Open Journal of Modern Hydrology, 2024, 14, 193-212
https://www.scirp.org/journal/ojmh
ISSN Online: 2163-0496
ISSN Print: 2163-0461

The 30th Anniversary of the Hula Reclamation Project: Profitable Agricultural Management Not Threatening Kinneret Water Quality

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How to cite this paper: Gophen, M. (2024) The 30th Anniversary of the Hula Reclamation Project: Profitable Agricultural Management Not Threatening Kinneret Water Quality. *Open Journal of Modern Hydrology*, **14**, 193-212.
https://doi.org/10.4236/ojmh.2024.144011

Received: August 11, 2024
Accepted: October 27, 2024
Published: October 30, 2024

Abstract

Until 1957, the Hula Valley was covered by swampy wetlands and a shallow lake, Lake Hula. In the 1950s, the valley was drained and 6000 ha of land was converted to agricultural development. Seven years later, the National Water Carrier was inaugurated, granting the only natural freshwater lake in Israel, Kinneret, a national drinking water reservoir function. Agricultural cultivation in the Hula Valley faced significant challenges. A reclamation project, the "Hula Project" (HP), was implemented. Thirty (1994-2024) years of HP management are summarized. TP and TN migration data from the Hula Valley southward into Lake Kinneret was approved as not threatening its water quality. During 40 years of post-drainage period underground fire, heavy dust storms were frequently followed by soil subsidence. Nevertheless, as a result of the HP renovated management, those nuisances faded away and significantly declined. Immediately after drainage, as a result of organic Peat oxidation, a great stock of nitrates in the upper layers was formed. Since the mid-1990s, when nitrogen deficiency was developed and Cyanobacteria replaced the bloom-forming *Peridinium* dominancy, surplus nitrate input has not threatened Kinneret water quality. The hydrological-eco-touristic component of the reclamation project (HP), Lake Agmon-Hula (LAH) became a successful tourist attraction and also an additional nutrient source through submerged vegetation. Two Peat soil areas of land have been denied: the central and the eastern blocks. Soil moisture enhancement, especially that of the Peat soil block, initiated the lowering of the TP migration range and consequently extra water allocation was assigned for summer irrigation (the "Peat Convention Agreement"). Surface, underground seepage and river discharge flows of freshwaters from the Golan Heights into the Hula valley diluted the concentration of migrated TP concentration contributed by the eastern Peat block.

Keywords

Hula Valley, Drainage, Reclamation Project, TP, TN

1. Introduction

Between 1950 and 1960, two mega eco-engineering projects were implemented in northern Israel: The drainage of the Hula Valley and the construction of the National Water Carrier (NWC) [1]-[3]. Twenty-four years earlier, the south dam of Lake Kinneret was completed, making human control of the lake Water level (WL). The Hula drainage demolished a natural, highly diversified flora and fauna [4]. The two projects were defined as national achievements: the creation of agricultural land whilst the NWC construction to ensure freshwater supply from Lake Kinneret for agriculture and domestic utilization (including drinking) to the central-southern parts of the country. Hula Valley and Lake Kinneret are two compartments of northern eco-hydrological ecosystems within the Syrian-African Great Rift Valley: Three northern major Headwaters and other smaller rivers joined creating the Jordan River [5], further combined with other rivers flows from the Golan Heights on the east side of the valley into Lake Kinneret. The surface area of the drainage basin of Lake Kinneret is 2730 km^2, of which 200 km^2 of the Hula Valley (7.3%). Shortly after Hula drainage, the landowners tackled severe difficulties of the Peat soil cultivation which required specific methodological usage. Nevertheless, during 40 years, the drained area was cultivated and the agricultural products were economically produced and nutrient flux into Lake Kinneret did not thoroughly threaten its water quality. Inappropriate irrigation methods accompanied by the decline of the Ground Water Table (GWT), frequent heavy dust storms which enhanced subsidence of soil surface and blocking of drainage canals, underground fire and rodent population outbreak which damaged agricultural crops stimulated in early 1994 the initiation of a reclamation project, the Hula Project (HP). The "Hula Project" was implemented during 1994-2006 and routinely accompanied by monitoring and research programs. The construction of the Hula Project included increasing soil moisture and elevating GWT by enhancement of water allocation and changing the flood-capillary watering by mobile-line of sprinkler irrigation method; Renewing and reconstruction of 90 Km of canal system throughout the entire valley. A shallow Lake Agmon-Hula (LAH) (presently, 0.2 average depth; 82 ha surface area) was created. LAH functions as a nutrient-rich drained water collector and recreational eco-touristic site; A plastic sheet (4 mm thickness) was placed vertically (0 - 4.5 m) along 2.8 km, crossing the valley from east to west, to prevent underground nutrients from leaking southward [1]-[3]. This paper is aimed at the usage of historical past experience for future improvement. A summary of 40-year post Hula drainage plus 30 years of reclamation project followed by future implications. The Hula drainage was a national eco-agro-settlement project that gave rise to concerns about

Kinneret water quality. The follower Hula Project (HP) was implemented as a complementary. The objective of the paper is to analyze past creative actions for future improvement of management design. The HP achievements are combined within two sensitive ecosystems and conclusively summarized as a message for future management design. The HP achievements of agricultural crops improvements and Kinneret water quality protection are presented as basis for future design.

2. Material and Methods

The chemical composition and discharge of channeled surface water flows were sampled in 4 stations (Figure 1): Station 48—The entrance of reconstructed Jordan into Lake Agmon-Hula (LAH); Station 57—The entrance of Canal Z (or 101) into LAH. Canal Z collects drained waters from the major central largest Peat soil block extended throughout the central part of the HP territory. Station 73—The entrance of Hula East canal which collects drained waters from the eastern Peat block extended along the east side of the major Eastern canal (Figure 1); Station 49—The outlet of LAH effluents outflow into either Zero canal to be removed for irrigation outside the Kinneret drainage basin or Canal 312 towards lake Kinneret. A weekly sampling program was carried out between 1994 and 2024, chemical analyses were done in the Migal-analytical chemistry department and Zemach analytical chemistry laboratories and annual reports were published [6]-[10].

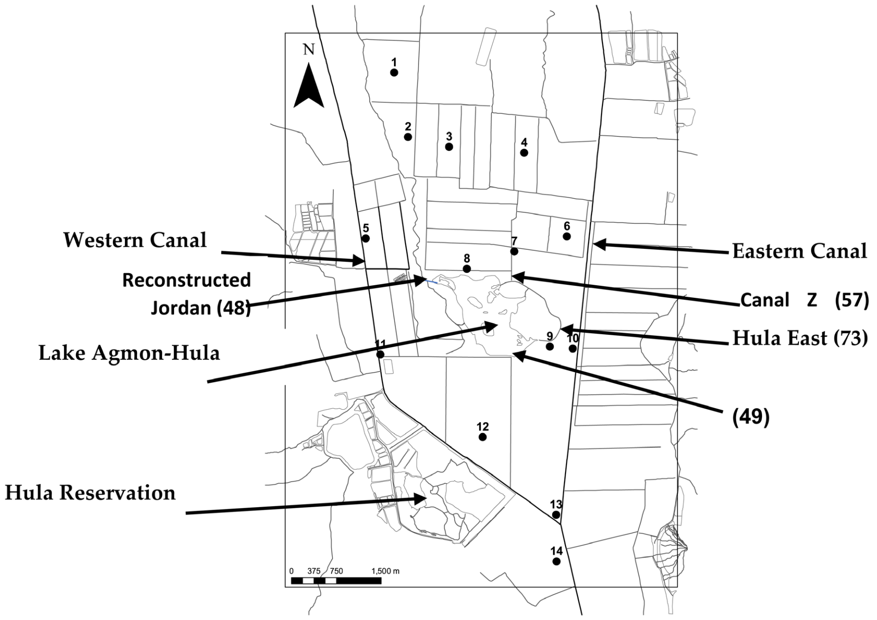

Figure 1. Ground Water Table (GWT). Depth monitor drillings (boreholes) for (numbered 1 - 14) distribution and station (48, 49, 57, 73) are indicated.

2.1. Hydrochemical and GWT Depth Monitoring

Weekly measurements of GWT depth in 14 boreholes between 1994 and 2024 were carried out. As the result of The HP management (1993-2024), an average increase throughout the entire valley of ~ 30 cm for the entire HP area (Figure 1) has been indicated.

Bi-weekly hydrological measurements were carried out manually from 2002 to 2010 (Unpublished data: H. Millard Regional Municipality Waterworks Galil Elion), and annual water inflows into LAH (10^6 m^3/y) were recorded. Combined TN and TP analyzed concentration and hydrological data resulted in periodical quantitative loads of TP, TN, and NO_3.

2.2. Statistical Methods

Statistical evaluation was done using software of STATA 17.0-Standard Edition, Statistics and Data Science, Copyright 1985-2021 StataCorp LLC, StataCorp, 4905 Lakeway Drive, 4905 Lakeway Drive, 800-STATA-PC, Stata license: Single-user perpetual, Serial number: 401706315938, Licensed to Moshe Gophen, Migal. Three Statistical methods were utilized: Quadratic regression (w/CI 95%) Linear Regression (w/CI 95%, Lowess Smoother (bandwidth 0.8)).

3. Results

3.1. Soil Subsidence

An underwater hydraulic gradient sloping from north to south was indicated, comprising a higher level of GWT in northern Hula Valley with lower fluctuations amplitude and a higher level in winter was recorded as well [11] [12].

The grand total mean of soil surface subsidence which includes all available data has indicated an average annual soil surface subsidence in the Hula Valley of 10 and 9 cm during the 1958-1964 and 1964-1965 periods, respectively. Shortly after the drainage, the rate of subsidence was higher and diminished later (>1964). Measurements carried out during the late 1990s confirmed a rate of 6 - 8 cm/year of soil surface subsidence [13]. During the post-drainage period (1958-present), as an average for the entire Hula Valley (including marl soil with a lower rate) the soil surface subsidence by approximately 4 - 5 meters. A survey carried out during 1958-1964 documented the highest soil surface altitude of 67.19 whilst presently it is around 62.00 MASL in the central part of the valley. Soil properties in the Hula Valley are very versatile, such as the content of $CaCO_3$ in the upper soil layer (0 - 16 m) in the southern part was documented as 40% - 80% and content of organic matter as 7% - 17% of the dry matter, whilst lower CaCO3 and higher organic matter content in the northern part of the valley was documented. [13]-[17]. The organic matter content in the upper 2.5 meters of the Peat soil was diminished from 75% to 10% - 20% [11] [13]-[18], whilst marl-carbonate soil in the southern part of the valley, which was covered by old Lake Hula during pre-drainage period contain 50% - 80% carbonates. Decomposition of organic matter in the peat soil enhanced underground fire. During the pre-Hula Project period (<1994), dry peat soil dust was intensively eroded by wind and consequently enhanced soil subsidence.

3.2. The Impact of HP on TN, TP and NO_3 Migration Dynamics

Averaged (1994-2024) (±SD) concentrations of TN, TP, and NO_3 in surface waters within the Hula Project territory: Canal Z, Hula East, LAH effluent, and reconstructed Jordan are given in **Table 1**.

Table 1. Averaged (1994-2024) (±SD) concentrations (ppm) (N = number of samples) of TN, TP and NO_3 in the Hula Project Territory: Canal Z (Station 57), Canal Hula-East (Station 73) LAH effluent (Station 49) and Reconstructed Jordan (Station 48).

Station	Mean-TP	Mean TN	Mean NO_3	N (TP)	N (TN)	N (NO_3)
48	0.122 (0.157)	3.846 (6.098)	2.873 (10.603)	883	883	949
49	0.265 (0.222)	6.943 (9.310)	2.763 (7.892)	556	552	472
57	0.100 (0.086)	16.421 (26.442)	9.600 (19.15)	562	561	556
73	0.133 (0.120)	5.678 (8.505)	4.578 (8.602)	354	359	357

Results given in **Table 1** indicate three TP input sources: 1) Central and Eastern blocks of Peat soil, transported into LAH through Canals "Z" and "Hula East"; 2) LAH submerged and emerged aquatic vegetation through seasonal onset and offset-decomposed processes development; 3) Within the northern part of the Kinneret drainage basin outside the Hula Valley partly transported through "reconstructed Jordan" into LAH. The concentration of TP in the LAH effluent is higher than that was measured in Canals Z and Hula East which is contributed by the Peat soil as well as in the Reconstructed Jordan which drifted outside the Hula Valley. TN contribution to the LAH water is mostly attributed to the Peat Soil as presented in Canal Z (Station 57) of which the highest TN concentration was measured. The internal LAH`s contribution to TN is reduced as a result of the denitrification and sedimentation of particulate matter processes. A vast stock of Nitrogen is stored in the Peat as a residue of the pre-Hula drainage vegetation. This vast Nitrogen stock is under accelerated oxidation impact and transformed to Nitrate (NO_3) which is weakly bounded to organic particles and migrates into drained waters as confirmed by its highest concentration presented in **Table 1**. The three LAH inflows, Canals Z and Hula East and Constructed Jordan also convey water with a lower TP concentration than that of the LAH effluent. Consequently, future management design might consider disconnection between LAH and Lake Kinneret and a direct connection between Canal Z and Canal 312 forwarded into the major western Canal and Lake Kinneret. It will reduce the Phosphorus migration regime into Lake Kinneret. Water supply to LAH could be compensated by increased allocation of Jordan water whereas lowering of LAH WL is predictable which will probably enhance bird nesting. The HP`s research, and mostly, the documented record of nutrient dynamics during 30 years, confirmed LAH as an environmental nuisance that contributes to pollutant loads (mostly TP) that originated from the submerged vegetation whilst enhancing touristic attractivity. The significant success of LAH as a major attraction element of tourism is undoubted.

The following **Figures 2-5** present the temporal (1994-2024) fluctuations of TN concentrations (Quadratic Prediction w/95%Cl) in 4 studied stations in the land of the HP: Reconstructed Jordan (48), Canal Z (57), Hula East (73) and the LAH effluent (49).

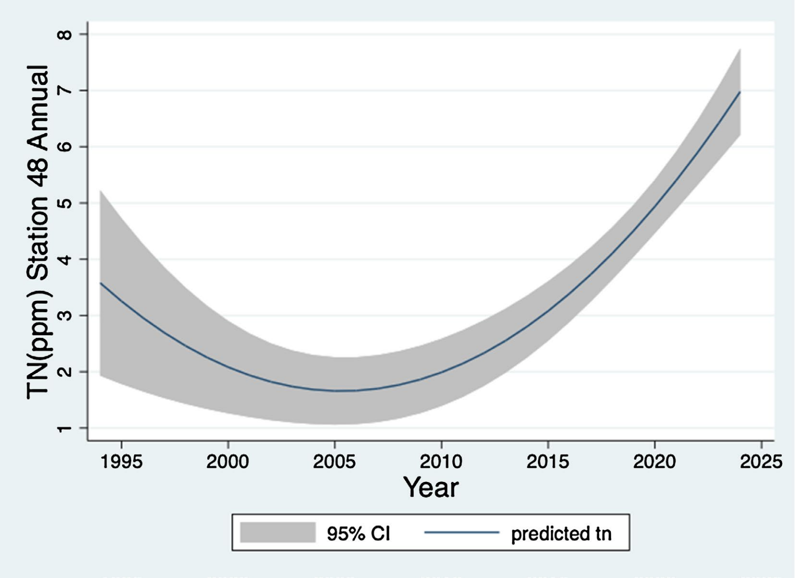

Figure 2. Station 48, temporal (1994-2024) changes of Annual means of TN concentrations (ppm).

Results indicate a decline during 1994-2005 probably with respect to rainfall and river discharge decline and the consequent decline of erosion capabilities outside the Hula Valley whilst vice versa later on (2005-2024).

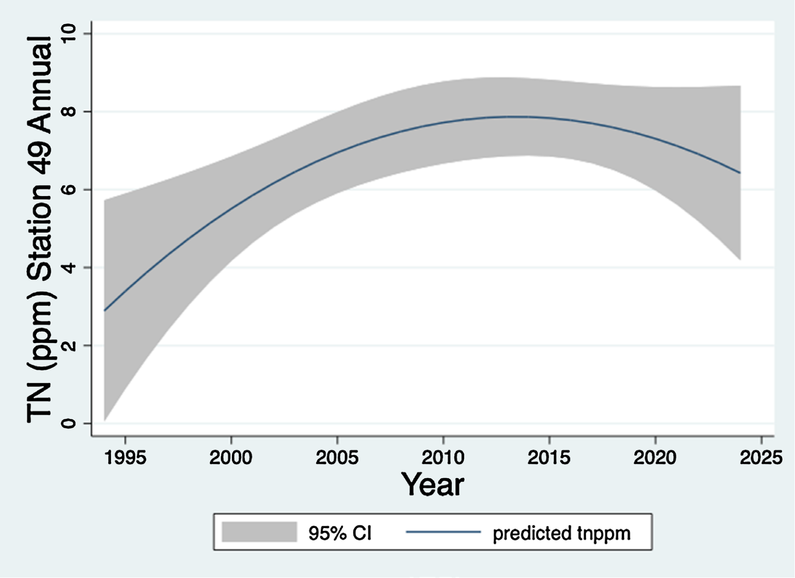

Figure 3. Station 49, temporal (1994-2024) changes of annual means of TN concentrations (ppm).

Results indicate a slight decline during 1994-2010 and a slight decline later on (2005-2024). The elevation of Nitrogen within the LAH effluent is probably due to the enhancement of submerged vascular plants' mass production and decomposition later. The hypsometrical reduction (surface area and volume) of LAH and the utilization of LAH as a roost for 30,000 - 55,000 stopover migrated Cranes (Grus grus) were followed by a slight deprived oxygen level decline (partial anoxia) and denitrification enhancement.

Results in Figure 4 indicate concentration stability due to the vast storage of Nitrogen in the peat soil. This Nitrogen is stored mostly as Nitrate which efficiently drifts into drained water and migrates through Canal Z (57).

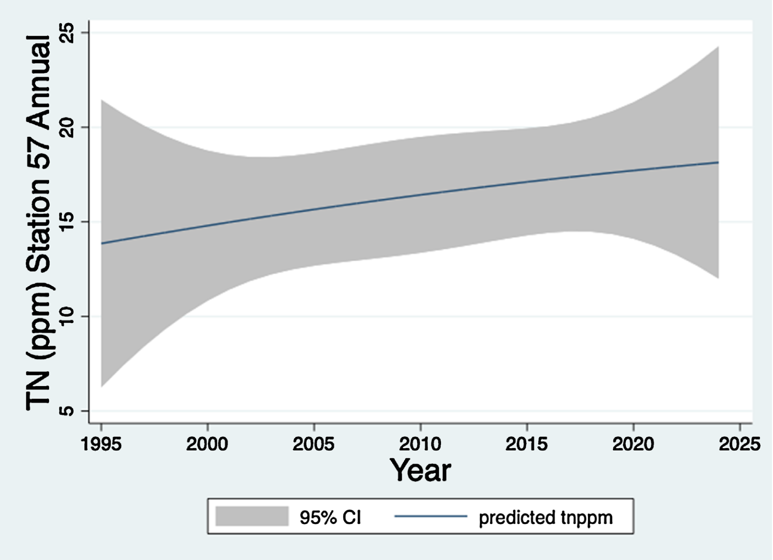

Figure 4. Station 57, temporal (1994-2024) changes of annual means of TN concentrations (ppm).

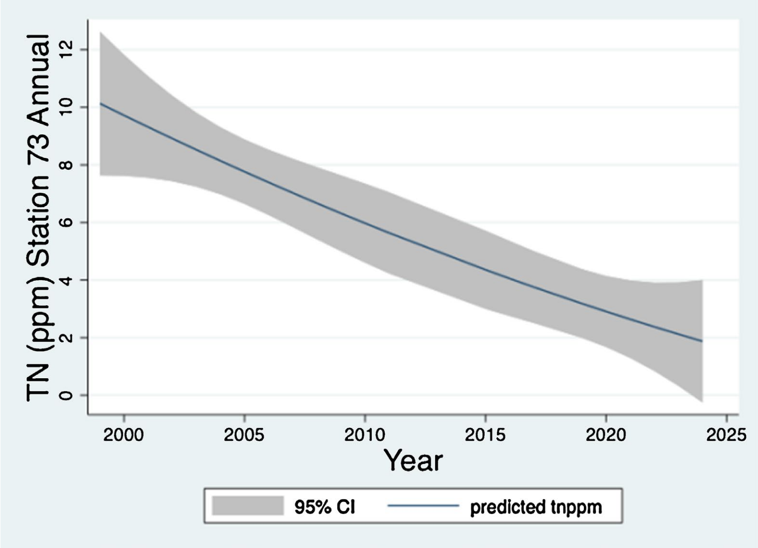

Figure 5. Station 73, temporal (1994-2024) changes of annual means of TN concentrations (ppm).

Results indicate a significant decline in TN concentration in the Hula East Canal waters. This decline is probably a result of dilution enhanced by east-west directed freshwater flows of river discharge, surface runoffs and seepage penetration from the Golan Heights into the Hula Valley.

The following Figures 5-8 present the temporal (1994-2024) fluctuations of TP concentrations (Quadratic Prediction w/95%Cl) in the 4 studied stations within the land of the HP: Reconstructed Jordan (48), Canal Z (57), Hula East (73) and the LAH effluent (49).

Since most of the TP content in the Jordan waters originates outside the Hula

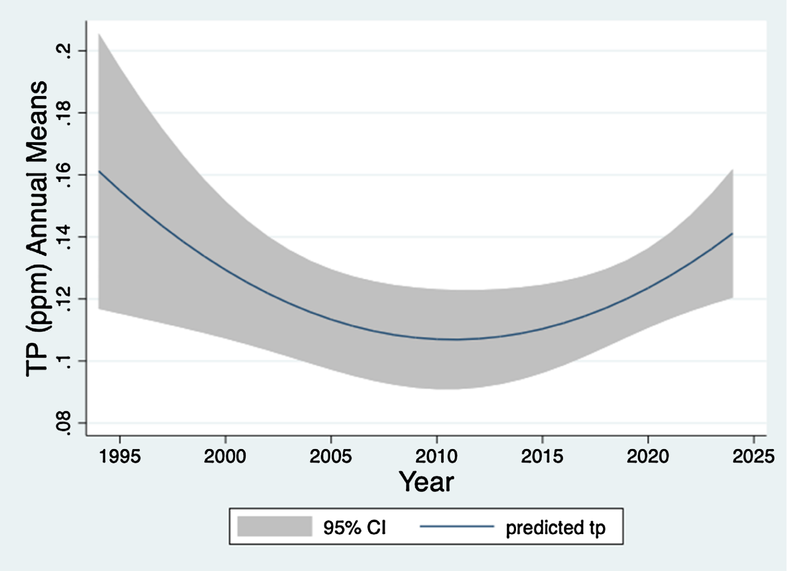

Figure 6. Station 48, temporal (1994-2024) changes of annual means of TP concentrations (ppm).

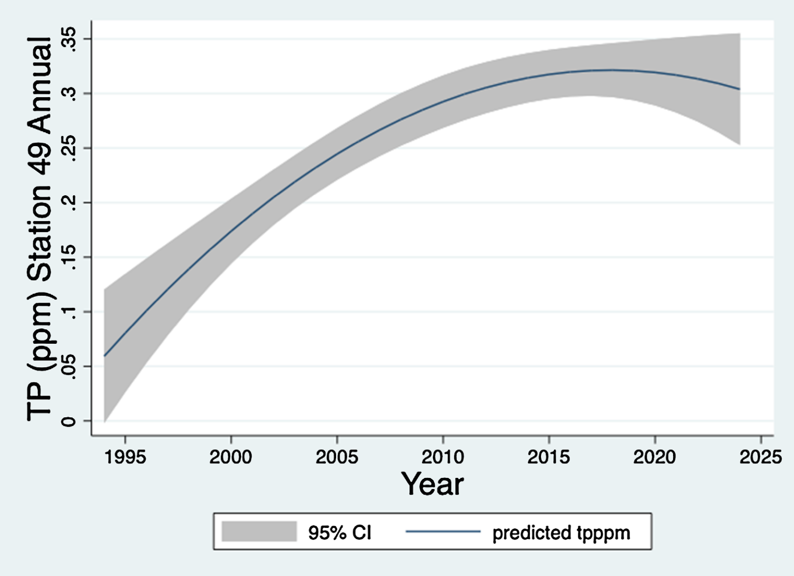

Figure 7. Station 49, temporal (1994-2024) changes of annual means of TP concentrations (ppm).

Valley the temporal changes reflect climatological fluctuations of rainfall and river discharge capacities forming erosion changes.

Results in **Figure 7** indicate a continuous increase of TP concentration within the LAH effluent which significantly reflects the enhancement of the decomposition of aquatic vegetation biomass. Moreover, since 2010, the LAH surface area and volume were significantly reduced, and consequently, the vegetation biomass was depleted.

The results presented in **Figure 8** are similar to those given in **Figure 5**. Similarity in the dilution effect of the Golan Heights freshwaters east-west

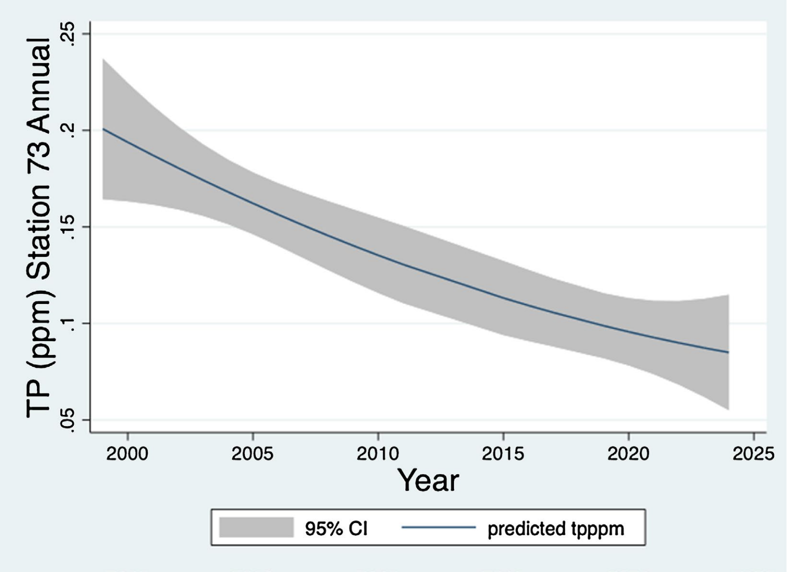

Figure 8. Station 73, temporal (1994-2024) changes of annual means of TP concentrations (ppm).

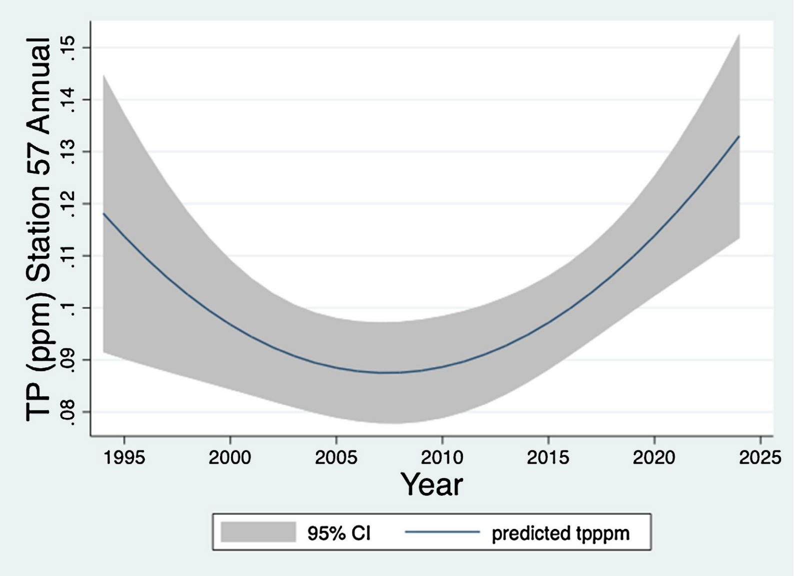

Figure 9. Station 57, temporal (1994-2024) changes of annual means of TP concentrations (ppm).

directed migration is suggested.

TP concentration in Canal Z which collects drained water from the Central Valley Peat soil block represents a decline from 1994 to 2005 and an increase later. The bound of phosphorous substances and Peat soil organic particles is moisture dependent: the higher the moisture the stronger the bound and the lesser it drifted into the drained waters.

The following Figures 10-13 present the temporal (1994-2024) fluctuations of Nitrate (NO_3) concentrations (Quadratic Prediction w/95%Cl) in the 4 studied stations within the HP area: Reconstructed Jordan (48), Canal Z (57), Hula East

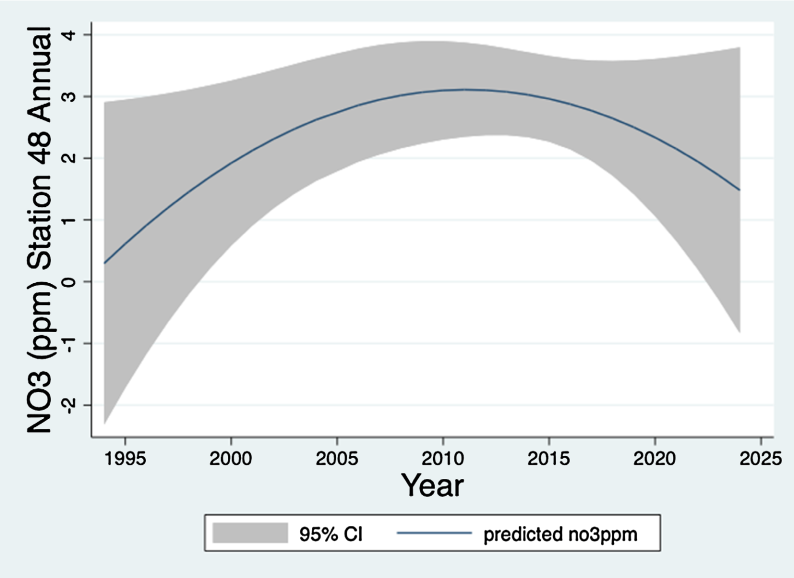

Figure 10. Station 48, temporal (1994-2024) changes of annual means of NO_3 concentrations (ppm).

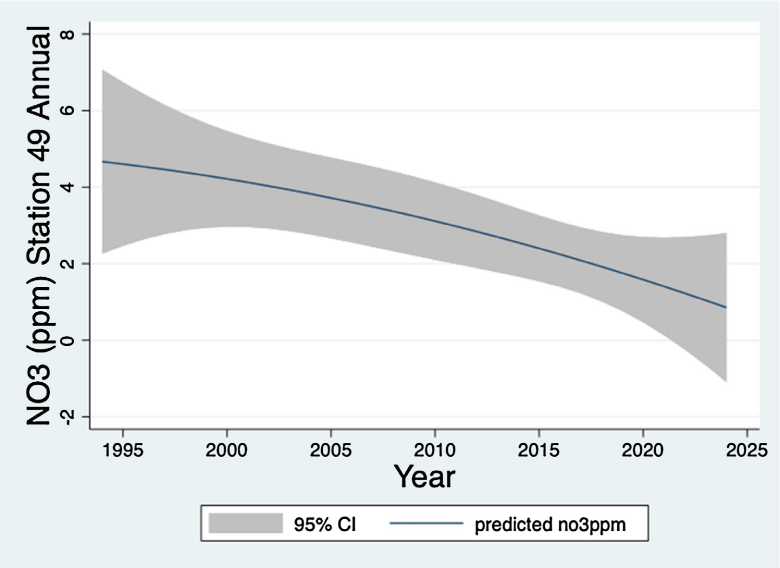

Figure 11. Station 49, temporal (1994-2024) changes of annual means of NO_3 concentrations (ppm).

(73) and the LAH effluent (49).

The bound of NO_3 and Peat soil particles is a weak linkage. Oxidized organic nitrogen was converted to NO_3 creating a huge, stocked load of NO_3 which drifting into drained water is moisture dependent. The higher the moisture or drainage flow through the higher is the drifted nitrate. Consequently, nitrate concentration in drained waters fluctuations are rainfall and irrigation dependents.

The temporal (1994-2024) changes of NO_3 concentration in the LAH effluent reflect the hypsometrical (Surface area, volume) decline of LAH, accompanied by

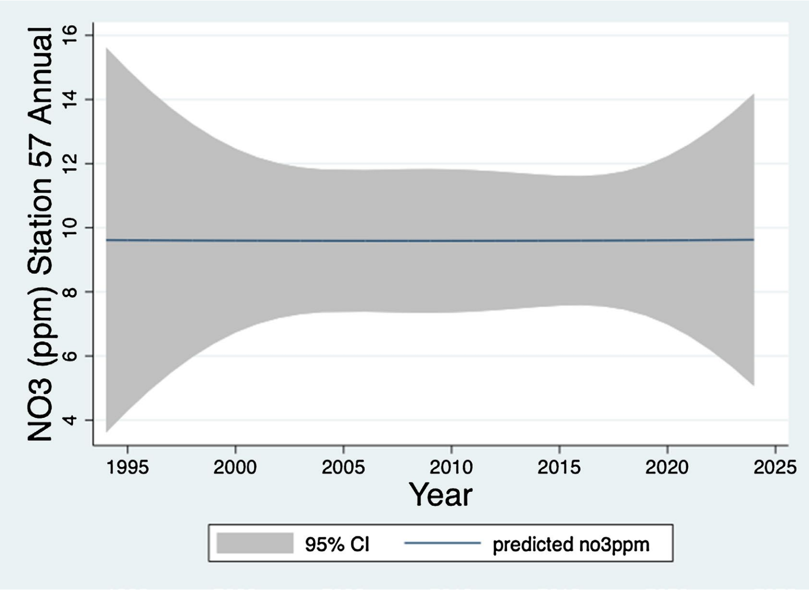

Figure 12. Station 57, temporal (1994-2024) changes of annual means of NO_3 concentrations (ppm).

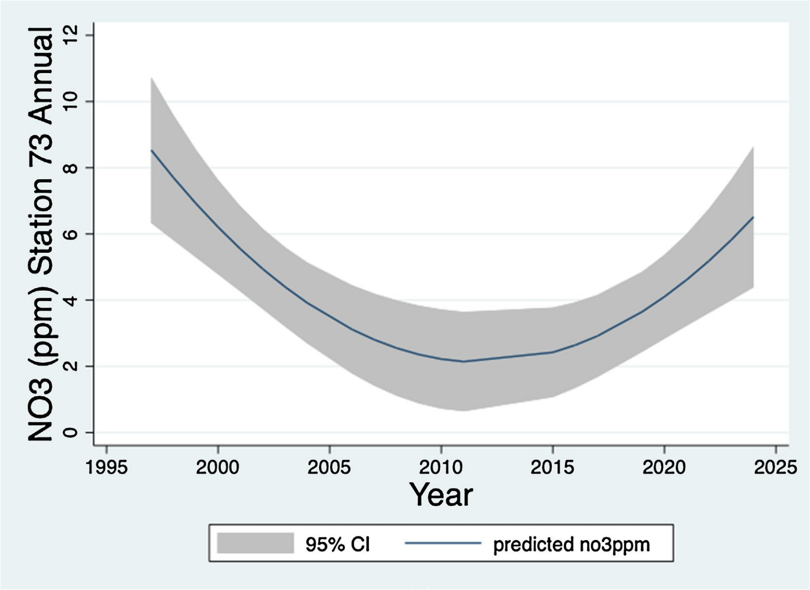

Figure 13. Station 73, temporal (1994-2024) changes of annual means of NO_3 concentrations (ppm).

a reduction of submerged vegetation biomass and occurrence of oxygen depletion which enhance denitrification and sedimentation processes.

Due to the vast stored load of Nitrogen and consequently its oxidative derivative, Nitrate, and the weak binding of these compounds to Peat particles, drainage in waterways is intensive and persistent.

Freshwater penetration directed east-west from the Golan Heights into the eastern block of Peat Soil dilutes NO_3 concentration in the drained waters. Fluctuations of NO_3 concentration in drained waters from the eastern Peat block reflect changes in eastern freshwaters penetration.

The Functional Status of LAH

The creation of the shallow Lake Agmon Hula was a fundamental element within the Hula Project proposal. The functional objectives were: conversion of 110 ha out of a total of 6000 ha from agricultural to touristic assignment, pollutants removal from the Kinneret input loads, and hydrological controlled maintenance of optimal water level (WL) of Ground Water Table (GWT) suitable for agricultural management in the vicinity. From 2003-2024, the WL of LAH was daily recorded, results are given in **Figure 14** and **Figure 15**.

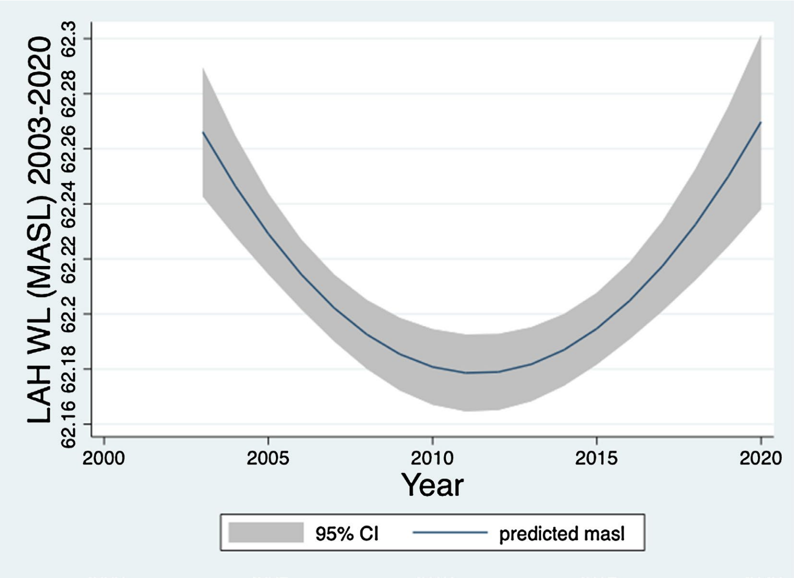

Figure 14. Annual temporal changes of daily record of WL in LAH (Altitude: Meter Above Sea Level; MASL) during 2003-2024.

Results in **Figure 14** indicate the close range of temporal 10 cm decline and 9.5 cm increase of WL. Temporal (**Figure 14**) and seasonal (**Figure 15**) WL changes are respectively responding to climate changes (rainfall and river discharges).

Monthly means of daily record of WL changes indicate respective rainfall (and consequent river discharge) regime: 9.7 cm averaged elevation during January-April and gradual decline later. Occasionally events of short and abrupt WL increase resulting from heavy rainfall events require an urgent WL decline to prevent surface flood.

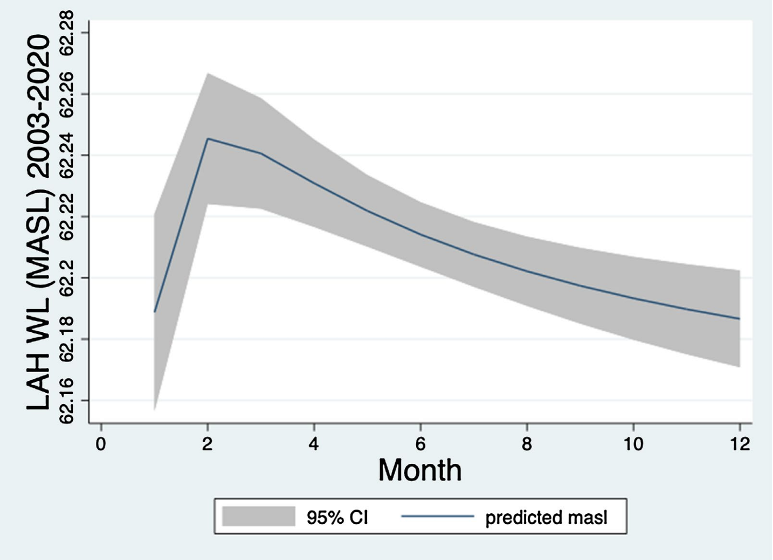

Figure 15. Seasonal (monthly) changes of daily record of WL in LAH (Altitude in meters above Sea Level; MASL) between 2003 and 2024.

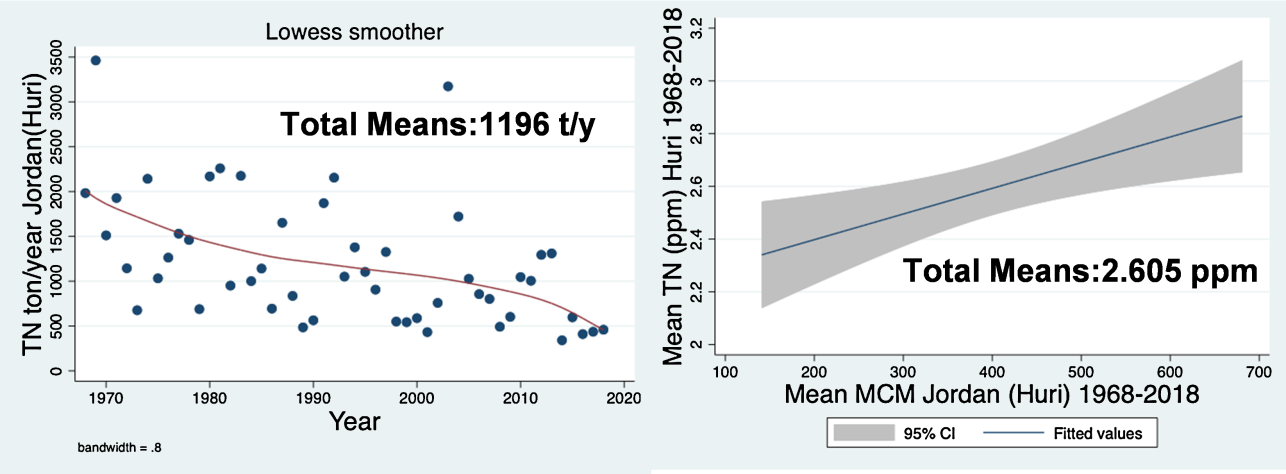

Figure 16. Left Panel: Lowess smoother plot of annual Jordan (Huri Station) TN loads (t/y), three years (1969, 1991, 2003) were excluded due to exceptional rainfall (1038, 1057, 964 mm respectively) and discharge (1098, 842, 807 mcm respectively) followed by great surface floods in the valley; Right Panel: Linear regression (w/95%CI) between annual mean of TN concentration (ppm) in Jordan waters and annual Jordan discharge (MCM; 10^6 m^3).

Results in Figure 16 (left panel) indicate a long-term (1968-2018) gradual continued decline in TN loads in Jordan waters, which are mostly sourced outside the Hula Valley. The TN migration through Jordan waters is dependently related to climate conditions, rainfall and consequently river discharge. The higher the rainfall regime, the heavier is the TN load. The right panel represents the positive regression relations between discharge and TN concentration. These relations reflect the intensification of erosion force by rainfall and consequently discharge enhancement.

Results in Figure 17 (left panel) indicate a long-term (1968-2018) decline of TP loads in Jordan waters, which are mostly sourced outside the Hula Valley. The

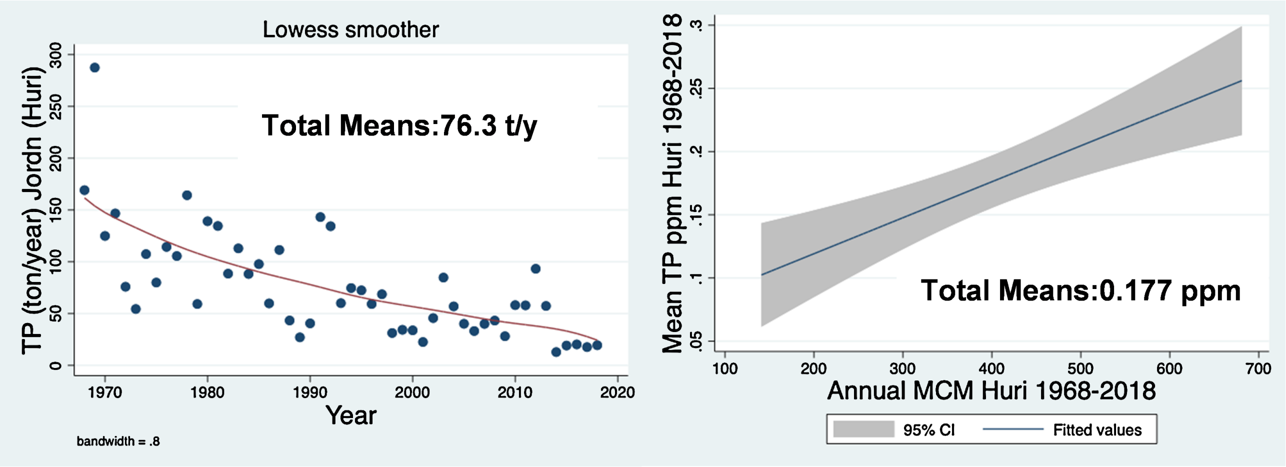

Figure 17. Left Panel: Lowess Smoother plot of annual Jordan (Huri Station) TP loads (t/y), three years (1969, 1991, 2003) were excluded due to exceptional rainfall (1038, 1057, 964 mm respectively) and discharge (1098, 842, 807 mcm, respectively) followed by great surface floods in the valley; Right Panel: Linear regression (w/CI 95%) between annual mean of TP concentration (ppm) in Jordan waters and annual Jordan discharge (MCM; 10^6 m^3).

decline range during 1968-1990 is greater than onwards due, probably, to fish-pond restriction and sewage removal. The TP migration through Jordan waters is dependently related to climate conditions, rainfall and, consequently, river discharge. The higher the rainfall regime, the heavier is the TP load. The right panel represents the positive regression between discharge and TP concentration. It is suggested that these relations reflect the intensification of erosion force by rainfall and consequently discharge enhancement.

4. Discussion

The review of the Hula Project's achievements is focused on three criteria: Agriculture, Kinneret water quality and ecological tourism.

The analysis of agricultural achievements was carried out and significant success was documented [19]. The great success of ecological tourism management with emphasis on bird watching, particularly the Crane case was evaluated and confirmed [1]-[3] [6]-[10].

A brief official reported conclusion declares: almost 15 years of HP successful management, soil surface subsidence is minor, no more underground fire outbreaks, damageable dust storm frequency is depleted, agricultural crops revenue almost tripled, winter surface floods significantly reduced, and Ecological tourism is a great success [20]. The critical issue of pollutant (nutrients) dynamics is discussed in this paper. This crucial concern received public importance as the result of contradicted interactions: the Hula drainage as a devastation of natural habitats aimed at the development of food production ecologically connected with a major source of drinking water supply. The review of the HP 30th anniversary includes the removal of concern about Kinneret water quality. Consequently, a summary of quantified nutrient (TN, TP, NO_3) migrations from the Hula Valley is given (**Table 2**).

Table 2. Mean (2002-2010), annual input through reconstructed Jordan, Canal Z and Hula East and output loads through LAH TP, TN, and NO_3. effluent composition.

Source	TP (ton/y)	TN (ton/y)	NO_3 (ton/y)
Input: Reconstructed Jordan (48)	0.4	11.2	9.2
Input: Canal Z (57)	0.6	97.0	57.0
Input: Hula East (73)	0.4	17.0	14.0
Total Input Load	1.4	125.2	80.2
LAH Total Output (49)	1.2	32.0	13

Data given in Table 2 does not represent nutrient entire budget balance but only the contribution of reconstructed Jordan, Canal Z and Hula East. There are more other TN, TP and NO_3 sources input as well as water outputs and inputs resources which are not considered in this paper. A significant potential TP contributor is 40,000 - 50,000 seasonal migrator Cranes. These birds partly occupy LAH as a night-sheltered roost, and their negligible TP contribution to LAH was confirmed whilst a significant elevation of TP concentration in LAH waters was documented during summer-fall when Cranes are absent. The contribution of drifted P within drained waters into the drainage canals is higher in the southern part of the valley where mineral soil type is dominant [21]. The reduction of TN, of which NO_3 comprised the dominant compartment, in the LAH water, as measured in the effluent, is due to nitrogen removal by denitrification and sedimentation in the LAH ecosystem. The impact of the Hula Project in general, and LAH specifically, of nutrient budgets on the Lake Kinneret ecosystem was confirmed as negligible. The monitoring and research results that followed the implementation of the HP (1994-2024) confirmed the existence of two Peat blocks, the central and the eastern compartments. These two Peat blocks present slightly different dynamics of nutrient migration patterns. The eastern block is western borders by the major Eastern Canal and the Golan Heights foot on the east side. Freshwater flows from the Golan Heights into Hula Valley through rivers, surface water, and underground seepage are mixed with peat soil drained waters causing nutrient dilution. There is no such dilution effect on dissolved nutrients within the drained waters in Canal Z which conveys drained waters from the central Peat block. The nutrient drifted from the central Peat Block migrated and was injected into LAH through Canal Z undisturbed or diluted. Data given in Table 2 confirm that TP, TN and NO_3 migrated loads originated in LAH are negligible in comparison with headwaters (Dan, Banias, Snir) and Jordan (Huri) loads (1967-1985, 1993-2018): LAH annual effluent loads comprise 4%, 3% and 1% of the Jordan loads of TN, TP, and NO_3 respectively. A brief insight into the values of mean annual load capacities (ton/y) of major headwaters and Jordan River prior to the HP constructions (1967-1985) and Jordan River during maintenance of the HP (1993-2018) is given in Table 3.

The three headwater (Dan, Hermon, Hazbani) rivers are segregated northern to the Hula Valley, and cross the Hula Valley jointly. From 1967 to 1985 the agricultural management of the Hula Valley included 1700 ha of fish ponds. Fish pond effluents and regional raw sewage were untreated and removed through the Jordan River. Therefore, TN and TP loads in the Jordan River were very high from 1967 to 1985. During the late 1980s and early 1990s fish ponds were converted into field crops and orchards and raw sewage was treated by removal into newly constructed reservoirs. Though fishponds and domestic raw sewage contain very high levels of Phosphorus their removal caused the distinct reduction of TP later and is not attributed to the HP management (1993-2018, in **Table 3**).

Table 3. Averaged values of annual loads (ton/y) of TP, TN, and NO_3 migrated through the Kinneret Headwaters (Dan, Banias and Snir), River Jordan prior to HP implementation (1967-1985) [5], and River Jordan during HP management period (1993-2018). River discharges (10^6 m^3/y) and LAH effluent (1993-2024) are given.

Source	Discharge (10^6 m^3/y)	TN (ton/y)	TP (ton/y)	NO_3 (ton/y)
LAH Effluent	5	32	1.2	13
River Dan	270	348	5.8	264
River Hermon	116	193	18.0	136
River Hazbani	129	215	19.0	144
River Jordan (1967-1985)	530	584	119.0	1042
River Jordan (1993-2018)	357	882	45.0	1427

The major part of Kinneret nutrient loadings through inflow rivers (exampled as TN in **Table 3**) originate outside the Hula Valley. During late 1980`s when HP was designed it wasn't likely to be thoroughly considered. Therefore, an important function was designated to LAH as nutrient remover. During 30 years of HP implementation the minor impact of nutrients removal through LAH was documented (**Figure 3**). Contrary to that conclusion, the LAH ecosystem was found as a great success of eco-touristic attraction [2] [3]. The intensive research and monitor throughout 30 years in the HP`s territory granted a valuable information about the Peat soil features (**Figure 4**, **Figure 5**). The Hula drainage enhanced oxidation of the Peat soil and the creation of a vast stock of nitrate. During the post drainage period and the agricultural development, the dynamics of nitrate migration from the Peat soil was enhanced by an increase of soil moisture. The higher the moisture is, the higher the capacity of nitrate migration was documented. Peat soil moisture is enhanced by rain (and river discharge) and summer irrigation. Though the impact of Peat soil moisture on nitrogen and phosphorus migration is dissimilar. Moisture enhancement increases nitrate but decline Phosphorus flushing from Peat soil (**Figure 8**, **Figure 9**). The nitrate migration is enhanced as the result of its high level of Ksp (solubility constant), and phosphorus is decline due to geochemical features. Temporal analysis of TN and TP migration (**Figure 8**, **Figure 9**) clarified the impact of another ecological parameter, river discharge, runoff and seepage intrusion of freshwater from the Golan Hights into the Hula valley. Mixing of these freshwaters with the drains from the eastern block of Peat soil enhanced dilution and nutrients concentration decline. The temporal fluctuations of nitrate concentrations in the Jordan waters within the Hula valley (**Figure 10**) are small probably because of the low input from the Peat soil. The temporal changes of nitrate concentration in the LAH (**Figure 11**) waters are slightly reduced as the result of volume/surface temporal decline and diminished bimass of submerged vegetation. The freshwater dilution effect on the Eastern block of Peat soil is shown in **Figure 12** and **Figure 13**: Temporal stability in the drains of the central block and diluted reduction in the eastern Peat block. The dependence of nutrient concentrations (TN, TP) in river Jordan on climate condition changes of rain capacity, river discharge and erosive forces, outside the Hula valley, is shown in **Figure 16** and **Figure 17**.

5. Conclusive Remarks

TN and TP loads contributed by the Hula Valley are negligible with respect to the Jordan River input loads. Two major threats to the Kinneret water deterioration existed during the 1980s and 1990s fish pond effluents and raw sewage and the Peat soil Nitrate source. The removal of raw sewage and conversion of 1700 ha fish ponds to orchards and field crops reduced significantly nutrient input from the Hula Valley into Lake Kinneret. The result was a distinct reduction of TP and TN through Jordan discharge. Earlier studies on the eco-physiological properties of Phytoplankton in Lake Kinneret documented a distinct change in its composition since the mid-1990s. The high nitrogen consumer, the bloom-forming *Peridinium* was replaced by unwanted Cyanobacteria [22] of which nitrogen nutritional supply is not critical. Therefore, since the late 1990 nitrate loading has not been a threat to the Kinneret Water quality. The impact of phosphorus supply is different, and its status is risky. Nevertheless, unlike nitrogen, Phosphorus sources are combined internal and external whilst those of nitrogen are mostly external. The external Phosphorus sources are partly controlled whilst the internals are not. Among external P sources, the Peat soil is significantly affected by soil moisture. High Peat soil moisture impact reduces P drifting and moisture decline enhances P drainage. Consequently, as a result of HP management, the recommendation was implemented to enhance peat soil moisture by subsidized summer water allocation. The elevation of the Ground Water Table level (GWT) supported moisture enhancement as well. There is a huge stock of nitrogen in the various soil types in the Hula Valley, mostly in Peat soil. The vast nitrogen reserve is a remnant of the pre-drainage Hula Valley. During post-drainage, the organic and intensive continuing nitrogen oxidation, a vast nitrate stock in the upper soil layers in the Hula Valley was established. These nitrates are weakly bound and easily drift through drained water. The successful HP management reduced P migration accompanied by drifted nitrates is ecologically accepted. The P removal is critical whilst that of nitrates is not. Loads size of TP and TN conveyed by the reconstructed Jordan route is mostly affected by erosion conditions outside the

Hula Valley. Therefore, seasonal fluctuations are minor. These outcome results of the HP management justified the agreement between the farmers and water authorities, the "Peat Convention", including appropriate pricing for summer irrigation. TP concentration in the eastern drained waters represents seasonal and temporal fluctuations caused by freshwater penetration from the Golan Heights into the Hula Valley, which is affected by climate conditions.

From the very beginning of HP implementation, much attention was given to LAH. After 30 years, it can be concluded as a great success. The management of its WL level was maintained in collaboration with agricultural demands to ensure vehicles, surface flood prevention, transportation, nutrient removal and nature protection. Nevertheless, the intensive growth rate of submerged and emerged vegetation was not predicted. This vegetation contributes natural value to the ecological diversity whereas it is a source of pollutants, emphasizing P. Periodical P growth onset intake by the aquatic plants is absorbed from the sediments during late winter-summer, stored in plant tissues and released into the lake water as documented in the effluents, during fall-early winter. The biotic cycle grants LAH the status of pollution factor. A preliminary future suggested design proposed a complete isolation by disconnection of LAH to Kinneret system. This preliminary design includes the hydrological connection between Canal Z to Canal 312 continuing to the major western canal and was accompanied by WL decline which gave a swampy trait to the LAH and enhanced bird nesting and biodiversity. An unexpected Crane migration case occurs in the 1990s. The crane migration case was initiated as the outcome of the introduction of Peanut cultivation. The Crane case was developed as a great success, but not without difficulties. Crane damage to agricultural crops and its prevention requires financial investment. The goodwill and cooperation between the landowners and HP administration initiate collaborative solutions.

Acknowledgement

Sincere appreciation is given to V. Orlov-Levin, and M. Peres, for unpublished data supply and T. Natanson, and E. Yasur for field sampling assistance.

Author Contributions

The author carried out data analysis, evaluation and the preparation of the original draft and final version.

Data Availability Statement

The data presented in this study are available on request from the corresponding author.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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