mean temperatures and relative humidity values observed at Srinagar. The total monthly mean evaporation volumes are given in Table 8. The annual evaporation is 119.51 million cubic meters, equating to a rate of 986 mm/year.

These abstractions amount to 255.25 million cubic meters annually. The total annual outflow volume from Wular Lake is shown in Table 9. (Figure 10-11)

The total outflows from the Wular Lake are to the tune of 8,139 million cubic meters and the contribution of each is provided in Table 10.

Comparison of inflow volumes (Table 10) and outflow volumes (Table 10) indicates that an increment of 675.62 million cubic meters is required as inflow, in order to balance the outflow of 8139.09 million cubic meters.

This is provided as increment from all subterranean

Table 8: Extractions on account of Evaporation

Month	Volume (Mm^3)	Month	Volume (Mm^3)	Month	Volume (Mm^3)
Jan	2.8	May	15.21	Sep	14.07
Feb	3.94	Jun	18.02	Oct	8.40
Mar	7.42	July	17.92	Nov	4.82
Apr	9.67	Aug	14.55	Dec	2.69

Figure 10: Mean monthly extractions from Wular Lake

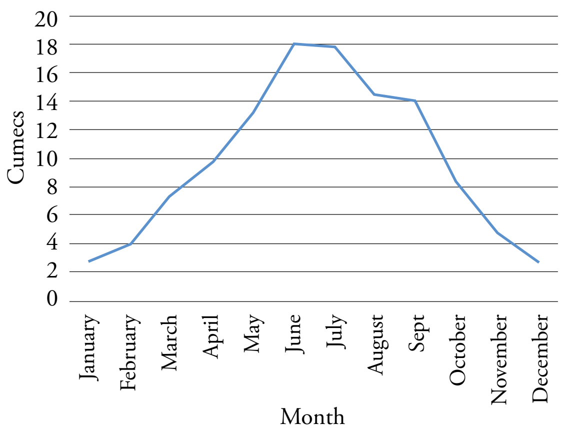


Table 9: Mean outflow from the lake through various sources (cumecs)

	River Jhelum	Evaporation	Irrigation	Total
January	68.27	2.8	3.39	74.46
February	128.02	3.94	4.47	136.43
March	261.47	7.42	8.01	276.9
April	445.52	9.67	28.38	483.57
May	534.57	13.21	34.55	582.33
June	421.98	18.02	36.73	476.73
July	382.2	17.92	37.25	437.37
August	282.59	14.55	33.28	330.42
Sept	231.81	14.07	33.39	279.27
October	122.99	8.4	8.99	140.38
November	62.95	4.82	23.53	91.3
December	51	2.69	3.28	56.97

sources, which includes lake bed springs. The monthly distribution for inflow from the springs is shown in Table 11. (Figure 12)

The total annual outflow volume of 8139.08 million cubic meters matches the total inflow volume to balance the water budget. The percentage of contribution to the flows on the basis of volume is in Table 14, which shows that the contribution due all subterranean sources, including lake bed springs, is 8%. River Jhelum contributes 81%, followed by Madhumati Nallah at 5%, Erin Nallah at 3% and other catchments at 3%.

The mean annual outflows from Wular are also given in Table 2.16, which shows that 98.86% flows out through River Jhelum, while just 0.09% is utilised for water supply purposes and 1.58% for irrigation purposes. Evaporation accounts for 1.47%.

2.10. Impact of Willow Plantation on Hydrological Aspects

Volumetric capacity: The original plan by Wetlands International (2007) (CMAP) recommends the removal of willow plantations from the shoals and silted pockets within the lake, as well at the ingress region of River Jhelum, where delta formation has taken place. This is expected to improve the water circulation patterns of the lake, aiming at uniformity of flow currents in the littoral and limonitic zones of the clear water expanse. This is to increase the volumetric capacity of the lake by about 40%, otherwise lost due to sedimentation, leading to shoal and island formation within the lake. For this purpose, the project stipulates selective mechanised dredging through cut suction dredgers in areas that are to be selected and earmarked as per the bathymetric profile of the lake. To achieve this objective , the removal of willow plantations is a pre-requisite and has been incorporated in the CMAP. The

Table 10: Outflow (Total outflow volume/year)

Source	Volume (in million m^3)
Jhelum Outflow	7883.83
Water supply	6.94
Irrigation	128.81
Evaporation	119.51
Total	8139.09

Figure 11: Monthly extractions from Wular from various sources

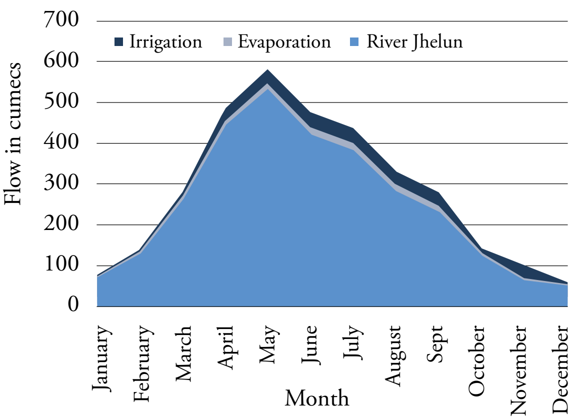


Table 11: Monthly mean sub-surface increments to inflow from springs.

Month	Vol Mm^3	Month	Vol Mm^3	Month	Vol Mm^3
Jan	57.38	May	57.38	Sep	55.53
Feb	51.83	Jun	55.53	Oct	57.38
Mar	57.38	July	57.38	Nov	55.53
Apr	55.53	Aug	57.38	Dec	57.38

Figure 12: Mean monthly inflow and outflow in Wular Lake

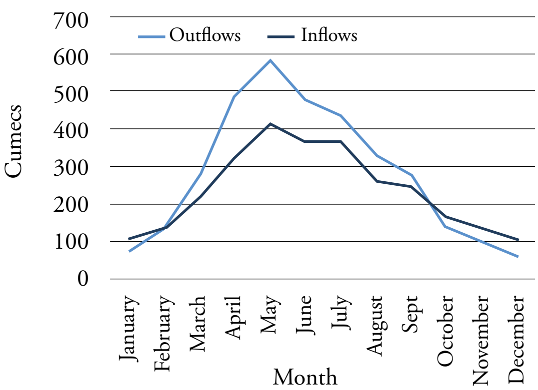


Table 12: Annual mean outflow volume from Wular

Month	Vol Mm^3	Month	Vol Mm^3	Month	Vol Mm^3
Jan	340.05	May	1149.49	Sep	690.43
Feb	375.35	Jun	1007.86	Oct	497.36
Mar	636.91	July	1049.07	Nov	387.36
Apr	907.65	Aug	765.23	Dec	332.34

Table 13: Total Outflow

Source	Volume (million m^3)	Volume (%)
Jhelum Outflow	7883.83	96.86%
Water supply	6.94	0.09%
Irrigation	128.81	1.58%
Evaporation	119.51	1.47%
Total	8139.09	100%

Table 14: Total inflow

Source	Volume (million m^3)	Volume (%)
Jhelum Inflow	6596.73	81
Madhumati Nallah	435.89	5
Erin Nallah	229.87	3
Kunoosa Catchment	58.36	1
Watlab Catchment	32.79	0
Erin adjacent Catchment	27.92	0
Lake surface Catchment	81.91	1
Sub surface increments (springs)	675.62	8
Total	8139.09	100

increased volumetric is expected to store flood water of river Jhelum and improve the flood absorption function of the wetland. Besides, the additional volume of stored water shall stabilise the power generation of downstream hydropower stations of Lower Jhelum Hydro Project and Uri Hydropower Projects Phase 1 and 2. Additional water shall become available in the lake, providing for increased demand of drinking water supply and irrigation, by augmenting the present water supply and irrigation facilities if and when required.

The additional water shall also have a positive impact on the lake water ecology, as it will improve the quality of water within the lake, due to increased dilution and flow. It will also improve lake aesthetics from the eco-tourism point of view, by increasing the water spread of the clear water expanse of the lake. The dredging of deposited sediments will also serve as a nutrient removal mechanism and reduce the nutrient loads recycling from the lake's benthos.

In order to quantify the above benefits, direct and indirect methods have to be adopted, which are discussed below:

1. Flood mitigation: removal of plantations within the lake is the prelude to a selective dredging operation that will contribute to 40% retrieval of lost volumetric capacity of the lake (as per the original plan, but significantly reduced in the revised plan) and provide equivalent volume for absorbing excess flood waters in the lake. Details of flood loss can be found at the revenue department. Reduced flooding, on the basis of areas directly impacted alongside the lake and downstream, can be attributed to be the benefits accrued by removing plantations and doing selective dredging.
2. Hydropower stabilisation: The generation capacity and water requirement of the existing hydropower installations downstream of Wular are below: (Table 15)

The above discharge is available for nearly seven months in the year and falls short of generating the installed capacity for five months. Maximum shortage is in the three months of winter. An additional storage of 40% is added to Wular Lake, and consequent enhanced storage for release will provide flow during winter months proportionately.

On an average, the increased volume capacity from the removal of willow plantations from 7.47 Km^2 will provide an additional volume of 11.20 M cusecs water. This volume of water, released for power generation during 3 winter months (90 days), will provide an additional 50.81 cusecs of water and generate an additional 19.10 MWS of power in the above three hydropower stations in winter. The cost of this generation, through the sale of power, is a direct benefit accrued by removing willow plantations.

3. Augmenting irrigation and water supply: For the balance period of 9 months other than winter, this additional 11.20 million m^3 volume of water from Wular Lake would be available for irrigation and meet water supply requirements, which are additional benefits of removing willow plantation.
4. Improved water quality and ecological aspects. Likewise, this additional volume of water would

Table 15: Power generation in various hydel power plants downstream

Name of Project	Installed Capacity
Lower Jhelum Hydro Power Installation	105 MWS
Uri Hydro Power Installation Phase 1	480 MWS
Uri Hydro Power Installation Phase 2	240 MWS

improve the quality of water by dilution, and also enhance the ecological usage of wetland biodiversity.

2.11. Water Chemistry

A detailed analysis of the physiochemical parameters has been conducted by Bhat and Pandit (2015) and Hassan et al. (2015), and the following is based on their results. The lake is mildly alkaline (pH 7.2-8.5). The mean transparency is between 0.86 and 1.15m, and the sites near the inflow (Jhelum) show lower depth than those near the outflows. The low values of dissolved oxygen (DO), ranging from 6.33 mg/l to 9.11 mg/l, indicate eutrophication of a water body. Low DO levels were associated with areas close to agricultural fields, the argument being that nutrient leaching and runoff from agricultural fields into the water bodies cause growth of micro-organisms, thus depleting dissolved oxygen levels. The chloride levels showed temporal variations, ranging from 29.7 mg/l in spring to a low of 9 mg/l in winter. The chloride content indicates organic load of animal origin. The concentration of nitrogen controls the productivity of an ecosystem and occurs as ammonia, nitrates and nitrites. In the case of the Wular Lake, higher nitrogen content is also associated with inflows of runoff from agricultural and horticultural fields in the catchment. High nitrogen content is also attributed to faecal and other effluent discharges from the settlements around the lake.

2.12. Flora and Fauna

2.12.1. Phytoplankton

Baba and Pandit (2014) documented 70 phytoplankton species from the lake, belonging to 36 genera. The taxa belonged predominantly to Bacillariophyceae, followed by Chlorophyceae, Cyanophyceae and Euglenophyceae. High presence of species like *Scanedesmus, Oscillatoria, Microcystis, Navicula* and *Euglena* is indicative of an organically polluted water body, which was the case in Wular.

2.12.2. Zooplankton

Diversity and abundance of Cladoceran zooplanktons was studied in Wular Lake by Shah and Pandit (2013). Cladocerans are a major group of zooplanktons, contributing largely to the zooplankton biomass. Shah and Pandit (2013) recorded 23 species of cladocera, belonging to six families. The most dominant Cladocerans reported were *Chydorus sphaericus,* which appeared to be generalist, *Chydros ovalis, Daphnia magna* and *D. retrocurva,* which had more restricted distribution. The species richness values indicate that the lake has a well-balanced Cladoceran community.

2.12.3. Flora

The abundance and composition of the aquatic macrophyte community has a great effect on a lake ecosystem, particularly shallow lakes like Wular. A recent study on the macrophyte community in Wular Lake identified 33 species (Table 2.20), divided into four groups, viz. emergent, rooted floating, submerged and free floating macrophytes (Masoodi *et al.* 2013). The communities living along the lakeshore have been utilising aquatic vegetation for various needs, particularly food, fodder and other purposes. The

Table 16: Chemical features of the Wular Lake

Parameter	Unit	1992*	2006*	Present**
Transparency	Meters	0.1-1.3	0.16-0.73	
pH		7.1-9.8	7.2-7.7	7.1-8.2
Conductivity	µs/cm	57.0-429	118-35	
Dissolved Oxygen	mg/l	1.3-15.2	4.5-8.0	5.8-9.4
Calcium	mg/l	4.6-73.8	20.5-62.3	
Chloride	mg/l	11.0-81.0	11.8-28.0	9-29.7
Magnesium	mg/l	0.8-35.6	12.2-30.1	
Ammonia	µg/l	1.0-205	64.0-101	71.3-170.3
Nitrate nitrogen	µg/l	9.0-580	205-419	176.7-304
Ortho Phosphate	µg/l	0.0-31.0	79-131.7	19.3-52.7
Total Phosphorus	µg/l	0.0-103	180-292.5	130=223.3

**Wetland International (2007), ** Bhat and Pandita (2014)*

WETLANDS

The recent introduction of some non-native invasive macrophytes is an emerging threat to Wular Lake. Invasive weeds may offset conservation measures by leading to local extinction of native species and altering ecosystem processes such as nutrient cycling, hydrology, and plant productivity

economically important species include *Trapa natans, Nelumbo nucifera, Nymphoiodes peltata* and *Phragmites australis.*

The recent introduction of some non-native invasive macrophytes, viz. *Azolla cristata* (Masoodi and Khan 2012a) and *Alternanthera philoxeroides* (Masoodi and Khan 2012b), is an emerging threat to the integrity and functioning of Wular Lake. These two invasive weeds might offset conservation measures. Invasive macrophytes lead to local extinction of native species, and alter ecosystem processes such as nutrient cycling, hydrology, and plant productivity in invaded ecosystems.

A separate wing of the revenue department, under *Naib Tehsildar,* and Mahali Singhara, (Sonawari), regulates the harvest of vegetation in the lakes. The department issues licenses for harvesting different vegetation components. The license fees for 2014-15 have been enhanced significantly. Licenses are issued for trapa collection for three time periods; a fee of ₹250 is charged for two months, i.e. July-August (for immature fruits, locally called *subz singhara*); ₹300 for the month of September (for harvesting relatively dry trapa directly from plants, and *dry singhara*) and a five-month license fee of ₹500 for October to February, for mature fruits called Kamai gaer (*Abi-singhara*).

Some commercially viable species in the lake are contracted out. These species are predominantly Phragmites, Typha, Nymphoides peltata and Nelumbo. Nelumbo was completely destroyed after the floods of 2014. Last year, the revenue office did not contract its harvesting in the previous year, with the objective of promoting production in the following year.

2.12.4. Fish

Wular is a very important fish resource for the Kashmir valley, with over 60% of the demand for fish met by Wular. The lake supports over 2,500 registered fishers

Table 17: List of the macrophytes in Wular Lake reported and their peak growth periods (adapted from Masoodi et al. 2013)

Emergent	Rooted floating	Submerged	Free Floating
Alisma plantago	*Nymphoides peltatum*	*Ceratophyllum demesum*	*Salvinia natans*
Sagittaria sagittifolia	*Nymphea alba*	*Hydrilla verticilliata*	*Spirodella polyrhiza*
Phragmites australis	*Nelumbo nucifera*	*Myriophyllum spicatum*	*Hydrocharis dubia*
Polygonium amphibium	*Trapa natans*	*Potomogeton pusilus*	*Azolla cristata*
Myriophyllum verticilliatum	*Potamogeton natans*	*Potomogeton cripsus*	*Lemna minor*
Sparganium ramosum	*Nymphaea tetragona*	*Potomogeton lucens*	
Bidens cernua	*Marsilea quadrifolia*	*Potomogeton pectinatus*	
Lycopus europaeus		*Vallisneria spiralis*	
Veronica anagallis			
Alternanthera philoxeroides			
Typha angustifolia			
Scripus lacustris			
Echinochloa crusgalli			

Table 18: Fish fauna of Wular Lake

Fish Species	Origin
Schizothorax esocinus	Native
Schizothorax curvifrons	Native
Schizothorax micropogon	Native
Schizothorax niger	Native
Schizothorax longipinus	Native
Crossocheilus diplocheilus	Native
Triplophysa sp.	Native
Cyprinus carpio communis	Exotic
Cyprinus carpio spicularis	Exotic
Carrassius carrassius	Exotic

Wanganeo et al. (2006)

but unofficially, the number of people dependent on fishing activity for their livelihood is much larger.

Fish extraction forms an important resource base of livelihoods for lakeshore communities. The number of licensed fishermen who are registered with the fisheries departments for 2014-15 was 2,061 in Bandipora and 438 in Sopore. As per the reports of the fisheries department of Kashmir, there are 11 species of fish in Wular Lake, of which seven species are native, and the remaining three are exotic. In the commercial catches, exotic carps contribute 60-65% of the total catch, while native species contribute the rest. The vegetation cover in the lake has expanded, which favors exotic carp, since dense vegetation cover is conducive to spawning, more so than for indigenous Schizothorax.

Wular Lake falls under the jurisdiction of two districts, viz. district Bandipora and district Baramulla. Alhough the larger part of lake area is under Bandipora, which controls the major resources that lie within the district, the fisheries department of Baramulla has control over the harvesting of fish and issuing licenses.

2.12.5. Avifauna

Wular Lake was designated as a Ramsar site in the year 1990, on account of the large assemblage of migratory waterfowl during winters in the lake. It is a part of the lakes and wetlands of the Jhelum basin, and receives several hundred thousand birds during winter, which move between the wetlands of Wular, Hygam, Hokersar and others.

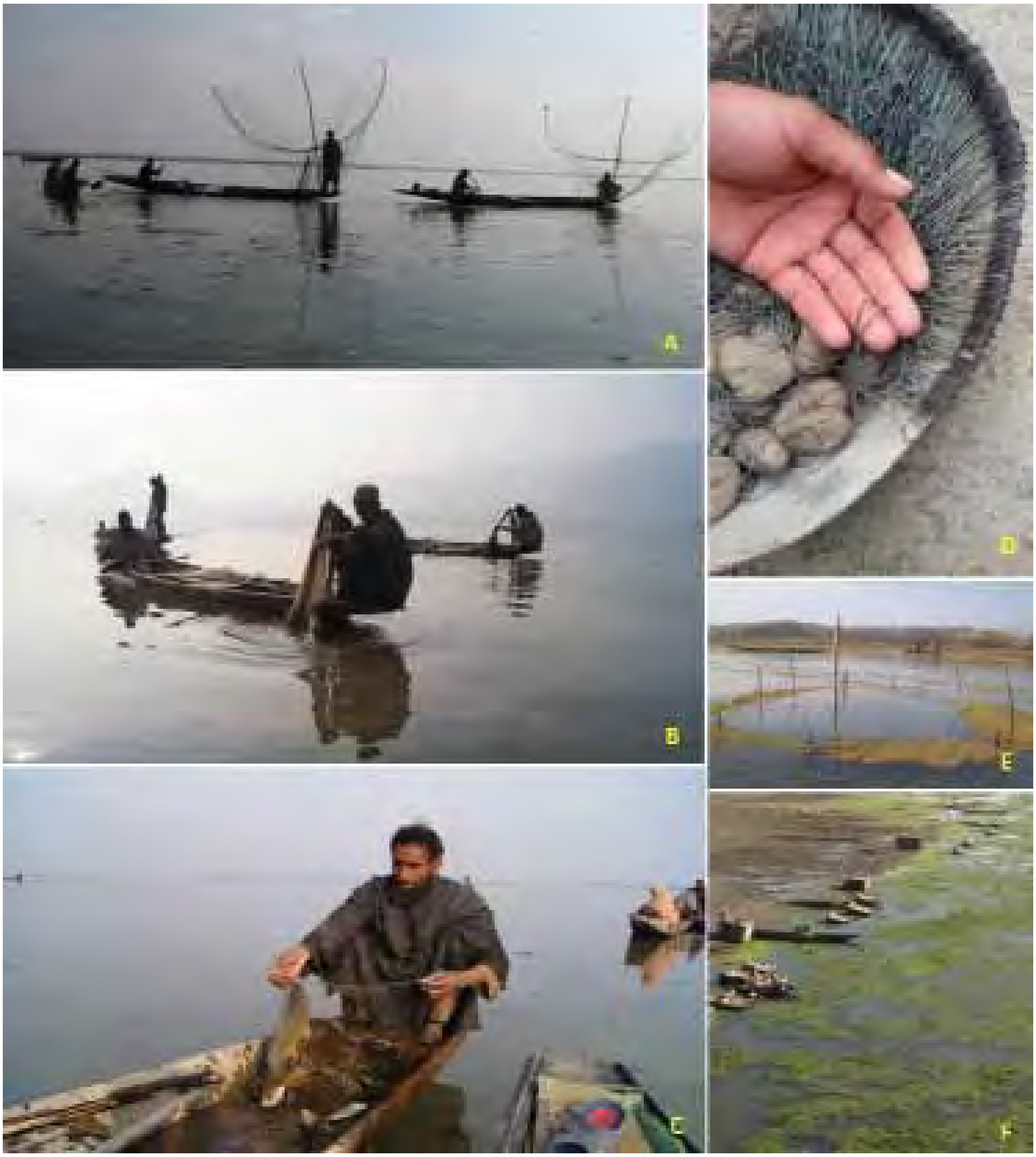
Eighty-eight species of birds in the wetlands and surrounding forest areas have been documented (Islam and Rahmani 2004). Species like the Pallas Fish-Eagle seem to have become rare, but were commonly found in the past (Loke 1946). Important species found in these wetlands are Ferruginous pochard (*Aythya nyroca*), Lesser grey-headed fish-eagle (*Ichthyopyga humilis*) and the Darter (*Anhinga melanogaster*). These three species are threatened. The predominant species of migrants is the mallard (Anas platyrhynchos), gadwall (*Anas strepera*) Eurasian wigeon, (*A. penelope*) Northern pintail (*A. acuta*), shoveller (*A. clypeta*), common coot (Fulica atra) and the greylag goose (*Anser anser*). Species like the lesser white-fronted goose (*Anser erythropus*) and marbled teal (*Marmaronetta angustrirostris*). are both suspected to be present, albeit in small numbers (Islam and Rahmani 2004).

In addition to the winter migrants, the Wular serves as a breeding habitat for several water birds species, such as the little grebe (*Tachybaptus rufficollis*), little bittern (*Ixobhrychus minutus*), water rail (*Rallus aquaticus*), common moorhen (*Gallinula chloropus*), pheasant-tailed jacana (*Hydrophasianus chirurgus*), and Eurasian wood cock (*Scolopax rusticola*), to name a few. Other species, which subsist on the lake and roost in the trees nearby, are egrets, herons etc.

The willows that have been planted inside and on the periphery of the lake provide nesting and roosting habitats for a host of species like warblers, flycatchers, kingfishers etc.

Fish extraction forms an important resource base of livelihoods for lakeshore communities. The number of licensed fishermen who are registered with the fisheries departments for 2014-15 was 2,061 in Bandipora and 438 in Sopore

Different types of crafts/gears used for fishing.



2.12.6. People

There are 31 settlements around Wular Lake, although many more occur within its catchment (127). Those living in close proximity to the lake are mainly fishermen who depend on the lake for their livelihood and for resources. The livelihoods mainly include extraction and sale of fish, trapa, and lotus root, all of which are sold. Products like reeds are made into mats and sold. Vegetation like nymphoids are used as fodder, while willows are extracted for firewood.

Although Wular is the largest freshwater lake in India and also a Ramsar site, it has not been able to draw tourists. Of the hundreds of thousands that visit the Kashmir valley annually, only a few hundred actually visit Wular Lake. Thus, dependence of people on tourism related to Wular is negligible not only around Wular, but also in Srinagar.

Although the lake is now managed by Wular

Wular is a Ramsar Site and provides refuge to a large congregation of waterfowl during winter

Eurasian Golden Oriole (top) and Eurasian Cuckoo (bottom), both using willow.

Conservation and Management Authority (WUCMA), several other government departments hold stakes in the lake. These are the Forest Department (for plantations, mainly of willows), Department of rakh and farms (farmland and willow plantations), Public Health and Engineering (irrigation and flood control), and Department of Wildlife Protection (wildlife mainly consists of migratory birds). Besides, there are also some privately owned willow plantations in the lake.

2.12.7. Importance

Wular Lake is associated with human use for long and the earliest references to Kashmir make a mention of the lake, partly for its size and also for the plentiful services it provides to people. The services that this lake provides can be divided into the following three broad heads: a) Provisioning Services b) Regulating Services and c) Cultural Services.

a) Provisioning Services

Amongst the most prominent provisioning services that the lake provides is the availability of fish. There are over 2,400 fishermen registered with the government, who are directly dependent on the fish of the lake for their livelihood, but the numbers may be much higher. The lake provides about 60% of the total fish consumed in the entire Kashmir valley. In addition to fish, the lake also provides plant products like water chestnuts (Trapa natans), lotus root (Nelumbo sp.) and green fodder in large quantities. The lake provides water as a resource for drinking and irrigation.

Another important provisioning service that Wular Lake provides is water for hydropower generation. There are three hydel power plants downstream of Wular Lake. These are run off the river projects on the river Jhelum and their power output depends on the amount of water flowing from Wular into the river Jhelum.

b) Regulating Services

One very important service that Wular Lake provides is that of regulating the hydrological regime of the valley. Wular and its now dried out associated marshes served as a hydrostat, absorbing moisture during peak months (July-September) and then releasing water gradually in the lean winter months.

Wular also acts as a flood sink, since all the water drained from the Jhelum catchment (practically the whole valley) falls into the lake before emerging as Jhelum, which flows down across the border into Pakistan and then eventually into the Indus. Therefore, maintenance of its volumetric capacity is essential, if it has to play its role in flood regulation.

c) Cultural Services

Although Wular Lake is the largest freshwater lake in India and a Ramsar site, it has not attracted tourism, perhaps due to the prevailing and continued strife in the valley. Some tourists visiting Kashmir may visit the lake, but very few target Wular Lake as a site to be seen and cherished. The lake also does not provide any recreational facilities. Recently however, a few resorts offer lodging facilities and offer excellent views and vistas of the lake.

3. Methods

3.1. Identification of Benefit and Cost Flows

The primary objective of willow removal is to increase the water retention capacity and flow rate of river Jhelum. A cost-benefit analysis first requires an identification of affected stakeholders and the benefit and cost flows of willow removal. Willow removal is a major intervention in the ecosystem of Wular Lake, affecting the various ecological services that the lake provides to its stakeholders. It is therefore important to identify the changes this intervention may bring in the ecosystem services of lake. This has to be done by comparing scenarios of the lake with and without intervention.

The stakeholders of the lake were be identified as the government, general public, local households and local business and industry. The changes in ecological services of the lake due to willow removal were identified as time flows of benefits and costs to various stakeholders. These were described as follows:

a) Government Benefits (B_g)

B_{g1}: One-time benefit of selling removed willows

B_{g2}: Saving cost of desilting the lake

B_{g3}: Increased revenue from selling fishing rights

B_{g4}: Increased supply of hydropower

B_{g5}: One-time benefit of selling silt.

Costs (C_g)

C_{g1}: Recurring loss of revenue from harvesting willows for commercial wood and fuel wood

b) General Public

Benefits (B_p)

B_{p1}: Recreation (User Benefits)

B_{p2}: Aquatic Life and biodiversity (non-use benefits)

B_{p3}: Damages from floods avoided

Costs (C_p)

C_{p1}: Loss of carbon sequestration benefits

c) Local Households

Benefits (B_h)

B_{h1}: Increased fish production

B_{h3}: Increased supply of water for irrigation and household uses

B_{h4}: Aquatic vegetation harvesting

Costs (C_h)

C_{h1}: Loss of fuel wood, fodder and manure

d) Local business and industry

Benefits (B_i)

B_{i1}: Increased Incomes from Recreational Tourism

Costs (C_i)

C_{i1}: Loss of income to willow wood based industries

Net annual benefits from willow removal to various stakeholders could be defined as follows:

Net benefits of government (NB_g)

$NB_g = B_{g1} + B_{g2} + B_{g3} + B_{g4} + B_{g5} - C_{g1}$

Net benefits of general public (NB_p)

$NB_p = B_{p1} + B_{p2} + B_{p3} - C_{p1}$

Net benefits of local households (NB_h)

$NB_h = B_{h1} + B_{h2} + B_{h3} + B_{h4} - C_{h1}$

Net benefits of local business and industry (NB_i)

$NB_i = B_{i1} – C_{i1}$

Net annual benefits from willow removal (NB^t) could now be measured as

$NB^t = NB^t_g + NB^t_p + NB^t_h + NB^t_i$

Given the rate of discount as r, the net present value (NPV) of willow removal could computed as:

$$NPV = \sum_{t=1}^{T} [NB^t/(1+r)^t]$$

The internal rate of return is the rate of discount r* at which NPV =0.

Considering the present value of benefits (PVB) and the present value of costs (PVC) as

$$NPB = \sum_{t=1}^{T} [B^t/(1+r)^t]$$

and

$$NPC = \sum_{t=1}^{T} [C^t/(1+r)^t]$$

The benefit-cost ratio (BCR) for a given rate of discount r, could be defined as

BCR = NPB/NPC

3.2. Data Requirements and Measurement

The measurement of the flow of benefits and costs of Wular Lake without willows, requires an analysis of hydrological and economic data for situations of the lake with and without willow plantations. We used both primary and secondary data for calculating the flow. For instance, income to the government from the sale of fishing and trapa extraction licenses were obtained from the respective state departments. The scope of activities

The rate of carbon sequestration depends on the growth characteristics of the tree species, the conditions for growth where the tree is planted, and the density of the tree's wood. It is greatest in the younger stages of tree growth, between 20 and 50 years

envisaged for completion under various works under the Revised Action Plan were obtained from WUCMA, including details of contracts for willow removal and soil excavation and dredging.

Time flow of benefits and costs attributed to the government (B_{g1}, B_{g2}, B_{g3}, B_{g4}, B_{g5} and C_{g1}) as one of the stakeholders was estimated using data from secondary sources.

The estimation of flows attributed to the stakeholder general public (B_{p1}, B_{p2}, B_{p3} and C_{p1}) required data from both primary and secondary sources. A travel cost method was used to estimate recreational benefits (B_{p1}). In estimating biodiversity such as aquatic and avian life (B_{p2}), which may be called non-use benefits, a sample of people from Kashmir valley and the rest of India were surveyed using the Contingent Valuation survey questionnaire. Damages from floods avoided (B_{p3}) were estimated by obtaining the cost (from government records) of the flood damages downstream and in close vicinity of the lake. Loss of carbon sequestration benefits (C_{p1}) were estimated using data from secondary sources about carbon prices (CDM price or European Carbon Trading price) and an estimate of loss of carbon sequestration due to removal of willows from the lake area (using method; see below).

For estimating the benefits and cost flows of local households, another category of stakeholders' survey of a sample of households was conducted, seeking information about the variables B_{h1}, B_{h2}, B_{h3}, B_{h4}, B_{g5} and C_{h1} and socio-economic characteristics.

The benefit and cost flows of local Business and industry NB_i (B_{i1}, C_{i1}) were estimated using data from a survey of retailers serving tourists and local willow wood based industries.

The benefits and cost flows described above were estimated at constant prices during the year 2015 and extrapolated for 25 or 50 years in future.

3.3. Method for Calculating CO2 Sequestered by a Tree

The rate of carbon sequestration depends on the growth characteristics of the tree species, the conditions for growth where the tree is planted, and the density of the tree's wood.

It is greatest in the younger stages of tree growth, between 20 and 50 years. The standard procedure was used for calculating CO_2 sequestered by a plant, involving the following steps: (http://www.unm.edu/~jbrink/365/Documents/Calculating_tree_carbon.pdf).

a) Determine the total (green) weight of the tree.

The algorithm is based on a tree species in the southeast the United States and varies as per the diameter of the tree. Based on the average diameter of salix trees around Wular, the total green weight of a tree has been estimated as $W = 0.15D^2H$

where W=above-ground weight of the tree in pounds; D = diameter of the trunk in inches and H = height of the tree in feet.

The root system weighs about 20% as much as the above-ground weight of the tree.

Therefore, to determine the total green weight of the tree, multiply the above-ground weight of the tree by 120%.

b) Determine the dry weight of the tree

The average tree is 72.5% dry matter and 27.5% moisture. Therefore, to determine the dry weight of the tree, multiply the weight of the tree by 72.5%.

c) Determine the weight of carbon in the tree

The average carbon content is generally 50% of the tree's total volume.

Therefore, to determine the weight of carbon in the tree, multiply the dry weight of the tree by 50%.

d) Determine the weight of carbon dioxide sequestered in the tree.

To determine the weight of carbon dioxide sequestered in the tree, multiply weight of carbon in the tree by 3.66 (the ratio of atomic weight of CO2 to C).

e) Determine the weight of CO_2 sequestered in the tree per year.

Divide the weight of carbon dioxide sequestered in the tree by the age of the tree.

4. Stakeholder Analysis

4.1. Valuation of Costs and Benefits

4.1.1. Government Benefits (Bg)

a) The One-time Benefit of Selling Removed Willows (B_{g1}): The Comprehensive Management Action Plan (Wetlands International 2007) calls for the removal of willow trees from 27 km^2 area of the lake, amounting to the removal of a total of 21.84 lakh trees. The magnitude of this activity has now been significantly reduced in the revised plan, which is currently being implemented. The removal would now be undertaken in an area of 7.4 km^2, with the number of trees involved being about 5.6 lakh. The willow extraction is contracted out by the Forest Department. During the year 2013-14, a target of 30,420 trees was set to be extracted after due marking by the Forest Department, the sale of which would amount to about ₹3.09 crores. Once the timber is removed, the rootstock is extracted to pave way for the excavation and desilting. The removal of rootstock does not involve any expenditure to the state government. This is because the contractor leaves the rootstock in the ground. Earlier, the rootstock was extracted at a cost, the value of the root being much less than the labour involved in its extraction. The strategy now seems to be to leave the rootstock in the ground, for locals to use in whatever way they can, and extract it along with the silt, without any additional cost at the time of desilting.

Calculations

Number of trees proposed to be uprooted in the original plan = 21.84 lakh
Lake area under Salix plantation proposed to be cleared of willow (original plan) = 27.72 km^2
Lake area under Salix plantation proposed to be cleared of willow (revised plan) = 7.3km^2
Approx. total number of trees to be uprooted = 5.6 lakh

Total number of trees cut so far = 30,420
Cost of one tree = ₹1,017.35
Total revenue generated by selling these trees= ₹3,09,47,849 in 2013-14
Potential annual revenue (revised plan) = ₹14,24,29,000
Total revenue generated if all the trees were cut as per the revised plan (Bg1) = ₹569716000

Under Original Plan

Annual potential income from the sale of willow = ₹55,54,73,100
Total four-year income for all trees= ₹222,18,92,400

The total value of the stock under the current rates of operation for the revised four-year plan is ₹56,97,16,000. This gives a potential annual income of ₹14,24,29,000, assuming that the target of removing 5.6 lakh trees is divided equally over four years (1.4 lakh trees per year). There are slippages in the targets and in the year 2013-14, only 30,420 trees were marked to be extracted, which is only 21% of the assumed target.

Had the original plan (Wetlands International 2007) been adopted, the one-time revenue would have jumped to ₹222,18,92,400, with the annual income to the Forest Department being ₹55,54,73,100 for the four-year period.

b) Increased Revenue from Selling Fishing Rights (B_{g2}). Although the removal of willow and subsequent dredging will result in an increase in volumetric capacity and thus, an increase in the available habitat for fish, we anticipate no change in the accrual of revenue to the government on account of the sale of fishing rights. This is because all fishermen around the lake are already licensed and we do not anticipate any increase in the number of fishermen.

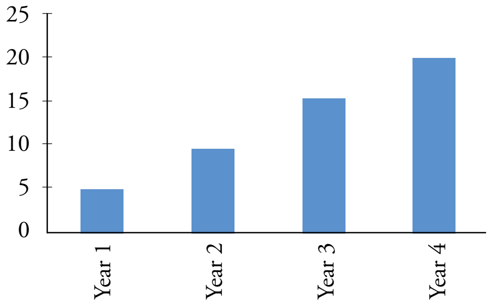
However, the fish yield is expected to increase and the benefits from this have been discussed in terms of benefit to individuals.

Therefore, (B_{g2}) = ₹ 0.0.

c) Increased Supply of Hydropower (B_{g3})

The present generation capacity and water requirement of the existing hydropower installations downstream of Wular are presented in Table 2.13. The removal of willow plantations and subsequent dredging will increase the volumetric capacity of Wular by 2.0 million m^3 over four years, according to the revised action plan. This will make an additional 50.81 cusecs of water available for power generation after four years. The water is surplus for the above power plants in summers and the main requirement is for the lean winter months, when the significantly reduced snowmelt reduces the inflow and thus also the outflow from the lake. The additional water, which would become available as a result of increased volumetric capacity of the lake, could be potentially used to supplement lean periods with the impounding mechanism, which is now in place.

Figure 13: Cumulative increase in volumetric capacity due to dredging (in lakh m³)



The volume of increase in lake capacity as per the plan is 4.84 lakh m^3 for the first year, 4.7 lakh m^3 for the second year, 5.79 lakh m^3 in the third year and 4.69 lakh m^3 in the fourth year.

The peak generation capacity at maximum discharge is 17.21 million units per day for Uri I and 2 power stations and the minimum discharge is 4.09 million units. Taking a mean of the two and finding the generation rate for 1 cusec, an increased capacity of 30 cusecs per month and an additional amount of 63,707 units of power per day could be generated. This translates to 23.2 million units per year, adding a revenue of ₹6.96 crore, assuming each unit is sold for ₹3.00.

However, in case the volumetric capacity of Wular Lake is increased by 40% (original plan) and impounding facilities are in place, this augmentation should allow the three power stations to generate power at full potential (summer generation). The power generation is at full capacity for the months of April-October, but begins to dwindle as water outflows from the lake deplete. In the two power stations, the winter production could be less than one-fourth of the summer production. With increased volumetric capacity, the plants would have the potential to run at full capacity for the additional five months of winter. This would produce an additional 432.03 million units of power, generating ₹129.61 additional revenue at ₹3 per unit.

Therefore, (B_{g3}) = ₹6.96 Cr for the revised plan and ₹129.61 Cr for the original plan.

d) Revenue to Government from the Sale of Aquatic Vegetation (Bg_4)

The details of the revenue generated from the sale of aquatic vegetation from Wular Lake are given in Table 19. A separate wing of the revenue department under the designation of Naib (Assistant) Tehsildar, Mahali Singhara, (Sonawari) regulates the harvest of lakes vegetation. The department issues licenses for harvesting the different vegetation components. The license fees for 2014-15 have been enhanced significantly. Licenses are issued for trapa collection in three phases. A fee of ₹250 is charged for two months, i.e. July-August (for immature fruits, locally called *subz singhara*); ₹300 for the month of September (for harvesting relatively dry trapa directly from plants; *dry singhara*) and a five-month license fee of ₹500 from October to February, for mature fruits called Kamai gaer (*Abi-singhara*). Details of the revenue collected in the last nine years are given in Table 19.

The area under trapa production is 21.2 km^2 and annually, the license fee generated is ₹2,94,660 (we have used rates for 2013-14 for the calculation of dry chestnut, since due to floods, dry water chestnut was damaged last year). However, since licenses are given out for ad *libitum* collection of resources, we do not see any increase in the number of license holders, even if the

Table 19: Details of the revenue accrued by the office of Mahali Singhara from variousvegetation products of Wular Lake from 2006 onwards (one financial year is from April to following March)

Year	Grass Contract	Nadroo Contract	Subz Singhara	Dry Singhara	Abi Singhara
2006-07	28000	nil	23712	7014	61608
2007-08	402000	nil	21236	17480	73600
2008-09	502000	35100	18000	14640	91200
2009-10	303000	257500	21000	24000	78800
2010-11	80000	nil	17000	10000	81100
2011-12	252000	118000	24742	8080	86600
2012-13	261600	265000	15048	11080	52500
2013-14	382000	nil	20496	11160	53000
2014-15	107000	nil	65500	nil	218000

area under trapa increases as a result of augmentation of the open water area. Thus, incomes will remain at ₹2,94,660 annually, with no additional accruals.

(Bg4) will thus remain unchanged.

Income from silt removed (B_{g5})

The focus of the plan is to increase the volumetric capacity of the lake by removing massive quantities of silt through various means. The revised plan envisages the removal of 0.21 million cubic meters (Mm^3) from plantation areas and an additional 0.385 Mm^3 from critically silted areas. In the original plan, 26.54 Mm^3 of silt was to be removed from critical areas as well as plantation areas.

The silt that is extracted is lake bottom silt, which is dumped by the contractor at a designated dumping site. This silt is not sold, but local villagers use it as manure for their farmland, for which no financial transactions occur.

Thus, although the silt is of benefit to locals, no financial accruals occur and thus $B_{g5} = 0$

4.1.2. Government Costs (Cg)

Recurring loss of revenue from harvesting willows for commercial wood and fuel wood (Cg1)

The fuel wood that comes from Salix plantations around Wular is mainly auctioned to the general public and for mosques in winter at a discounted rate of ₹190/Qtl. Thus, the total annual income from the sale of firewood to locals (2000 mt) is ₹38,00,000. However, since under the revised plan, willows from only 7.4 km^2) shall be extracted, as against the 27km^2 in the original plan, there is ample firewood available to sell. Therefore, we see no loss to the government on that front.

The quantity of fuel wood obtained from salix plantations around Wular and sold by the Forest Department annually = 20,000 Quintals or 2,000 tonnes.

Cost of one quintal of fuel wood = ₹190

Total revenue generated from fuel wood annually = ₹38,00,000

Cg: None expected

Saving Cost of desilting the lake (Cg2)

The rivers flowing into the lake bring in large quantities of silt. It has been estimated that in the decade 1970-1980, an average of 3,331 acre ft/year of silt flowed into Wular (Kulkarni and Khan 2014). This translates to a silt load of 4.1 million m^3 per year. Part of it is washed down by Jhelum, but a part settles down in the lake bed, especially in parts where the flows are reduced.

The removal of willows from the lake is seen as a precursor to dredging, at least from the plantation areas. Therefore, for the benefits of increased capacity to be realised, costs of desilting need to be calculated. In the revised plan, a volume

of 0.717 Mm3 is planned for removal from the plantation areas. The cost of contracting out the removal of silt over four years is ₹21.5 crore. Although physical targets vary across the project period, for the sake of analysis, we have assumed similar rates of extraction across the four years, giving an average expenditure of ₹5.375 crore a year. In this analysis, we have not taken into account the silt that needs to be removed from other critical areas, outside of the plantation areas. In the original plan, silt was planned to be removed from 7.47 km2 and the volume of silt to be extracted was 11.20 Mm^3. Using similar rates in the revised plan, a total expenditure of ₹336 crore would have had to be made on desilting (₹84 crore annually).

Thus (C_{g2}) is ₹5.375 crore in the revised plan and ₹84 crore in the original plan.

4.1.3. General Public Benefits (Bp)

Recreation (User Benefits) (Bp1)

Wular Lake is largely a shallow lake, with an abundance of macrophytic vegetation. There is no recreational activity in the lake (for example angling, boating, swimming etc). As such, there are not many people dependent on recreational activities. The vistas are excellent and a small park called the Vintage Park has been made for the benefit of tourists. A small entry fee is charged. However, visitation to this park is very low and revenue accruing from the sale of entry tickets is very negligible. A questionnaire survey conducted with tourists indicated that none of the tourists had any intention of visiting the lake for whatever purpose. However, a few hotels on the bank of the lake have registered some tourists, but not enough to contribute significantly to tourism. Therefore, we feel that merely the removal of willows and clearing of areas will not affect tourism in any way. Many more activities need to be undertaken simultaneously for it to be a significant attraction for tourism.

Therefore, (Bp1) = ₹ 0.0

Aquatic life and biodiversity (non-use benefits) (Bp2)

The lake is a Ramsar site and therefore an important site for bird congregations. These are mainly waterfowl, which use open water stretches or those patches with macrophytes. We undertook an avifauna survey within the willow plantations to see if any important species breed there. We listed about 30 species using willow habitats, of which a fairly significant proportion was formed by waders. Thus, true users of willow trees like the passerine species are very few and found elsewhere. Our opinion is that removing willows from the lake will not impact any birds in terms of species loss. However, we do acknowledge that every animal has a role and the removal of 5.6 lakh trees would cause losses to nesting and roosting habitats, resulting in the loss of an undetermined number of individuals of several taxon groups. We have been unable to account for these losses and therefore excluded this service from the analysis.

Damages from costs to floods avoided (Bp3)

Kashmir valley is flood prone and the recent floods of September, 2014 were the most devastating the valley has witnessed in the last 80 years. The damage estimates caused by the floods ranged from ₹25,000 crores (World Bank) to ₹44,000 crores (state government).

All the water that the valley gets in the form of precipitation, snowmelt and from springs ultimately goes through Wular Lake, to emerge and flow into the Indus in Pakistan. Thus, Wular acts as a basin for all the water that the valley accumulates.

Its role in flood regulation is mainly that of an absorption basin for waters flowing through Jhelum and other streams, albeit to a much lesser extent. However, this downstream control is constrained by the loss of volumetric capacity of the lake, and slowing of inflow from rivers, mainly Jhelum.

Several wetlands and swamps in the course of the Jhelum, helped in absorption of excess water and thus had a definite role in flood control. Swamps, for instance, at Sonawari, Bemina, Hokersar, Hygam and the associated marshes of Wular, all played their part. However, several of these swamps, especially those that were not protected, were drained and turned into residential colonies in the last few decades.

An increased holding capacity of Wular can certainly play a major role in flood control by allowing excess water to be drained into it through either Jhelum (35,000-40,000 cusecs) or the existing flood channel (12,000 cusecs). The proposed new spill channel from Dongripora to Wular (55,000 cusecs), which is estimated to cost ₹2,200 crore, cannot be effective unless the retention capacity of Wular Lake is increased significantly. With this in place, excess water is expected to be diverted upstream of Srinagar and carried to Wular, bypassing the capital city of Srinagar and saving immense costs due to flood damages.

It is not possible to assess whether with a larger volumetric capacity, the Wular would have had a more prominent role in reducing the impact of the catastrophic floods in September, 2014 in the upstream areas of the lake. However, it would certainly have prevented flood damages within the district Bandipora.

The total loss to government infrastructure in Bandipora district was ₹100 crores, in addition to the damage of 20,000 private properties (Shah Faesal 2015). The compensation given by the government to 3,654 households, mostly in tehsils Hajin and Sonawari, which lie in the floodplains of Wular Lake, is ₹5,37,53,000.

Thus, a better volumetric capacity would have been able to avert the cost of about 105.37 crores.

(Bp3) = ₹105.37 crores

4.1.4. General Public Costs (Cp)

Loss of carbon sequestration benefits (Cp1)

The extraction of 5.6 lakh trees would result in a huge reduction of the sequestration potential of the area. We have used standard methods to calculate the loss of carbon and carbon dioxide sequestration benefits.

The standard methodology was followed in calculating carbon sequestration (see methodology):

After conferring with the concerned officials, we assume that:

- Average diameter of the tree = 14 inches
- Average height of the tree = 20 feet
- Average age of the tree = 15 years

1. The standard formulae for calculating the above-ground green weight if the tree $W = 0.15D^2H$ or $0.15\times12\times12\times20$. Thus, the green weight of one tree is 675 pounds or 306.17 kg.

An increased holding capacity of Wular would play a major role in flood control. If Wular's retention capacity is significantly increased, the proposed spill channel will divert excess water to Wular, thus bypassing Srinagar and saving immense costs due to flood damage

WETLANDS

The root system weighs about 20% of the above-ground weight. Therefore, the total weight of the tree is 675×120/100 = 810 pounds or 367.41 kg.

2. Dry weight is calculated by the standard formulae, assuming that an average tree is 72.5% dry matter and 27.5% moisture. Therefore, the dry weight of the tree = 72.5% of its green weight.

Therefore, dry weight = 810×72.5/100, which is 587.25 pounds or 266.37 kg.

3. The average carbon content is generally 50% of the tree volume. So, the weight of carbon is 50% of the dry weight of the tree ie. 587.25/2, which is 293.62 pounds or 133.18 kg.

4. Weight of Co2 sequestered/tree. Multiply the weight of C in a tree by 3.663 (see method), which gives a figure of 1075.5 pounds or 487.6 kg. The average age of a tree is 15 years. So, the amount of Co2 sequestered by a tree annually is 1075/15 or 71.70 pounds or 32.50 kg.

Assuming that the trees are being extracted in four equal installments across four years, the total Co2 sequestered would be 45,52,800 kg in the first year, 91,05,600 kg in the second year, 1,36,58,400 kg in the third year and 1,82,58,400 in the fourth year.

Going by the rate of Voluntary Carbon Trading (reference) of $5.9/ton, the total monetary value of carbon dioxide sequestered would be (as per the revised plan) US$ 26861.5 02 or ₹16,11,691 for the first year, US$ 53,723 or ₹32,23,382 for the second year, US$ 80,584.5 or ₹48,35,073 for the third and US$ 107446 or ₹64,46,764 for the fourth year.

Had the original plan been implemented, the loss from carbon dioxide sequestration would be 17,745 tonnes in the first year, 35,490 tonnes in the second year, 53,235 tonnes in the third year and 70,980 tonnes in the fourth year. This translated into a loss of US$ 104,695 or ₹62,81,730 for the first year, US$ 209,391 or ₹1,25,63,460 for the second year, US$ 314,086 or ₹1,88,45,190 in the third year and US$ 418,782 or ₹2,51,26920 in the fourth year.

4.1.5. Local Household Benefits (Bh)

Benefits (Bh_1)

Increased Fish Production (Bh_1)

The number of licensed fishermen registered to operate in Wular (2014-15) was 2,499. Going by the license fee of ₹500 per fisherman, the total revenue accruing to the government was ₹12,49,500.

The income to the government from licenses to fishing amounted to ₹12,49,500 in the year 2014-15. While an increase in volumetric capacity of the lake would increase the potential fish yield, it would not result in any increase in incomes from license fees, since there are not any new fishermen left in the area, and the same ones would explore the new area cleared from desiltation.

The average volumetric capacity of the lake for the year 2012-13 was estimated at 267.675 × 10^6 m^3 (Bhatt and Pandit 2015). The average fish production of the lake for the year 2012-13 was 3580285 kg's or 3580.28 Mt. Therefore, the average volume of water per kg fish production (for year 2012-13) = 74.76 m^3.

In other words, an increase of one cubic meter of water would yield 0.0133kg/year. It is proposed that 2.02 Mm^3 of volume will be increased from dredging/excavation. Therefore, a potential increase in fish production would be 27,019 kg or 27 metric tonnes. From our questionnaire survey, the average rate of fish sold is ₹115/kg. Thus, additional incomes from fish resources accruing to local fishermen would be ₹31,07,185.

Therefore, (**Bh_1**) = ₹31,07,185

Increased supply of water for irrigation and household uses (Bh_2)

The removal of willow plantations from 7.47 Km2 (as per the revised plan), will increase the volumetric capacity of the lake and 50.81 cusecs of additional water will be available. Between April and July, there is no shortage of water. Additional availability of water (as per the revised plan) will not benefit irrigation, as there is surplus water available during these months, at the present level. A significant difference is not expected in terms of household usage either.

Therefore, (**Bh2**) = ₹0.0

Aquatic vegetation harvesting (Bh_3)

Income generated by locals harvesting Trapa

Licenses are issued for trapa collection in three phases. A fee of ₹250 is charged for two months, i.e. July-August (for immature fruits, locally called *subz singhara*); ₹300 for the month of September (for harvesting relatively dry trapa directly from plants; *dry singhara*) and a five-month license fee of ₹500 during October to February, for mature fruits called Kamai gaer (Abi-singhara).

Income from Kamai Gaer (Abi-singhara)

The largest revenue for the government is generated by issuing licenses for Abi- singhara (Kamai gaer). As per details of revenue generated by the department (refer to Table 4.1), the total number of licenses issued for 2013-2014 was 436. The average yield of trapa is 75-100 kg/person/day. Thus, the approximate average yield of

Willow removal would yield no expected costs on local households and businesses, but would accrue significant benefits from acquatic vegetation harvesting and increased fish production

trapa from Wular (estimated for 436 licenses) is 32,700-43,600 kg/day.

The approximate average yield of trapa from Wular during the season (comprising 5 months, from October-February) would be 49,05,000-65,40,000 kg. The average selling price is ₹50/kg. Therefore, the income generated from the total extraction over five months is ₹24.52 crore to 32.70 crore.

Income from fresh chestnut (Sabz Gaer)

The total number of licenses issued for 2013-2014 was 262. On an average, the extraction of trapa was at 35–100 Kg/person/day. The approximate average yield of trapa from Wular (estimated for 262 licenses) is thus 9,170-13,100 kg/day. The approximate average yield of trapa from Wular during the season comprising two months (from July-August) is 5,50,200-7,86,000 kg. The average selling price of trapa is ₹10/kg. Therefore, total income generated is ₹55,02,000-78,60,000. The total annual income generated by locals from Trapa is ₹25.07-33.48 crore (Average 29.27 Cr). This is the 'business as usual' scenario.

For the amended plan, an additional 1.5 km^2 is expected to be opened up by willow clearance and subsequent dredging/excavation. With the predisposition of Trapa to open spaces, it is assumed that the species will colonise the newly opened up areas. Using the existing rates, an additional revenue of 2.27 crore (56 lakh annually) can be potentially generated by the local people.

In the original plan, a total of 10.31 crore can be generated (annual ₹2.57 crore*).

4.1.6. Local Household Costs (Ch)

Loss of fuel wood, fodder and manure (Ch_1)

The Forest Department sells 20,000 quintals of fuel wood, which goes to mosques and some part to the public at a discounted tariff. Other than this, the fuel wood, which locals get from willow plantations, is extracted illegally. No changes are expected in this regime, since a significant portion of willow plantations, especially in the peripheral areas, would be left for people to utilise.

Therefore, (**Ch1**) = ₹0.0

4.1.7. Local Business and Industry Benefits (Bi)

Benefits (Bi)

Bi_1: Increased incomes from Recreational Tourism

The results of our questionnaire survey indicate that less than 1% tourists travelling to Kashmir actually visit/know about Wular Lake. While the handful of tourists who visited the lake were mesmerised by the landscape, most of them complained of the lack of recreational facilities. There is no benefit derived from the recreational activities at present.

Therefore, (Bi1) = ₹0.00

4.1.7. Local Business and Industry Costs (Ci)

Loss of income to willow based industries (Ci_1)

No major industries are dependent on wood from Wular. The wood is not of desired quality for commercial purposes, such as the bat industry. However, logs of willow are used for construction. Apart from this, there is no commercial application and hence there will be no loss of income for willow based industries. Wood from the willow plantations here is mainly used as fuel wood.

Therefore, (Ci_1)= ₹0.0

4.2. Analysis

Benefit and cost flows are estimated considering three scenarios: Scenario S1 represents the revised plan of removing willows from the lake; Scenario S2 is the original plan and Scenarios B1 and B2, are business as usual scenarios corresponding to S1 and S2. Given that the planned project is yet to be implemented

*In our calculations, we have provided only the additional income potentially generated if either scenario 1 or scenario 2 is implemented, which is on top of the business as usual. It is important to mention that in scenario 2, dredging @1.5m is proposed for area under willow (7.47 sq km) and @ 0.75m in critically silted areas (20.25 sq km). The figures for scenario 2 have been calculated for dredged area under willow, which can potentially be colonised by trapa

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Table 20: Estimates of Annual Flow of Benefits and Costs per year (₹ Million) for four years

			Value /yr in Million ₹	
Stakeholder Government (Forests, Rakhs and farms)		Code	Scenario 1 (revised plan)	Scenario 2 (Original plan)
Benefits				
	Onetime benefit of selling Removed Willow	Bg1	142.429	555.47
	Increased Revenue from Selling Fishing Rights	Bg2	0	0
	Increased Supply of Hydro Power	Bg3	69.6	1296.1
	Increase in revenue to government from sale of aquatic vegetation	Bg4	0	0
	Benefits from sale of silt	Bg5	0	0
Costs				
	Recurring loss of revenue from harvesting willows for commercial wood and fuel wood	Cg1	0	0.95
	Cost of De silting of Lake	Cg2	53.75	840
General Public				
Benefits				
	Recreation (User Benefits)	Bp1	0	0
	Damages from Floods Avoided	Bp2	1050	1050
Costs				
	Loss of Carbon Sequestration Benefits	Cp1	8.088	31.54
Local households				
Benefits				
	Increased Fish Production	Bh1	3.1	41.17
	Increased Supply of Water for Irrigation and Household Uses	Bh2	0	0
	Aquatic Vegetation Harvesting	Bh3	5.6	25.7
Costs				
	Loss of Fuel Wood, Fodder and Manure	Ch1	0	0
Local Business and Industry				
Benefits				
	Increased Incomes from Recreational Tourism	Bi1	0	0
	Overall regional Economy Redistribution Benefits	Bi2	0	0
Costs				
	Loss of Income to Willow Wood Based	Ci1	0	0
	Industries			

fully, willow removal is considered a one-time activity in estimating benefit and cost flows. In the case of ex post evaluation, willow removal activity may have been actually observed during the initial three or five years and could have been considered in estimation. Ideally, estimation of loss of carbon sequestration benefits in scenarios of willow removal or gain in benefits in the scenarios of business as usual have to be estimated, factoring the growth of biomass of willows during the 50 or 100 year period considered in estimation. This requires precise information about biomass growth of willow plants over time, which could be incorporated in any future detailed study of Wular Lake conservation.

The benefits of ecological conservation will be spread over a much longer period than the benefits of general investment projects. Investment projects with ecological objectives must therefore be evaluated at relatively lower discount rates in order to compete with development projects

We do not anticipate large scale effects on the lake's ecology that would hamper its natural processes, but there could be insignificant changes in user or recreational and non-user benefits of the lake. In this study, we are not attempting an ecological modeling of Wular Lake that considers various conservation strategies, including dredging, willow removal, agricultural and fisheries development, hydropower etc. In the context of ecological modeling, dynamic optimisation techniques could be used to consider the trade off between ecological services and development benefits that the lake provides and to obtain shadow prices of these services. Alternatively this problem may also be studied using game theory models for identifying strategies of various stakeholders to maximise their individual benefits. This may help us know the benefits of co-operation in relation to free riding or non-cooperation of stakeholders.

However, these models are not relevant when we are considering only one intervention, i.e. willow removal for lake conservation. In this study, we are evaluating only a marginal project of willow removal from the lake, for which a cost-benefit analysis is the right methodology. Normally, the methodology of cost-benefit analysis is used for evaluating marginal projects, which consider that shadow prices, inputs and outputs, and the rate of discount are given parameters, unaffected by the project. For inputs and outputs for which markets exist (examples are fuel wood, hydropower, fisheries and agriculture in the current case) the shadow prices are market prices. However, for goods and services for which markets do not exist (examples are carbon sequestration. flood control and recreational benefits in the current case), shadow prices have to be estimated, using specially designed methodologies.

There is uncertainty in the application of rates of discount in environmental projects (Guth 2009). In the context of social cost-benefit analysis, the discount rate used to estimate the present value of benefits and costs is social time preference, which could be lower than the market rate of interest. However, for the evaluation of investment projects for the conservation of ecological resources (conservations of rivers and lakes, forests and soil), it is observed that the rate of discount used should be less than the rate used for the evaluation of general investment projects. If the rate of discount used for general public investment projects is 10-12%, it could be 6-8% for public investment projects for ecological conservation. The argument is that the benefits of ecological conservation like lake or river conservation will be spread over a much longer periods (say 100 years or more), while the benefits of general investment projects such as steel plants, thermal power projects etc. accrue during a much shorter period (say 25-50 years). Therefore, in a scenario of choice of investment projects with budgetary constraints, ecological conservation projects do not compete with general investment projects at 10-12% rates of discount. Therefore,

Table 21: Net Present Value (NPV) of Removing Willows in Alternative Scenarios (₹ million at current prices).

Rate of Discount	Lifetime (100 yrs)		Lifetime (50 yrs)	
	Scenario 1	Scenario 2	Scenario 1	Scenario 2
0.05	23993.96	41637.9	22069.4	38298.19
0.08	15104.27	26211.2	14788	25664
0.10	12088.03	20976.98	11985.9	20799.7
0.12	10073.9	17481.8	10039.2	17421.6

Notes: *Scenario1: Revised Plan, Scenario 2: Original Plan* investment projects for achieving ecological objectives have to be evaluated at relatively lower rates of discount, so that they may compete with development projects.

Table 21 provides estimates of net present value (NPV) of benefits of willow removal, considering different scenarios and 100 years of benefits and costs in the future for different rates of discount. The business as usual scenario B has only carbon sequestration benefits from willows, while willow removal could provide a variety of benefits described in table 4.2, providing estimates of cost-benefit flows. Irrespective of rates of discount used, the NPV of willow removal under two scenarios considered are substantial, in comparison to business as usual scenario (B). At an 8% rate of discount, the NPV in the revised plan scenario (S1) is ₹15,104.27 million, while the NPV of the original plan scenario (S2) is ₹26,211.2 million. The NPV is very sensitive with respect to rate of discount. The NPV of scenario S1 falls from ₹23,993.96 to 10,073.97 million, as the rate of discount decreases from 12% to 5%. This result explains that a conservation project having a spread of benefits for a longer period of 100 years (into the distant future) could not compete with a development project that mainly yields benefits in the very near future, at higher rates of discount. Table 4.3 also provides similar results, if we consider a future of only 50 years of benefits from willow removal. As expected, there is no significant difference between estimates of NPV for 100 years of benefits and 50 years of benefits at a higher rate of discount of 12%. However, there is significant difference between these estimates at a lower rate of discount of 5%. Also, as expected, Scenario 2, representing the original plan, has very high NPV (₹26,211.2 million) in comparison to Scenario 1, describing the amended plan (₹15,104.27 million) at an 8% rate of discount.

4.3. Conclusion

There is clear evidence to suggest that willow removal and the accompanying dredging of Wular Lake provides substantial benefits to various stakeholders, especially in the form of revenue to the government from cut willows, and increased hydropower supply due to increased water holding capacity of the lake. The general public gets flood control benefits, while households get benefits from harvesting increased aquatic vegetation and fish. The benefits to various stakeholders exceed the costs, in terms of loss in carbon sequestration benefits and increased cost of dredging the lake. The net present value of benefits from willow removal and dredging of the lake are very high, even with higher rates of discount. At a moderate rate of discount of 8%, the net present value of the project as per the original plan is estimated as ₹15104.27 million, suggesting that the project is worth completing.

This is despite the fact that this study did not take into account several ecological impacts, which might be detrimental to the lake. For instance, clearing the lake of the willows will increase the exposed surface of the lake, increasing evapo-transpiration, and hence water loss. The open areas can also encourage expansion of the invasive alligator weed (Masoodi et al. 2013), the removal of which will require financial expenditure. Alligator weed forms large floating islands in the lake and reproduces. Floating mats of Alligator weed can cover water bodies, restricting human use and interfering with the ecology. Prolific growth restricts flow, increases sedimentation and aggravates flooding by acting as a barrier and collecting debris. It also provides habitat for mosquitoes. Floating mats of Alligator weed crowd and compete with native aquatic species, restrict light penetration and ultimately cause anoxic or anaerobic conditions. It can affect hydroelectric power production, impede fishing, and degrade wetland aesthetics.

Siltation, especially near the ingress of Jhelum, has formed deltas and shoals, on which willows have been planted. Thus, these willows occupy critical areas and their removal along with their rootstock paves the way for dredging/excavation work. Removal of shoals will help the lake by improving water flows, so that the

There is clear evidence to suggest that willow removal and the accompanying dredging of Wular Lake provides substantial benefits to various stakeholders. Benefits include government revenue, flood control, and increased hydropower, vegetation and fish

It is imperative that a robust impact assessment is undertaken before any restoration works are carried out inside Wular. This is especially true for major dredging activities, as the ecological consequences of such actions must be understood

inflow will be higher. Further, dredging from critical areas (outside the plantation areas), as envisaged in the revised plan, will increase the water holding capacity of the lake.

This will help increase water availability for power generation downstream, but more importantly, capacity to absorb water during excess rains, saving significant flood related costs. Augmenting the lake holding capacity is important for flood control measures planned by the government. During the recent floods, the discharge was 122,000 cusecs. The Jhelum has a peak discharge capacity of 35,000 cusecs, whereas the existing flood channel has a capacity of 12,000 cusecs, giving it a combined capacity of about 50,000 cusecs. Given that the recent floods were perhaps a once in a century phenomenon, by augmenting the discharge capacity by 30%, either through restoration dredging of the river or the flood channel, the additional capacity created in Wular Lake will allow it to absorb this increased discharge.

It is learnt that two other works related to desilting in the waterways in Kashmir are underway, linked to river Jhelum, at both the upstream and downstream sites. This is in addition to the work already ongoing in Wular Lake. However, it is important to realise that dredging must be carried out in prescribed areas to maximise impact and minimise ecological damage and such interventions must be undertaken only after robust Environmental Impact Assessments.

The removal of trees will also give the Forest Department a one-time income of over 50 crore in four years. We feel that this amount should be ploughed back into lake conservation, since the direct cost of removal is a loss of CO_2 sequestration, which will become quite significant over time.

Increase in the lake volume will also benefit the locals through higher production of fish and vegetation produce, which are extracted by the local communities and form a large part of their livelihoods.

One major fact that arose was the low recreational value of the lake. Kashmir being a state dependent heavily on tourism, low tourist turnout in and around Wular was surprising. There could be several factors contributing to this a) the Dal lake in Srinagar takes all the tourist load and people do not feel the need to visit another water body b) Its distance from Srinagar means that a tourist must spend one day traveling, out of an already tight itinerary, which is difficult c) The periods of strife have made tourists stick to safer and more frequently visited locations d) Lack of infrastructure and recreational facilities also discourages tourists from coming. A few hotels constructed recently on the banks of Wular have had encouraging responses from tourists. We feel that with the opening of the Gurez valley, tourists will come to Wular, provided appropriate facilities exist. The need for an interpretation centre somewhere around Wular, emphasising the importance of Wular and the surrounding areas, will go a long way in spreading awareness about the importance of the area amongst tourists.

We felt that the removal of willows would not affect biodiversity significantly. We are unable to assess the impact of its removal on micro-fauna. There will be very little impact on avifauna using the willows since a) no uncommon or threatened species was found to use the plantations and willows still abound in the area b) open areas, resulting from willow removal, would provide more habitat for ducks (both dabbling and diving).

Therefore, work must be intensified under the revised plan to ensure that it is carried out in a timely fashion. The creation of Wular Conservation and Management Authority is an important step and needs to be strengthened on the lines suggested by the CMAP (WI, 2007), for only then can the lake be conserved and developed along sound scientific lines, since one of the mandates of the WUCMA is to integrate inputs from various agencies having stakes in the lake. It is imperative that a robust impact assessment is undertaken before any restoration works are carried out inside Wular. This is especially true for major dredging activities (envisaged in conjunction with the new spill channel to increase capacity of the lake), for the ecological consequences of such actions must be understood.

REFERENCES

- Aronsson, P., and Perttu, K. (2001). Willow vegetation filters for wastewater treatment and soil remediation combined with biomass production. *The Forestry Chronicle, 77*(2), 293-299.
- Ather Masoodi, Anand Sengupta, Fareed A. Khan, Gyan P. Sharma (2013). Predicting The spread of alligator weed (*Alternanthera philoxeroides*) in Wular Lake, India: a mathematical approach. *Ecological Modelling* 263, 119-125.
- Ather Masoodi and Fareed A. Khan (2012). Invasion of an alien species *Alternanthera philoxeroides* in Wular Lake, Kashmir, India. *Aquatic Invasions* 7(1):143-146.
- Ather Masoodi and Fareed A. Khan (2012). A new record to the invasive alien Flora of India-*Azolla cristata. National Academy Science Letters* 35 (6):493-495.
- Baba AI, Pandit, A.K. (2014) Species Composition, Diversity and Population Dyanamics of Phytoplankton at Saderkot in Wular Lake, Kashmir. *J Ecosys Ecograph* 4: 142. doi:10.4172/2157-7625.1000142.
- Bhatt and Pandit (2015) Surface Water Quality Assessment of Wular Lake, A Ramsar Site in Kashmir Himalaya, Using Discriminant Analysis and WQI. *Journal of Ecosystems* Volume 2014, Article ID 724728, 18 pages http://dx.doi.org/10.1155/2014/724728 (Accessed on 25 May 2015).
- Burbank D. W, et al. (1996) Bedrock incision rock uplift and threshold hillslopes in The northeastern Himalaya. *Nature*, 379 p505-510.
- Burchfiel, B.C., Chen, Z. Hodges, K.V., Liu, Y., Royden, L. H., Deng, C. And Xu, J. (1992). The south Tibetan detachment system, Himalayan orogen: Extension contemporaneous with and parallel to shortening in a collisional mountain belt. *Geol. Soc. Amer. Spec. Paper,* 269: 1-44.
- Christersson, L., Sennerby-Forsse, L., & Zsuffa, L. (1993). The role and significance Of woody biomass plantations in Swedish agriculture. *The Forestry Chronicle, 69* (6), 687-693.
- Ebbs, S., Bushey, J., Poston, S., Kosma, D., Samiotakis, M., &Dzombak, D. (2003). Transport and metabolism of free cyanide and iron cyanide complexes by willow. *Plant, Cell & Environment, 26*(9), 1467-1478.
- Gray, D. H. and Sotir, R. B.: 1996, *Biotechnical and Soil Bioengineering Slope Stabilization*, Wiley, New York, p. 271.
- Guth, J.H. 2009. Resolving the Paradoxes of Discounting in Environmental Decisions. *Transnational law and Contemporary Problems.* Vol 18:95. 95-114.
- Hassan, Zahoorul, Shah JA, Kanth TA and Pandit AK. (2015) Influence of land use/land cover on the water chemistry of Wular Lake in Kashmir Himalaya (India). *Ecological Processes (2015) 4:9 DOI 10.1186/s13717-015-0035-z*
- Islam, Z. and Rahmani, A.R. (2004). *Important Bird Areas of India. Priority Sites for Conservation.* Indian Bird Conservation network, Bombay Natural History Society and Bird Life International.
- Klang-Westin, E., & Eriksson, J. (2003). Potential of Salix as phytoextractor for Cd on moderately contaminated soils. *Plant and soil, 249* (1), 127-137.
- Kulkarni, U. D and Khan, A. 2014. Environmental hazards due to rate of siltation in the Wular Lake (Jammu and Kashmir), India. *International Journal of Recent Trends in Science and Technology,* August 2014. 12(1): 38-46. (http:/ www.stateperson.com accessed on 25/5 2015).
- Kuzovkina, Y. A., Knee, M., & Quigley, M. F. (2004). Cadmium and copper uptake And translocation in five willow (Salix L.) species. *International Journal of Phytoremediation, 6*(3), 269-287.
- Loke, W.T.(1946). A Bird Photographer in Kashmir. *J Bombay Nat Hist. Soc.* 46:431- 436.
- Masoodi, A., Sengupta, A., Khan, FA., Sharma, GP. (2013). Predicting The spread of alligator weed (Alternantheraphiloxeroides) in Wular Lake, India: a mathematical approach. Ecological Modelling263, 119-125.
- Masoodi. A., Khan, FA. (2012a). Invasion of an alien species Alternantheraphiloxeroidesin Wular Lake, Kashmir, India. Aquatic Invasions 7(1):143-146.
- Masoodi. A., Fareed. AK. (2012b). A new record to the invasive alien Flora of India-Azollacristata. National Academy Science Letters 35 (6):493-495.
- Shah, J.A. and Pandit A.K. (2013) Diversity and Abundance of Cladoceran Zooplankton in Wular Lake, Kashmir. *Research Journal of Environmental and Earth Sciences* 5(7):410-417, 2013.
- Wanganeo, A, Mir A. R., Yousuf, A.R., and Wanganeo, R. (2006) Fisheries Status of River Jhelum towards the confluence of River Indus (Wular Lake). *In Fisheries and Aquaculture in Indus River Basin* (Ed. MPS Kohili) pp-80-86. Indian Society of Fisheries, Mumbai.
- Wetland International (2007) *Comprehensive Management Action Plan for Wular Lake, Kashmir.* Final Report. Wetlands Intrnational-South Asia.
- Wilkinson, A. G. (1999). Poplars and willows for soil erosion control in New Zealand. *Biomass and Bioenergy,* 16(4), 263-274.

ANNEX 1

List of macrophytes recorded in the lake (Masoodi et al 2013).

Plant Species	Family	Growth habit
Alisma plantago-aquatica L.	Alismataceae	Emergent
Alternanthera philoxeroides(Mart.) Griseb.	Amaranthaceae	Emergent
Azolla cristata Kaulf.	Azollaceae	Free floating
Bidens cernua L.	Asteraceae	Emergent
Ceratophyllum demersum L.	Ceratophyllaceae	Submerged
Echinochloa crus-galli Beauv.	Poaceae	Emergent
Hydrilla verticillata Royle	Hydrocharitaceae	Submerged
Hydrocharis dubia Backer	Hydrocharitaceae	Free floating
Lemna minor L.	Lemnaceae	Free floating
Lycopus europaeus L.	Lamiaceae	Emergent
Marsilea quadrifolia L.	Marsileaceae	Rooted floating
Myriophyllum spicatum L.	Haloragaceae	Submerged
Myriophyllum verticillatum L.	Haloragaceae	Emergent
Nelumbo nucifera Gaertn.	Nelumbonaceae	Rooted floating
Nymphaea tetragona Georgi.	Nympheaceae	Rooted floating
Nymphea alba L.	Nympheaceae	Rooted floating
Nymphoiodes peltatum Kuntze.	Menyanthaceae	Rooted floating
Phragmites australis Trin.	Poaceae	Emergent
Polygonum amphibium L.	Polygonaceae	Emergent
Potomogeton crispus L.	Potamogetonaceae	Submerged
Potomogeton lucens L.	Potamogetonaceae	Submerged
Potomogeton natans L.	Potamogetonaceae	Rooted floating
Potomogeton pectinatus L.	Potamogetonaceae	Submerged
Potomogeton pusillus L.	Potamogetonaceae	Submerged
Sagittaria sagittifolia L.	Alismataceae	Emergent
Salvinia natans All.	Salviniaceae	Free floating
Scirpus lacustris	Cyperaceae	Emergent
Sparganium ramosum Huds.	Sparganiaceae	Emergent
Spirodela polyrhiza Schleid.	Lemnaceae	Free floating
Trapa natans L.	Trapaceae	Rooted floating
Typha angustifolia L.	Typhaeceae	Emergent
Vallisneria spiralisL.	Hydrocharitaceae	Submerged
Veronica anagallis-aquatica L.		Scrophulariaceae

ANNEX 2 List of birds occurring in the Salix plantation and open waters or Wular Lake

Common name	Scientific Name	Location
Ashy Drongo	*Dicrurus leucophaeus*	W, O
Asiatic Paradise Flycatcher	*Terpsiphone paradist*	W
Barn Swallow	*Hirundo rustica*	W, O
Black Bellied Tern	*Sterna acuticauda*	O
Black crowned Night Heron	*Nycticorax nycticorax*	W
Black Kite	*Milvus migrans*	W, O
Blue Whisteling Thrush	*Myophonus caeruleus*	W
Bronze Winged Jaccana	*Metopidius indicus*	O
Brown Dipper	*Cinclus pallasi*	W, O
Collared Kingfisher	*Todirhamphus chloris*	W
Common Coot	*Fulica atra*	O
Common Hoopoe	*Upupa epops*	W
Common Kingfisher	*Alceodo atthis*	W
Common Moorhen	*Gallinula chloropus*	W, O
Common Myna	*Acridotheres tristis*	W
Common Pochard	*Aythya ferina*	O
Common Sandpiper	*Tringa hypolleucos*	W, O
Common Starling	*Sturnus vulgaris*	W
Common Teal	*Anas crecca*	O
Eurasian Collared Dove	*Streptopelia decaocto*	W
Eurasian Cuckoo	*Cuculus canorus*	W
Eurasian Golden Oriole	*Oriolus oriolus*	W
European Gold finch	*Carduelis carduelis*	W
European Roller	*Coracias garrulus*	W
Great Tit	*Parus major*	W

Common name	Scientific Name	Location
Grey Heron	*Ardea cinerea*	W, O
Grey Wagtail	*Motacilla cinerea*	W
Himalayan Bulbul	*Pycnonotus leucogenys*	W
Himalayan Woodpecker	*Dendrocopos himalayensis*	W
House Crow	*Corvus splendens*	W
House Sparow	*Passer domesticus*	W
Large Billed Crow	*Corvus macrorhynchos*	W
Lesser Pied Kingfisher	*Ceryle rudis*	W, O
Little Egret	*Egretta garzetta*	W, O
Little Grebe	*Tachybaptus ruficollis*	O
Long tailed Minivet	*Pericrocotus ethologus*	W
Long tailed shrike	*Lanius schach*	W
Mallard	*Anas platyrhynchos*	O
Pheasant tailed jaccana	*Hydrophasianus chirurgus*	O
Pond Heron	*Ardeola grayii*	W, O
Reed Warbler	*Acrocephalus scirpaceus*	O
Rock Pigeon	*Columba livia*	W
Ruddy Shelduck	*Tadorna ferruginea*	O
Scaly Bellied Woodpecker	*Picus squamatus*	W
Tickells Thrush	*Turdus unicolor*	W
Verditer Flycatcher	*Eumyias thalassinus*	W
White Breasted Kingfisher	*Halcyon smymensis*	W, O

India a biodiversity hotspot

India is one of the megadiverse countries in the world. It faces unique circumstances as well as challenges in the conservation of its rich biological heritage. With only 2.4% of the world's geographical area, her 1.2 billion people coexist with over 47,000 species of plants and 91,000 species of animals. Several among them are the keystone and charismatic species. In addition, the country supports up to one-sixth of the world's livestock population. The rapid growth of her vibrant economy, as well as conserving natural capital, are both essential to maintaining ecosystem services that support human well-being and prosperity.

To demonstrate her empathy, love and reverence for all forms of life, India has set aside 4.89% of the geographical space as Protected Areas Network. India believes in "वसुधैव कुटुम्बकम" i.e. "the world is one family".

Supported by

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