Scientific Research Publishing

Open Journal of Modern Hydrology, 2025, 15(2), 204-217
https://www.scirp.org/journal/ojmh
ISSN Online: 2163-0496
ISSN Print: 2163-0461

Seasonal and Spatio-Temporal Distribution of Nutrients in the Hula Valley after Drainage: C: Carbonate and Sulfate

Moshe Gophen

MIGAL-Galilee Scientific Research Institute, Kiryat Shmona, Israel
Email: gophen@migal.org.il

How to cite this paper: Gophen, M. (2025) Seasonal and Spatio-Temporal Distribution of Nutrients in the Hula Valley after Drainage: C: Carbonate and Sulfate. *Open Journal of Modern Hydrology*, **15**, 204-217.
https://doi.org/10.4236/ojmh.2025.152013

Received: December 16, 2024
Accepted: April 18, 2025
Published: April 21, 2025

Copyright © 2025 by author(s) and Scientific Research Publishing Inc.
This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).
http://creativecommons.org/licenses/by/4.0/
Open Access

Abstract

The Hula wetland and old Lake Hula drainage were completed in 1957, and the land was converted into agricultural use. However, the adoption of inappropriate irrigation methods led to several critical concerns, including the oxidation of organic matter, frequent outbreaks of subsurface unsecured fire, soil surface subsidence and disruption of the hydrological system. Additionally, nitrogen mineralization created an accumulation of nitrate loads, which increased the risk of leaching into Lake Kinneret and deteriorating its water quality. The natural intrusion of gypsum into peat soil's organic matter has contributed to increased levels of sulfate and calcium, enhancing soil salinization. Consequently, a reclamation project was implemented, the Hula Project (HP). The dependence of climate conditions and consequently soil moisture on Alkalinity (ALK), Total Dissolved Solids (TDS) and Sulfate (SO_4) concentrations, Electrical Conductivity (EC), and pH properties within the Peat soil drained waters composition was documented. A temporal decline of ALk, TDS, SO_4, EC, and, to a lesser extent, pH measures during 1994-2010 and an increase later were indicated. The nutrient migration dynamic is evaluated through spatial and temporal dimensions to confirm the dominant effect of soil wettability with negligible fluctuation of the pH values.

Keywords

Hula, Peat, EC, TDS, Alkalinity, Sulfate

1. Introduction

The Hula Valley and Lake Kinneret are located in the northern part of Israel's

Syrian-African Great Rift Valley. Lake Kinneret is the only natural freshwater lake in Israel and its water quality including the cardinal impact of nutrient migrations from the Hula Valley is therefore a national concern. The total annual national water supply is 2.11 bcm (10^9 m^3), of which 0.55 bcm is sourced from the Kinneret-Jordan water system. The area of the Kinneret drainage basin is 2730 km^2 and is located mostly to the north of the lake, of which the total Hula Valley is about 200 km^2. Three major headwater rivers, The Hatzbani, Banyas, and Dan originate from the Hermon Mountain region and flow into the northern part of the Kinneret drainage basin. These rivers converge to form the Jordan River. Prior to the late 1950s, the Jordan River flowed through the Hula Valley through three tributaries that inflowed into the old Lake Hula. From the old Lake Hula, situated at an altitude of 61 - 68 masl (above sea level), the Jordan River flows downstream into Lake Kinneret (Mean WL 211 mbsl) for a distance of approximately 15 km. Before the drainage of the Hula wetlands and old Lake Hula, the Valley was characterized by old Lake Hula and 3500 ha of swampland. The swampy area was totally covered by water in the winter and partly covered in the summer. To the north of the swamps was an area (3200 ha) where water table levels were high in winter, thus making agricultural cultivation impossible. During the summer, when underground water levels declined, this 3200-ha land surface was efficiently cultivated. After drainage, land use was converted into agricultural management. Several processes of organic matter oxidation and the usage of inappropriate irrigation methods which enhanced soil properties deterioration initiated concerns about Kinneret water quality: Frequent outbreaks of subsurface unsecured fire; Soil surface subsidence deteriorating the hydrological system; Nitrogen mineralization has led to the accumulation of nitrates, increasing the risk of partial migration into Lake Kinneret causing deterioration of its water quality. A reclamation project was implemented, the Hula Project (HP), resuming its current 30 years of existence. The Intrusion of Gypsum into the Peat organic matter has contributed to increased levels of sulfate and calcium, enhancing soil salinization. The present study examines the impact of climate conditions and consequently soil moisture on Alkalinity (ALK), Total Dissolved Solids (TDS) and Sulfate (SO_4) concentrations and Electrical Conductivity (EC), and pH properties on drained waters from the Peat Soil in the Hula Valley. The objective of the present study is to evaluate the impact of the HP on the fluctuations of Sulfate, Carbonate, Electrical Conductivity and pH in the Hula Peat soil-drained waters. The Hula Project challenges were agricultural crops improvement, prevention of soil properties devastation and Kinneret water quality protection. Nevertheless, information about Peat soil response to ecological changes aimed at management predictability was incomplete. Consequently, evaluation of temporal and seasonal distribution of nutrients (SO_4, Alkalinity, TDS) and physicochemical parameters (EC, pH) are critically required.

2. Material and Methods

2.1. Study Area

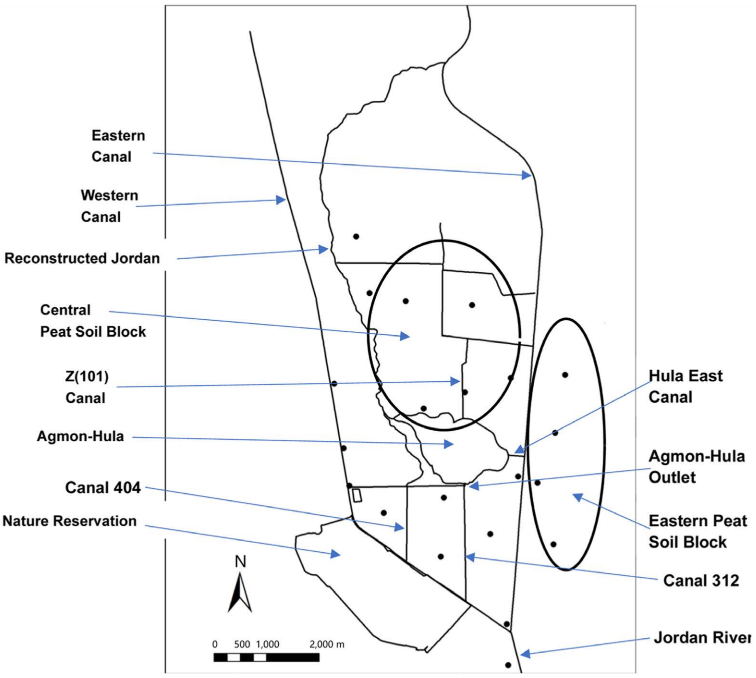

Figure 1. Chart map of the Hula Project territory: Inflow and drainage water lines and Peat soil blocks regions are outlined: Ecosystem compartments are arrowed; black dots are bore-hole drill locations for the underground water sampling. (Modified from HPDB 1994-2019)

2.2. Chemistry

Analysis of Sulfate, Alkalinity (Carbonate), Total Dissolve Solids (TDS), Total Suspended Solids (TSS), pH, and Electrical Conductivity (EC) (Specific Conductance) was carried out on weekly and bi-weekly sampled water in Station 57: the inflow of Canal Z waters into Lake-Agmon-Hula (LAH), the optimal presentation of Peat soil drained water. Hula Valley coordinates: 33˚06'12" North; 35˚36'33" East. Hydrological Balance of Lake-Agmon-Hula (10^6 m^3/year) as averaged for 2008-2018.

2.3. Inflow

From Reconstructed Jordan—2.2; Through Canal Z (101)—6. 5; From Eastern Peat soil—0.28; Rain—0.27: Total—9.2.

2.4. Outflow

Agmon effluent—5.9; Irrigation consumption—1.7; Evaporation—1.5; Total—9.2.

Method of Analysis were [1]:

Total Dissolved Solids—180˚C evaporation.

Sulfate (SO_4^{2-})—Turbidimetric ($BaCl_2$) method.

Alkalinity ($CaCO_3$)—Titration method.

pH—pH meter.

The data was obtained from the Hula Project Monitor Program:

MIGAL-Hula Project Data Base [2]—MIGAL-Galilee Scientific Research Institute, Jewish National Fund and Israel Water Authority [3]-[7].

2.5. Statistical Methods

Statistical evaluation included the following methods: Quadratic and Linear Regressions (w/CI 95%). Quadratic regressions (w/CI 95%) are used for modeling relationships between variable distributions with a parabolic best-fit curve, as most likely relevant to the analyses presented in this paper.

3. Results

Results given in **Table 1** & **Table 2** indicate the tight correlation between Alkalinity, Total Dissolved Solids, Electrical Conductivity, and Sulfate suggested to be dependents of soil moisture which is strongly affected by climate (rain capacity) conditions. The high correlation between EC, TDS and Alkalinity emphasizes the impact of soil moisture. The exceptionally low level of fluctuations presented by pH and TSS values is an indication of the ineffective impact of soil moisture on pH and TSS. (**Figures 1-16**)

Table 1. Grand total mean, SD, Maximal, Minimal and % of SD of the Mean (1994-2019) Nutrient concentrations measured in Station 57.

Nutrient	Mean	SD	Min.	Max.	% SD
ALK ($CaCO_3$ ppm)	213.2	148.4	64.7	527.3	70
EC (mS)	1.17	0.65	0.5	2.57	56
pH	7.25	0.14	7.05	7.59	2
SO_4 (ppm)	351.2	312.1	63.8	1010.4	89
TDS (ppm)	1086.4	711.5	365	2516	65
TSS (ppm)	25.2	4.92	18.48	34.9	20

Table 2. Parameters of Linear Regressions in between nutrient and Sulfate (SO_4), nutrients and Alkalinity (ALK) and Electrical Conductivity (EC) and Total Suspended Solids. S = Significant, NS = Not Significant. The high percentage of SD from the Mean (**Table 1**) confirms the impact of climate conditions variability and the adhesion linkage weakness of those nutrients to the Peat soil particles. Abrupt release of the nutrients from the soil particles into the pore waters as a response to rain or irrigation wettability.

Nutrients	r^2	p	Significance
ALK/SO_4	0.9854	<0.0001	S
TDS/SO_4	0.9735	<0.0001	S
TSS/SO_4	0.3671	0.0368	S
EC/SO_4	0.9835	<0.0001	S
pH/SO_4	0.0928	0.3356	NS

Continued

EC/ALK	0.9842	<0.0001	S
TDS/ALK	0.9868	<0.0001	S
TSS/ALK	0.3858	0.1115	NS
pH/ALK	0.0985	0.6272	NS
EC/TDS	0.9532	<0.0001	S
EC/TSS	0.9669	<0.0001	S
TSS/TDS	0.2941	0.0685	NS

The similarity of seasonal distribution of concentrations of TDS, SO_4, Alkalinity, and EC, and rain capacity within the Peat soil (Station 57) drained waters is clearly shown in Figures 2-6.

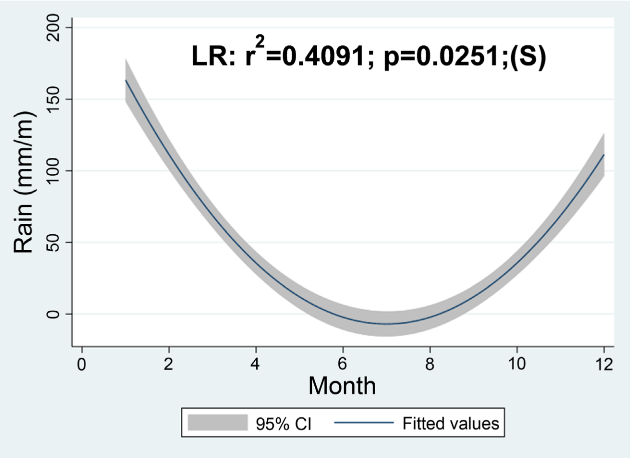

Figure 2. Quadratic regression (w/95%CI) plot between annual mean (1994-2019) of rain capacity and month. Linear regression parameters (r^2, p) are given (S-significant).

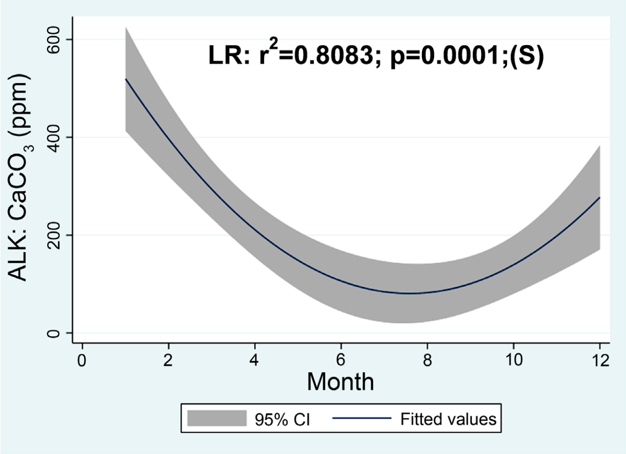

Figure 3. Quadratic regression (w/95%CI) plot between annual mean (Station 57) (1994-2019) of Alkalinity (ALK) (ppm $CaCO_3$) and month. Linear regression parameters (r^2, p) are given (S-significant).

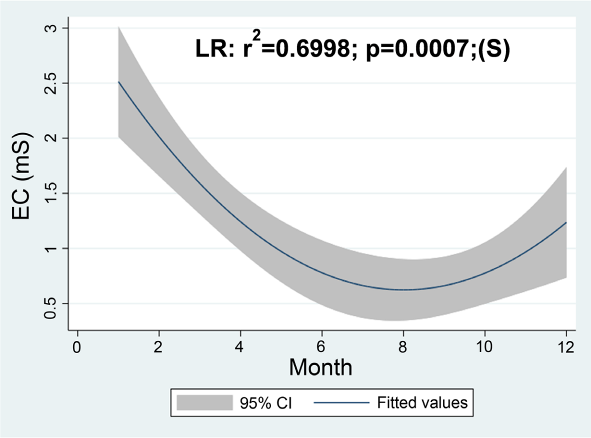

Figure 4. Quadratic regression (w/95%CI) plot between annual mean (Station 57) (1994-2019) of Electrical Conductivity (EC) (mS) and month. Linear regression parameters (r^2, p) are given (S-significant).

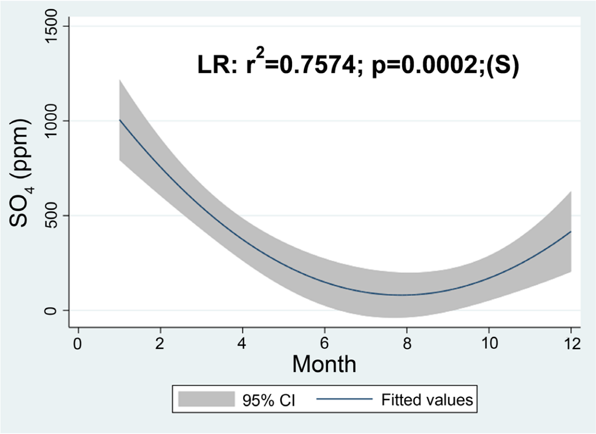

Figure 5. Quadratic regression (w/95%CI) plot between annual mean (Station 57) (1994-2019) of Sulfate (SO_4) concentration (ppm) and month. Linear regression parameters (r^2, p) are given (S-significant).

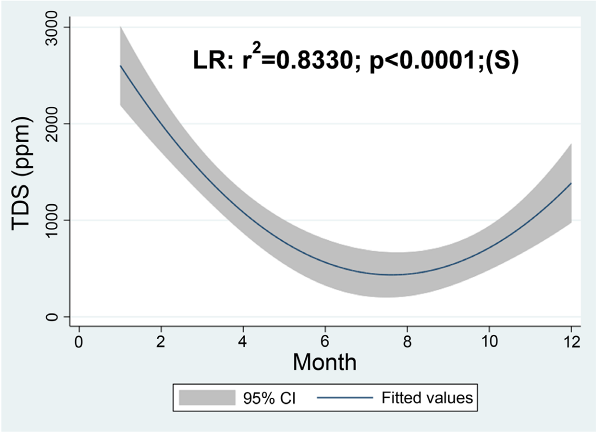

Figure 6. Quadratic regression (w/95%CI) plot between annual mean (Station 57) (1994-2019) of Total Dissolved Solids (TDS) concentration (ppm) and month. Linear regression parameters (r^2, p) are given (S-significant).

The insignificance of nonlinear seasonal distribution (monthly) relations of pH and the concentration of Total Suspended Solids (TSS) within the Peat spill drained waters (Station 57) is shown in Figure 7 and Figure 8.

The obvious linear significant relation between TDS and EC is confirmed in Figure 9. The higher the soil moisture, accompanied by salt flushing, the greater the enhancement of EC.

Obvious Inverse relations of TDS and EC with TSS are consequently confirmed in Figure 9 & Figure 10.

Results of temporal distribution given in Figures 12-15 indicate a decline in nutrient (Alkalinity, SO_4) concentrations and EC and TDS during 1994-2009 and increase onwards. Information about distributional pattern of rain capacity and consequently intensity, presented as annual rainy days is given in Figure 16. The pattern similarity of temporal rain capacity and nutrient distribution is emphasized.

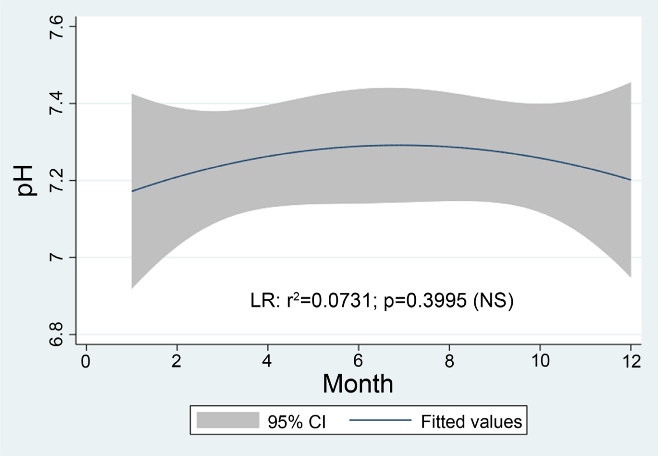

Figure 7. Quadratic regression (w/95%CI) plot between annual mean (Station 57) (1994-2019) of pH and month. Linear regression parameters (r^2, p) are given (NS = Not Significant).

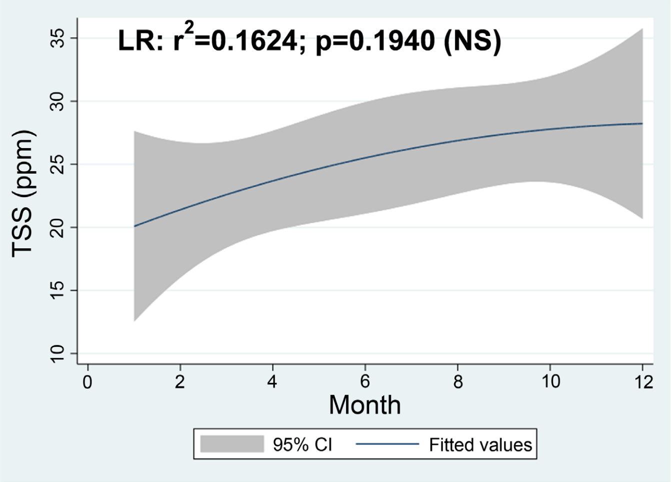

Figure 8. Quadratic regression (w/95%CI) plot between annual mean (Station 57) (1994-2019) of Total Suspended Solids (TSS) concentration (ppm) and month. Linear regression parameters (r^2, p) are given (NS—Not significant).

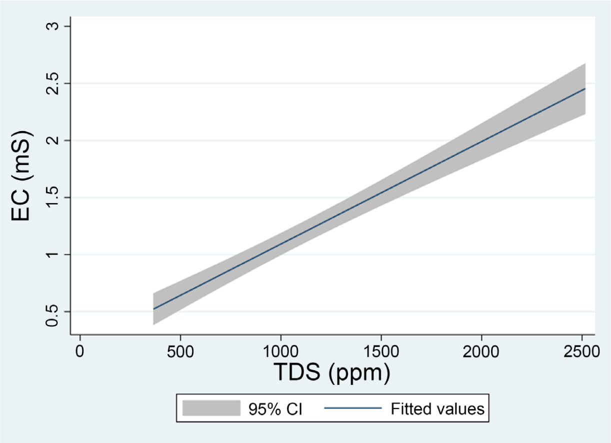

Figure 9. Linear regression (w/95%CI) plot between annual mean (Station 57) (1994-2019) of Total Dissolved Solids (TDS) concentration (ppm) and Electrical conductivity (EC) (mS).

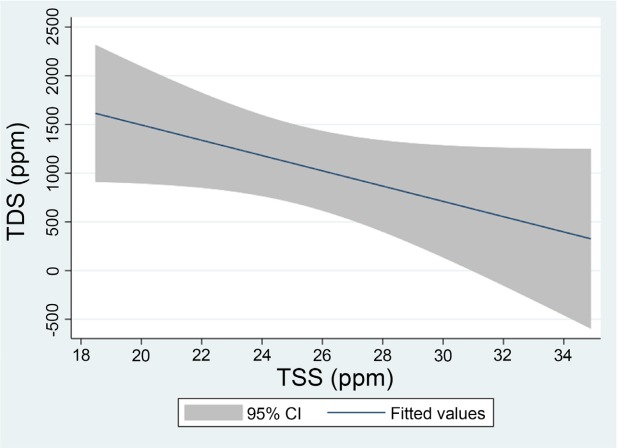

Figure 10. Linear regression (w/95%CI) plot between annual mean (Station 57) (1994-2019) of Total Dissolved Solids (TDS) and Total Suspended Solids (TSS) concentrations (ppm).

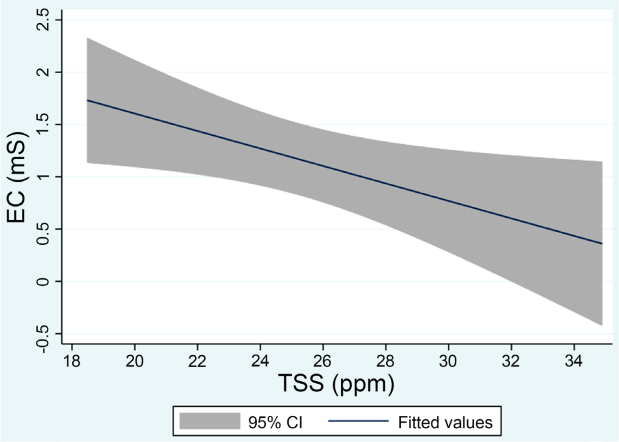

Figure 11. Linear regression (w/95%CI) plot between annual mean (Station 57) (1994-2019) of Electrical Conductivity (EC) (mS) and Total Suspended Solids (TSS) concentration (ppm).

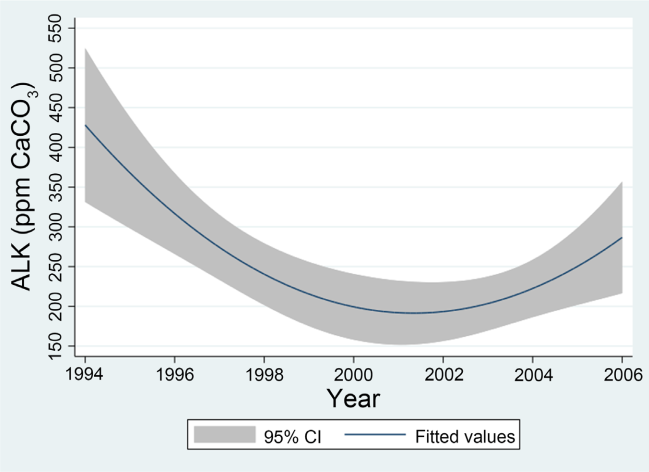

Figure 12. Quadratic regression (w/95%CI) plot between temporal, (annual mean) (Station 57) (1994-2019) of Alkalinity ($CaCO_3$ ppm) concentration and Years.

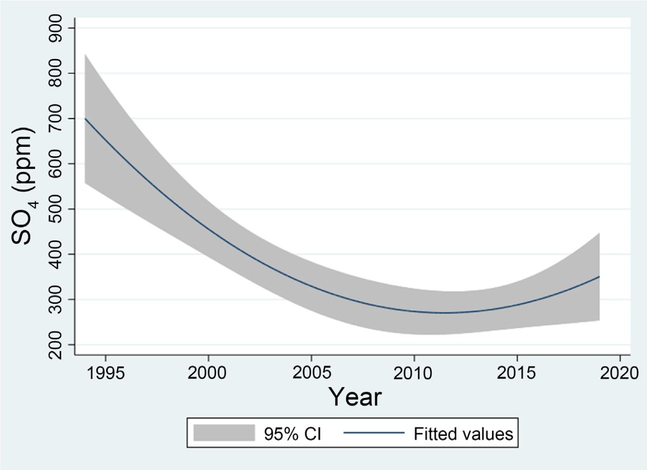

Figure 13. Quadratic regression (w/95%CI) plot between temporal (annual mean) (Station 57) (1994-2019) of Sulfate (SO_4) concentration (ppm) and Years.

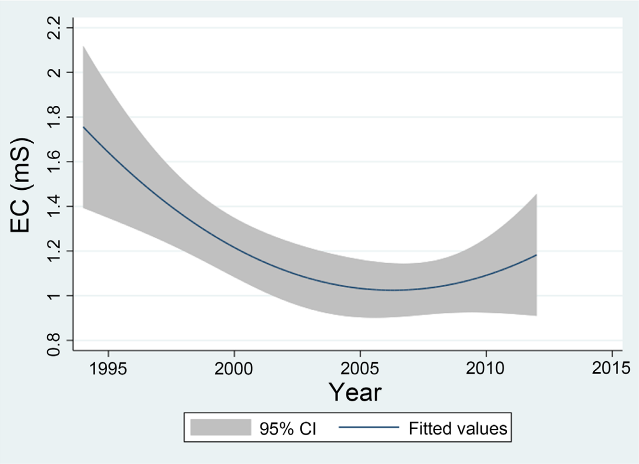

Figure 14. Quadratic regression (w/95%CI) plot between temporal (annual mean) (Station 57) (1994-2019) of Electrical Conductivity (EC) (mS) and Years.

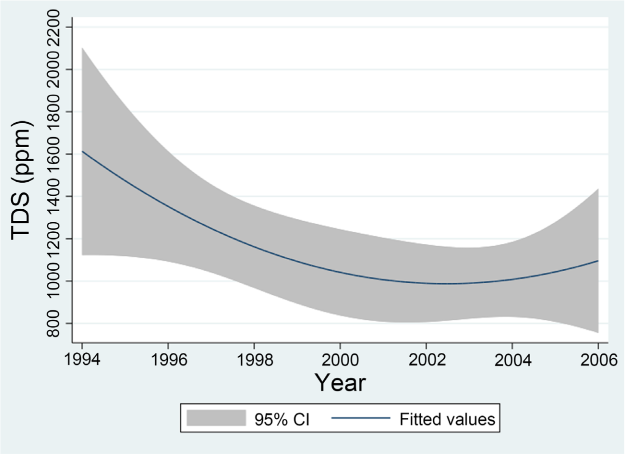

Figure 15. Quadratic regression (w/95%CI) plot between temporal (annual mean) (Station 57) (1994-2019) of Total Dissolved Solids (TDS) concentrations (ppm) and Years.

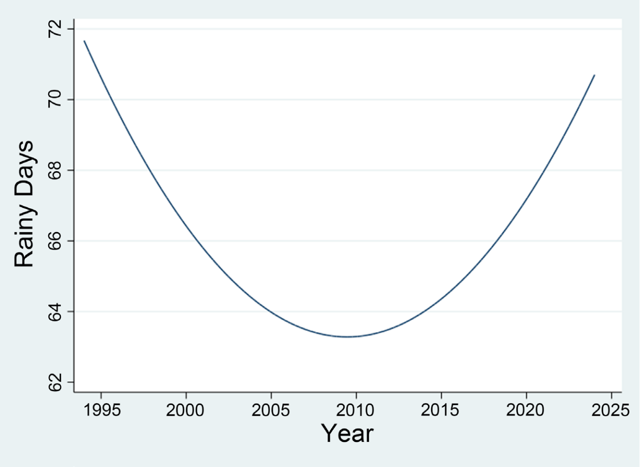

Figure 16. Fractional Polynomial plot of total number of rainy days per annum and Years during 1994-2024.

4. Discussion

Cases of wetlands drainage aimed at extending food production land use are well known in Europe and the USA [8]-[10]. The drainage of the Hula Valley concluded the search for food production combined with the prevention of Lake Kinneret water quality. Soil Survey [11] confirmed 21% (750 ha), 34% (1200 ha), 19% (660 ha) and 26% (910 ha) of the Hula Valley soils are lacustrine marl, Peat soil, Transition Peat soil and alluvial soil respectively [12]. The Peat soil in the Hula Valley contains huge loads of Gypsum ($CaSO_4$) and migration of SO_4^{2-} —from the Peat-Soil into Lake Kinneret might have an impact on water quality. A long period of heavy bloom-forming *P. gatunenze* domination was replaced by Cyanobacteria including N_2-fixers in Lake Kinneret. The competitive properties of SO_4^{2-} with Molybdenum were documented [13]-[15]. In the Lake Kinneret-Hula ecosystem, enhancement or reduction of supplemental SO_4^{2-} induces strengthening or weakening competition with MoO_4^{2-} affecting suppression of N_2-Fixer Cyanobacterium. Consequently, sulfate migration from the Hula Valley into Lake Kinneret might have an impact on the development of the Bloom Forming Harmful Cyanobacteria (BFHC).

Previous studies have documented the high content of Gypsum ($CaSO_4$) in the Hula Peat soil [3]-[7]. The Gypsum is significantly dissolved in water releasing free Ca^{2+} and SO_4^{2-}. The decline of rainfall, and consequently lowered river discharge and suppression of SO_4^{2-} concentrations and loads in the Hula Valley runoffs, River Jordan and Lake Kinneret waters were documented [16]. Carbonate sources and consequently Alkalinity properties in the Peat soil are mostly from lacustrine marl sediments. The documented [17] linkage between high alkalinity and high base cations content, such as Ca^{2+}, and Mg^{2+}, providing suitable conditions for the precipitation of Fe is relevant to the Hula Peat soil ecosystem. The sulfate sources include the breakdown of proteins into amino acids, which releases oxidized Sulfur. Sulfate existence is dependent on aerobic conditions maintenance. Sulfide production through Anaerobic conditions development was not documented in the Hula Peat soil whilst rarely traced (7 - 8 μM) in the sediments of Lake Agmon-Hula [18]. Enhanced activity of anaerobic sulfate-reducing bacteria was observed in surface soils from P-enriched areas, which yielded 10^3 to 10^4 times higher numbers of these bacteria compared to soils from P-unimpacted sites [19]. Agricultural crops within the Hula Peat Soil land are intensively P-fertilized [12] whilst anaerobic conditions are very scarce in the surface soil layer. Therefore, reducing Sulfate to sulfide is not predicted. Frequencies of anoxic condition within the shallow layers of Hula Peat soil are presently scarce but it might be possible in deeper layers contacting crops root system. Therefore, the prediction of sulfate reductive bacteria existence and toxic sulfide production within the agricultural crops root system is negligible.

The migration of Gypsum ($CaSO_4$) derivate, the SO_4^{2-} is moisture dependent, the higher the soil moisture, the higher is SO_4^{2-} drained concentration and vice versa [18] [20]. Dryness conditions therefore initiate the decline of SO_4^{2-} migration from the Hula Valley towards Lake Kinneret.

Averaged (SD) nutrient concentrations in water samples collected in Station 57 close to the beginning of Hula Project implementation (1994-1996) indicate wetting after a long period of dryness characterized by fluctuated values and percentage SD levels [18]:

Ca^{2+}—403 (SD 236) ppm.

SO_4^{2-}—997 (SD 752) ppm.

Alkalinity (Carbonate)—192 (SD 61) ppm.

pH—6.6 - 7.6.

Results given in **Table 1** & **Table 2** indicate two major geochemical components which control the EC measure of the Peat soil drained waters (Station 57): Carbonate as Alkalinity (ppm $CaCO_3$) and Sulfate capacities. Unpredictable, negligible pH level of fluctuation was indicated. The distributional pattern similarity of seasonal (monthly) changes in nutrient concentrations (**Figure 3-6**) highlighted the potential of its dependence on climate conditions: rainy winter-spring and dry summer-fall months (**Figure 2**). During winter-spring time, soil moisture is high as the result of rain wettability whilst during post rainy season, summer-fall months, soil moisture declines. Water content and wettability are probably the major factors that enhance nutrient migration and consequently induce the similarity of the major nutrient distribution patterns. Moreover, the evaluation of the correlation between nutrient migrations and annual rain capacity did not indicate a temporal trend. Whereas consideration of the temporal distribution of rain capacity in terms of the number of rainy days has indicated migrated nutrient concentration enhancement through an increased number of rainy days. In other words, the rain capacity is an insufficient factor and its distribution as a number of rainy days distribution and also by intensity, is critical (**Figures 12-16**). The dominant impact of soil moisture on nutrient migrations is a combinative effect of capacity and seasonal prolongation. The dominant impact of soil moisture on nutrient migrations in the Peat soil is also supported by the distinct relation between TDS and EC (**Figure 8**). Moreover, the complex interactions between TDS, TSS and EC are shown in **Figures 9-11**: inverse relations between EC and TSS as well as between TSS and TDS confirm distinct positive relations between soil moisture (expressed as TDS) and EC (**Figure 9**). It is essential to note that nutrient migration in this study is evaluated using spatial and temporal measurements, whereas geochemical processes are not accounted for. An indirect confirmation of the sole impact of soil wettability is coming from the stable with negligible fluctuation of the pH values. The temporal trends of nutrient migration and their dependence on soil moisture and consequently climate changes emphasize the management implication outcome: enhancement of summer irrigation water allocation aimed at salts leaching.

5. Conclusion

Quantified temporal and seasonality of climate condition of rain capacity measures as mm/annum or periodical distribution respective to the number of rainy days, and nutrient migrations from the Hula Peat soil are dependently correlated. The higher the rain capacity or temporal distributional dispersed, the higher the nutrient concentration. The ecological significance of correlative similarity between migration dynamics of Alkalinity, Sulfate, Total Dissolved Solids and Electrical Conductivity confirm mutual properties of weakness adhesion onto the peat soil particles. A common abrupt response is the increase of soil salinity. Additional irrigation water allocation to enhance salts leaching is therefore recommended.

Acknowledgements

The author would like to express his sincere appreciation to Prof. D. Levanon and D. Klein for their fruitful and friendly collaboration; V. Orlov-Levin and M. Peres for providing unpublished data supply; T. Natanson and E. Yasur for their assistance in field sampling.

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.

Funding

This study was supported by the MIGAL-Galilee Scientific Research Institute.

Conflicts of Interest

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

References

[1] American Public Health Association, American Water Works Association, Water Environmental Federation (2023) Standard Methods for the Examination of Water and Wastewater. 24th Edition, APHA Press.

[2] HPDB (1994-2019) Hula Project Data Base. MIGAL-Galilee Scientific Research Institute.

[3] Gophen, M. and Levanon, D. (1994-2006) Hula Project, Annual Reports. MIGAL-Scientific Research Institute, Jewish National Fund (Keren Kayemet LeIsrael), US Forestry Service International Project, Israeli Water Authority. (In Hebrew)

[4] Gonen, E. (2007) Hula Project Annual Report. Jewish National Fund (Keren Kayemet LeIsrael) MIGAL-Scientific Research Institute and Israeli Water Authority, 133 p. (In Hebrew)

[5] Barnea, I. (2008) Hula Project Annual Report. Jewish National Fund (Keren Kayemet LeIsrael) MIGAL-Scientific Research Institute and Israeli Water Authority, 159 p. (In Hebrew)

[6] Barnea, I. and Kaplan, D. (2008-2018) Hula Project Annual Report. Jewish National Fund (Keren Kayemet LeIsrael) MIGAL-Scientific Research Institute and Israeli Water Authority, 232 p. (In Hebrew)

[7] Perlson, O., Klein, D. and Kaplan, D. (2021) Hula Project Annual Report. Jewish National Fund (Keren Kayemet LeIsrael), MIGAL-Scientific Research Institute and Israeli Water Authority, 127 p. (In Hebrew)

[8] Hollis, G.E. (1990) Environmental Impacts of Development on Wetlands in Arid and Semi-Arid Lands. *Hydrological Sciences Journal*, **35**, 411-428. https://doi.org/10.1080/02626669009492443

[9] Kracauer Hartig, E., Grozev, O. and Rosenzweig, C. (1997) Climate Change, Agriculture and Wetland in Eastern Europe: Vulnerability, Adaptation and Policy. *Climatic Change*, **36**, 107-121. https://doi.org/10.1023/a:1005304816660

[10] Snyder, G.H., Deren, C.W. and Glaz, B. (1999) Wetland Crops versus Wetland Drainage. *HortScience*, **34**, 46-49. https://doi.org/10.21273/hortsci.34.1.46

[11] AMI (Agriculture Ministry, Israel) (1986) Hula Valley: Soil Survey, Final Report. Agriculture Ministry, Water Commission, Department of Soil Conservation and Drainage, 45 p.

[12] Barnea, I. (2009) Reexamination of Phosphorus Practices in the Altered Wetlands Soils of Hula Valley, Israel. MSc Thesis, Faculty of Agriculture, Food and Environ-

mental Quality, The Hebrew University, 104 p. (In Hebrew, English Abstract)

[13] Howarth, R.W. and Cole, J.J. (1985) Molybdenum Availability, Nitrogen Limitation, and Phytoplankton Growth in Natural Waters. *Science*, **229**, 653-655. https://doi.org/10.1126/science.229.4714.653

[14] Marino, R. and Howarth, R.W. (2016) Why Is Planktonic Nitrogen Fixation So Rare in Coastal Marine Ecosystems? Insights from a Cross-Systems Approach. In: Gilbert, P. and Kana, T., Eds., *Aquatic Microbial Ecology and Biogeochemistry*: *A Dual Perspective*, Springer International Publishing, 127-139. https://doi.org/10.1007/978-3-319-30259-1_11

[15] Gophen, M. and Levin-Orlov, V. (2022) Sulfate (SO_4^{2-}) Decline Supported Lake Kinneret (Israel) Invasion of N_2-Fixing Cyanobacterium *Aphanizomenon ovalisporum*. *Hydrobiology*, **1**, 146-163. https://doi.org/10.3390/hydrobiology1020012

[16] Gophen, M. (2022) Lake Kinneret (Israel) Invasion by N_2-Fixer Cyanobacterium Was Enhanced Simultaneously by Nitrogen Deficiency, Phosphorus Sufficiency, and Sulfate Decline. *Modern Approaches in Oceanography and Petrochemical Sciences*, **3**, 278-282.

[17] Pecharova, E., Hezina, T., Prochazka, J., Prikryl, I. and Pokorny, J. (2001) Restoration of Spoil Heaps in Northwestern Bohemia Using Wetlands. In: Vymazal, J., Ed., *Transformations of Nutrients in Nature and Constructed Wetlands*, Buckhus Publishers, 129-142.

[18] Markel, D., Sass, E., Lazar, B. and Bein, A. (1997) Iron and Sulfur Interactions in Anaerobic Sediments: Toxicity to Macrophytic Vegetation in the Newly Created Agmon Wetland, Northern Israel. *Proceedings 4th International Conference Biogeochemistry of Trace Elements*, Berkeley, 23-26 June 1997, 5270.

[19] Reddy, K.R., White, J.R., Wright, A. and Chua, Y. (1999) Influence of Phosphorus Loading on Microbial Processes in the Soil and Water Column of Wetlands. In: Ready, K.R., O'Connor, G.A. and Schelske, C.L., Eds., *Phosphorus Biogeochemistry in Subtropical Ecosystems*, CRC Press, 249-271.

[20] Hambright, K.D., Bar-Ilan, I. and Eckert, W. (1998) General Water Chemistry and Quality in a Newly-Created Subtropical Wetland Lake. *Wetlands Ecology and Management*, **6**, 121-132. https://doi.org/10.1023/a:1008484506420