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The Coincidence of Nitrate Migration and Salinization Processes Led by Soil Moisture Enhancement in the Hula Valley

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Abstract

The drainage of the Hula wetlands and old Lake Hula was completed in 1957. Agricultural development replaced the natural ecosystem land use with agricultural cultivation. The Hula pre-drainage anaerobic conditions were replaced by organic matter oxidation and Sulfur and Nitrate carbonate enrichments. The ecosystem structure of highly diversified fauna and flora was devastated. During the post-drainage period, enhancement of accumulated carbonates and Gypsum ($CaSO_4$) and organic matter oxidation created soil salinization and nitrate accumulation. Ammonia was oxidized to nitrate, and its accumulation was concerned to Kinneret water quality protection managers. Evaluation of long-term (1994-2024) study through monitoring program of the temporal and seasonal distributional pattern of Nitrate, Sulfate, pH, Alkalinity, and Electrical Conductivity within the Peat soil drained and pore-waters indicates soil moisture as the dominant impact factor which controls two geochemically independent coincide processes, nitrate migration and soil salinization.

Keywords

Hula Valley, Nitrate, Salinization, Peat Soil Moisture

1. Introduction

The Hula Valley and Lake Kinneret are located in northern Israel's Syrian-African Great Rift Valley. Lake Kinneret is the only natural freshwater lake in Israel. Until 2010, an average of 336 mcm (336 million cubic meters) of water was pumped annually from the lake, supplied mostly for domestic usage and partly for agricultural irrigation. The water quality of Lake Kinneret is therefore a national concern, and pollutant migration from the Hula Valley is prominent. More than 95% of Israel's natural water resources are utilized. The total national water supply is 2.11 bcm (2.11 billion cubic meters), of which 0.55 bcm comes from the Kinneret–Jordan water system and 0.7 bcm comes from desalinization. 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 (Hatzbani, Banyas, and Dan) flow from the Hermon Mountain region in the northern part of the Kinneret drainage basin. These rivers join and form the Jordan River. Before the Hula drainage, the Jordan crossed the valley through three branches (tributaries) flowing into the old Lake Hula. From Lake Hula, at an altitude of 61 - 68 masl (m above mean sea level), the Jordan River flows downstream into Lake Kinneret (Mean WL 211 mbsl) for a distance of approximately 15 km. The altitude difference between top Hermon (2814 masl) and Kinneret WL (mean 211 mbsl) along a spatial distance of 70 km resulted in a mean slope of 4.3% creating a rather strong erosive force. The Jordan River contributes approximately 63% of the Kinneret water budget and more than 50% of the total external nutrient inputs. Before the drainage of the Hula Valley (1957), the land was covered by Lake Hula (1.5 m mean depth; 13 km^2 water surface) and 3500 ha of swamps. 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.

In the 1950s, the Hula Valley landscape underwent significant modifications. The anthropogenic intervention was carried out by drainage of the Hula swampy wetlands and old lake (1957). The land use was converted into agricultural development. Forty years later, as a result of cultivation difficulties, a reclamation project was implemented, the Hula Project (HP) resuming presently 30 years of existence. The Hula Project (HP) territory (**Figure 1**) is part of the total Hula Valley which is the northern section of the Syrian-African Great Rift Valley. HP is bordered between 70 - 61 MASL altitudes and 33˚06'12" North and 35˚36'33" latitude coordinates. Several developments and concerns were initiated as a result of organic matter oxidation. Frequent outbreaks of subsurface unsecured fire; Soil surface subsidence deteriorating the hydrological system; Nitrogen mineralization has led to the accumulation of weakly bound nitrates, increasing the risk of leaching into Lake Kinneret and deteriorating its water quality. Additionally, the Intrusion of soluble Gypsum into the Peat organic matter has contributed to increased levels of sulfate and calcium, enhancing soil salinization. A hypothesis was considered by the late principal Hula Peat soil scientist, Dr. I. Levin (D. Levanon, personal communication): there is a linkage between nitrate enhancement in Peat and its drained water and soil salinization process. The present study examines this 50-year-old assumption about the Ecological linkage between nitrate migration and soil salinization in the Hula Valley. As well as long-term records of the dynamics of Alkalinity (ALK), Electrical Conductivity (EC), Nitrate (NO_3), and Sulfate (SO_4) concentration [1]-

[3] in the Peat soil drained and porewaters water in relation with soil moisture were investigated. Soil moisture was investigated. The dynamics of the chemical composition of water sampled in Canal Z (**Figure 1**), which transporting drained water from the central Peat soil block in the Hula Valley conveyed into Lake Agmon Hula (LAH) (**Figure 1**) were evaluated. The migration of nutrients in Peat soil, including Nitrogen, Phosphorus, Carbonates, Sulfates, and others, occurs hypsometrically, directed downwards and horizontally (spatially). This process continues continuously, representing seasonal fluctuations. A significant portion of those nutrients are deeply buried. A portion of the nutrients within the shallow (0 - 6 m) layers are exported horizontally in a north-south direction. Routine monitoring of Hydrological and soil moisture conditions was not documented in previous geological investigations in the Hula Valley. Nonetheless, the monitoring program of quantitative and qualitative qualities of surface waters was routinely recorded over the long term.

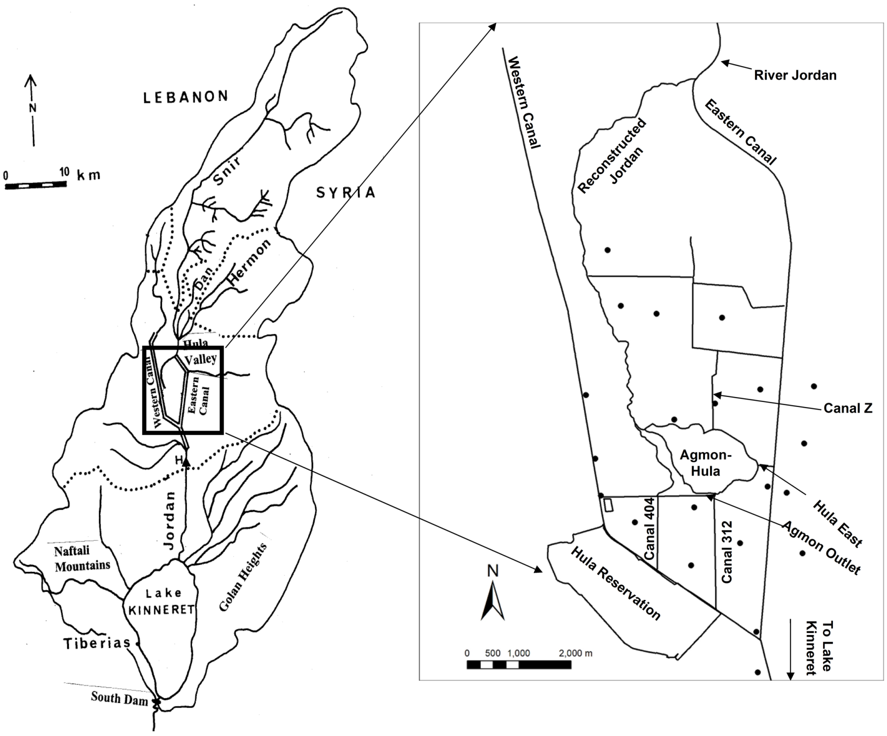

Figure 1. Geographic outline chart map of the Hula Project territory: Major ecosystem compartments and sampling stations are arrowed; black dots are borehole drill locations for the underground water (GWT) sampling.

2. Material and Methods

2.1. Sampling Methodology

Study Site (**Figure 1**):

The Hula Project (HP) territory (**Figure 1**) is part of the total Hula Valley which is the northern section of the Syrian-African Great Rift Valley. HP is bordered between 70 - 61 MASL altitudes and 33˚06'12" North and 35˚36'33" latitude coordinates.

Sampling Stations (Figure 1):

The 14 borehole drilling locations for the underground water sampling were selected as optimal presentation of soil types in the Hula Valley.

The four water sampling stations represent the minimum required for optimal presentation of different surface water types in the Hula Valley. Technical difficulties prevented sampling during winter floods and a few cases of extremely low GWT during the summer of the drought season.

1) Underground (GWT) waters were sampled in the 14 boreholes.

2) The entrance of Canal Z into Lake Agmon-Hula (LAH). Canal Z conveys drained water from the Central block of Peat Soil.

2.2. Sampling Methodology

Sampling was carried out weekly at: 1) the entrance of Canal Z (Canal 101) into Lake Agmon-Hula (LAH) Station 57; 2) Reconstructed Jordan, Station 48; 3) the outlet of Lake Agmon effluents Station 49 and 4) Hula East Station 73 (Figure 1). Analyzed parameters were: Electrical Conductivity (EC) (mS), NO_3 (ppm), SO_4 (ppm), Alkalinity (ALK) (as ppm$CaCO_3$), pH and discharge (10^3 m^3/hour). Canal Z conveys drained water from the Central block of Peat Soil within the Hula Project territory (Figure 1). The data obtained from the Hula Project Monitor Program (1994-2024): Migal-Galilee Scientific Research Institute, Jewish National Fund and Israel Water Authority [4]-[8].

2.3. Chemistry

The following parameters were analyzed as instructed in Standard Methods APHA 2023:

Electrical Conductivity (EC)(mS), NO_3 (ppm), SO_4 (ppm), Alkalinity (ALK) (as ppm $CaCO_3$), pH and discharge (10^3 m^3/hour).

Electrical Conductivity (EC) was measured by a Conductivity meter *in-situ* in the Ground Water Table and experimentally in sampled waters.

Nitrate analysis was carried out using the Cadmium Reduction (NED) method on a Millipore-filtered sample. The analysis of ammonia was done using the Indophenol Method, which is based on the formation of a blue color resulting from the reaction between phenol and hypochlorite in the presence of ammonia (APHA 2023).

The data obtained from the Hula Project Monitor Program (1994-2024): Migal-Galilee Scientific Research Institute, Jewish National Fund and Israel Water Authority [4]-[8].

2.4. Statistical Methods

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

2.5. PCA Analysis

PCA Analysis is a dimensionality reduction technique for exploratory data analysis of a multivariate Gaussian distribution. The vectors shown and the separated Biplot presentation are used to visualize the data preprocessing. The data is linearly transformed into a new coordinate system such that the directions (principal components) capturing the largest variation in the data can be identified. PCA is used when variables are correlated with each other, and it is desirable to reduce their number to an independent set. The first principal component can equivalently be defined as a direction that maximizes the variance of the projected data. PCA defines a new orthogonal coordinate system that optimally describes variance in a single dataset.

The statistical evaluation was carried out using the software STATA 17.0-Standard Edition for Statistics and Data Science.

3. Results

3.1. Seasonal Fluctuations

The seasonal (monthly) distribution (Quadratic Regression, w/CI95%) of NO_3, Alkalinity and SO_4 concentrations, pH, and Electrical Conductivity in Canal Z averaged for 1994-2024 are given in Figures 2-6.

Results given in Figure 2 indicate that rainfall impacts soil moisture, enhancing the migration of NO_3 within the peat soil habitat, which is high from December to March and lower later.

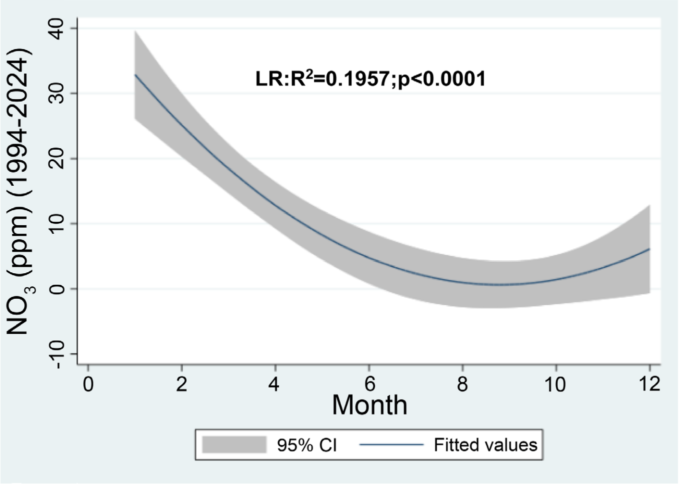

Figure 2. Seasonal (monthly) changes (1994-2024) of NO_3 concentration (ppm): Quadratic regression plot (Linear Regression parameters are given).

Results given in Figure 3 indicate that similar to the NO_3 pattern of seasonal changes, the EC level in the Peat soil drained waters is rainfall and consequently soil moisture dependent: Increase during September-April and decline later.

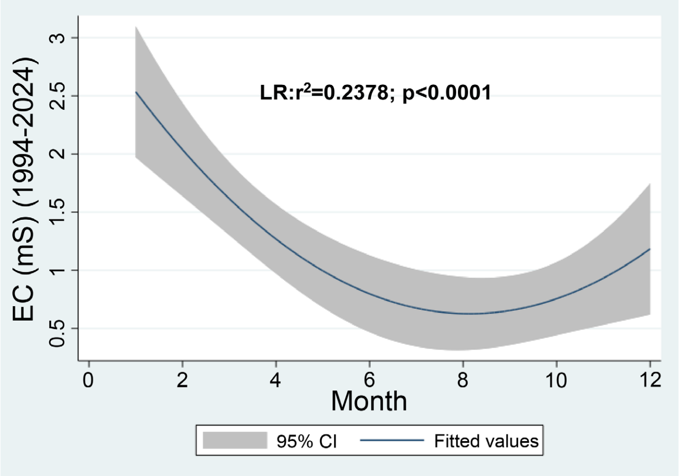

Figure 3. Seasonal (monthly) changes (1994-2024) of Electrical Conductivity (EC): Quadratic regression plot (Linear Regression parameters are given).

Results given in **Figure 4** indicate that similar to NO_3 and EC pattern of seasonal changes, the ALK level in the Peat soil drained waters is rainfall and consequently soil moisture dependent: Increase during Winter and decline during Summer.

The seasonal fluctuations of NO_3, EC and Alkalinity are dependent on rainfall and consequently soil moisture changes pattern.

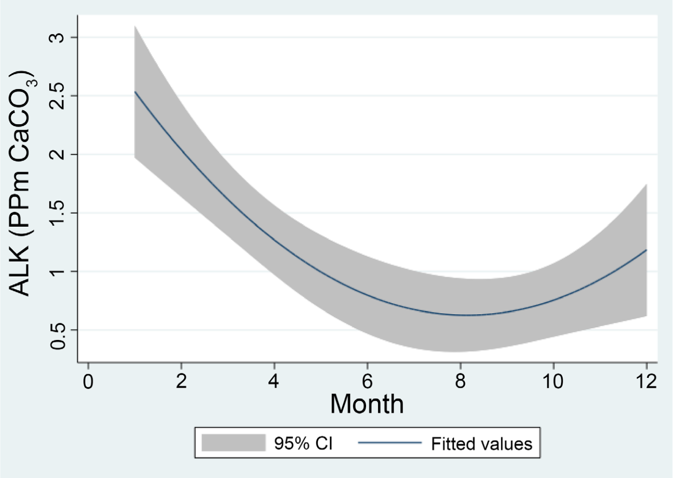

Figure 4. Seasonal (monthly) changes (1994-2024) of Alkalinity (ALK) (ppm $CaCO_3$, Quadratic regression plot.

Results shown in **Figure 5** indicate that, unlike seasonal fluctuation of NO_3, EC and Alkalinity, the amplitude of seasonal pH fluctuations is rather stable.

Seasonal Rainfall and Peat soil moisture induce seasonal fluctuations whilst pH changes are minor. Seasonality of nitrates and carbonate (ALK) drifted by drained waters from the peat soil, consequently enhancing EC elevation (salinization), which is a seasonal case process.

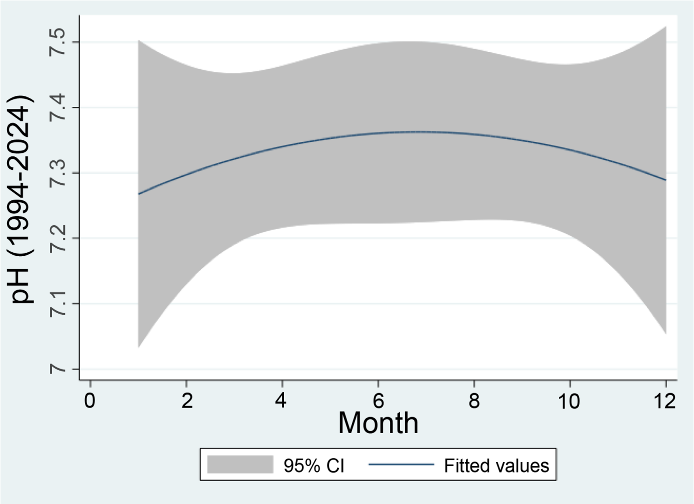

Figure 5. Seasonal (monthly) changes (1994-2024) of pH, Quadratic regression plot.

Results given in **Figure 6** indicate the similarity of SO_4 to NO_3, ALK and EC patterns of seasonal changes. The proof of the dependence of SO_4 to NO_3, ALK and EC distribution in rainfall and soil moisture distribution in the Peat soil-drained waters is getting stronger. The seasonal fluctuations of NO_3, EC, Sulfate and Alkalinity in the Peat soil-drained water are dependent on rainfall and consequently soil moisture pattern of changes.

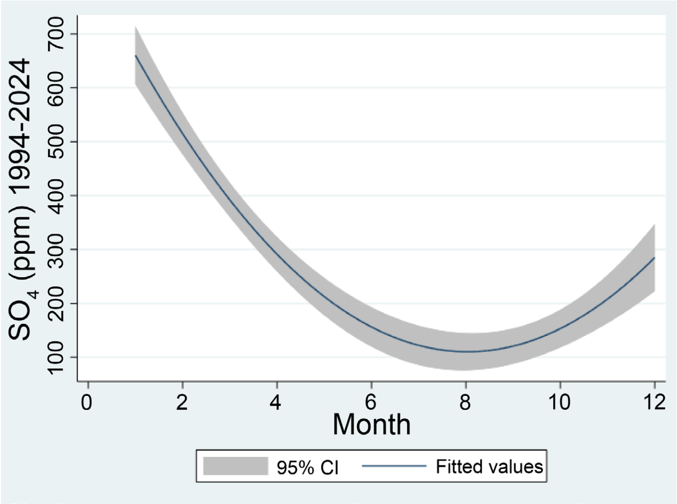

Figure 6. Seasonal (monthly) changes (1994-2024) of Sulfate (SO_4) (ppm), Quadratic regression plot.

3.2. Temporal Fluctuations

The Temporal, annual averages (1994-2024) distribution of EC, NO_3 concentration, pH, Alkalinity, and SO_4 concentrations in Canal Z averaged for 1994-2024 are given in **Figures 7-9**.

Results given in **Figure 7** confirm that during 1994-2024, unlike EC, temporal changes of NO_3 (ppm)are minor.

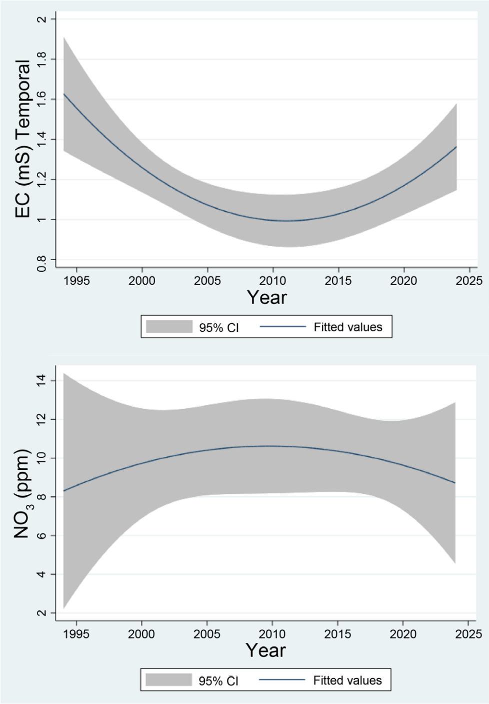

Figure 7. Quadratic regression plot of temporal fluctuations of EC (upper) and NO_3 (lower) during 1994-2024.

Results given in **Figure 8** confirm minor temporal fluctuations of pH and a distinct decline of ALK during 1994-2002 and a slight increase later.

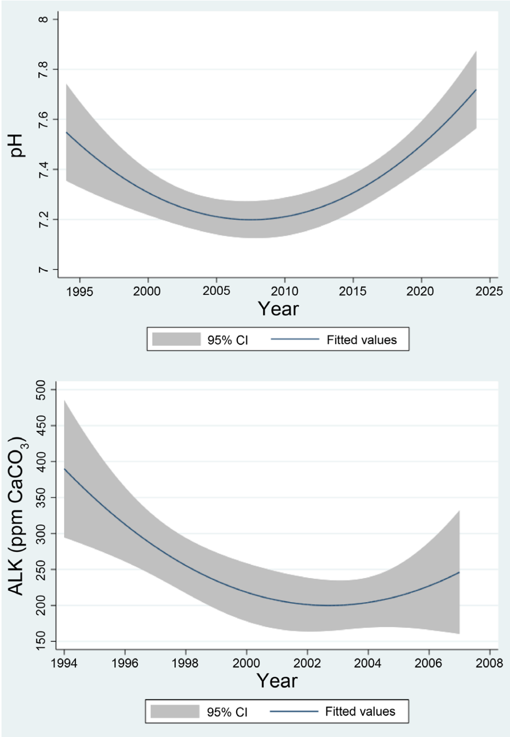

Figure 8. Quadratic regression plot of temporal fluctuations of pH (upper) and ALK (lower) during 1994-2024.

Results confirm the similarity between seasonal and temporal patterns of distribution of pH, EC, ALK and SO_4 parameters: winter elevation and summer decline. The temporal distribution of NO_3 is exceptionally different.

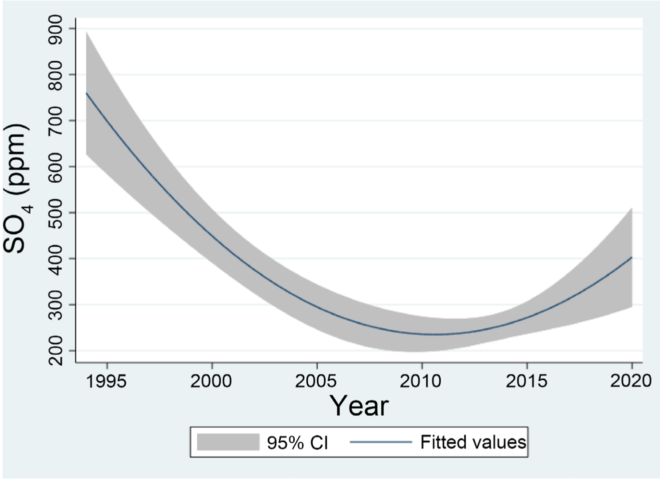

Figure 9. Quadratic regression plot of temporal fluctuations of Sulfate (SO_4); t) from 1994-2024.

Results given in **Figures 2-6** indicate that seasonal distribution patterns of EC, ALK, SO_4 and NO_3 are similar: high in winter and summer decline. The pattern of temporal distribution of EC, pH, ALK, and SO_4 (**Figures 7-9**) are also similar: decline during 1994-2010. Two distributional pattern exceptions were documented: seasonal pH and temporal NO_3. Soil moisture seasonality, characterized by high levels in winter and declines in summer, significantly impacts changes in the concentration of parameters (EC, pH, Alkalinity, and SO_4) in drained waters, and this relationship is therefore confirmed. The temporal pattern of NO_3 changes represents stability due to its high availability resulting from the high Ksp of $Ca(NO_3)_2$ in comparison with much lower Ksp of SO_4 carbonate (Gypsum). The similarity of temporal and seasonal changes of EC, pH, SO_4 and ALK confirm a similar response of migration capacity to soil moisture.

3.3. Interactions between EC, NO_3, and ALK Parameters

The interactive relations between NO_3 and EC, EC and Alkalinity and NO_3 and Alkalinity are plotted as Linear regressions and presented in **Figures 10-12**.

The significant relationship between NO_3 and EC parameters in the Peat soil drained water is clearly shown in **Figure 10**.

The significant relationship between EC and ALK parameters in the Peat soil drained water is clearly shown in **Figure 11**.

The significant relationship between NO_3 and ALK parameters in the Peat soil drained water is clearly shown in **Figure 12**.

Soil moisture is dependent on two water sources: Rainfall and irrigation. Quantitative Irrigation data is not available and rainfall capacity as averaged (1994-2024) for 3 stations in the Hula Valley is given in **Figure 13**.

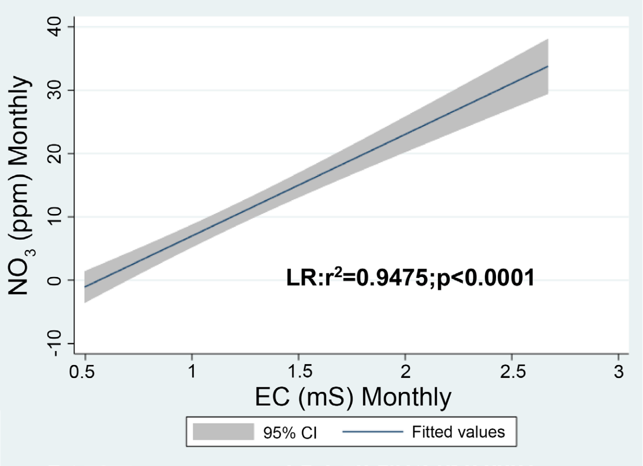

Figure 10. Linear regression between the monthly mean distribution of NO_3 (ppm) and EC (mS) during 1994-2024.

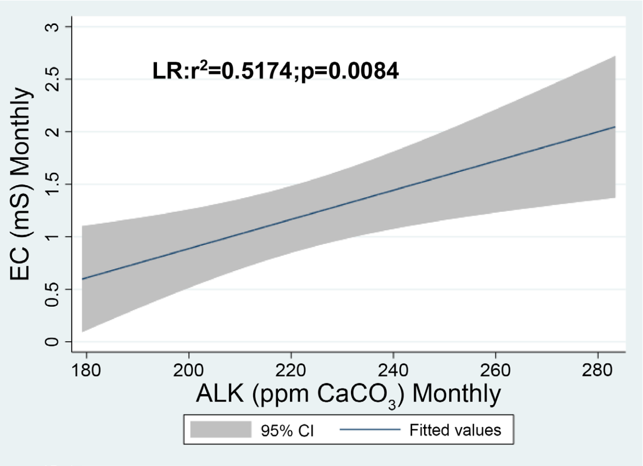

Figure 11. Linear regression between the monthly mean distribution of EC (mS) and ALK (ppm $CaCO_3$) during 1994-2024.

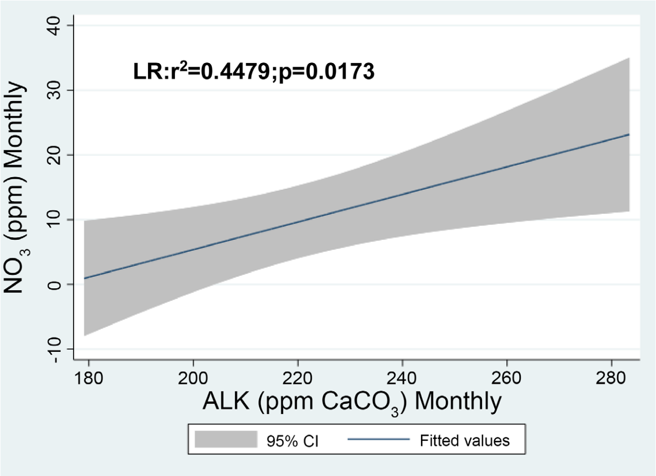

Figure 12. Linear regression between the monthly mean distribution of NO_3 (ppm) and ALK (ppm $CaCO_3$) during 1994-2024 [3]-[8].

The sub-tropical climate conditions of 4 winter wet months (12-1-3) and 8 dry summer months (4 - 11) are presented in **Figure 13**.

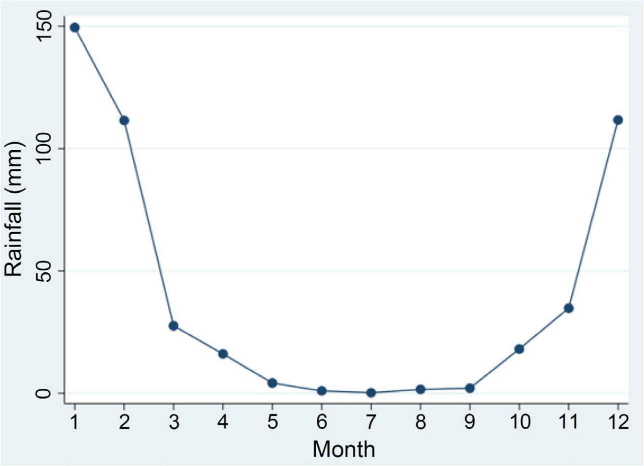

Figure 13. Monthly Rainfall (mm), average (1994-2024) of Gadash, Kfar Blum and Dafna meteorological Stations in the Hula Valley.

3.4. Climate Change (Rainfall) and Ground Water Table Relations

Statistical evaluation (Linear Regression) of rainfall records (2002-2017) in three stations (Gadash, Kfar Blum, Dafna) located in the Hula Valley has indicated significant similarity between each other with the following range of parameters: $r^2 = 0.847 – 0.5145$; $p = <0.0001 – 0.0018$. The statistical relations (Linear Regression (w/95%CI) between mean (3 stations) annual rainfall and the depth (annual mean) of Ground Water Table (GWT) and the temporal changes of rainfall capacity are given in **Figure 14** and **Figure 15**.

Results given in **Figure 14** indicate a positive relation between rainfall and GWT: The higher the rain, the higher is the GWT and consequently soil moisture.

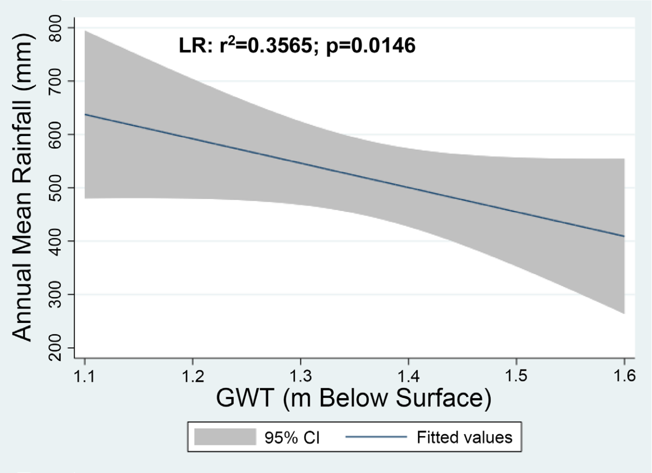

Figure 14. The statistical relations (Linear Regression (w/95%CI) between mean (3 stations) annual rainfall and the depth (annual mean) of Ground Water Table (GWT). Parameters of Linear regression (**r^2**, p) are presented.

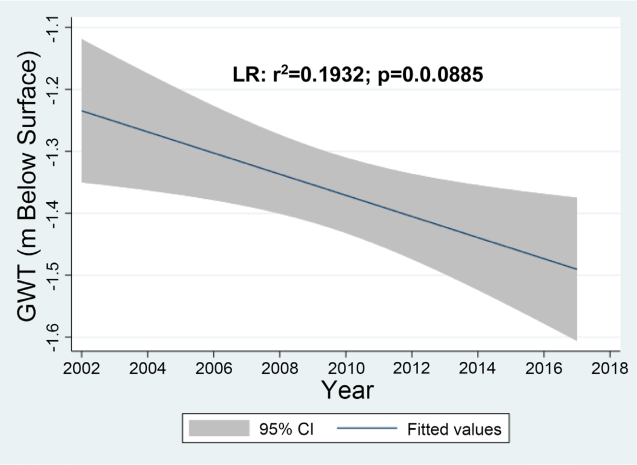

Figure 15. Linear Regression (w/95%CL) between temporal (2002-2017) changes of Ground Water Table (GWT) depth (m below surface) and years. Regression parameters (r^2, p) are presented.

Considering **Figure 14**, the temporal decline of rainfall was associated with a lowering trend of GWT.

Results presented in **Figures 14-16** indicate the impact of climate change on soil moisture, GWT and consequently on the dynamics of nutrient migration in the Hula Valley.

3.5. Principal Component Analysis (PCA)

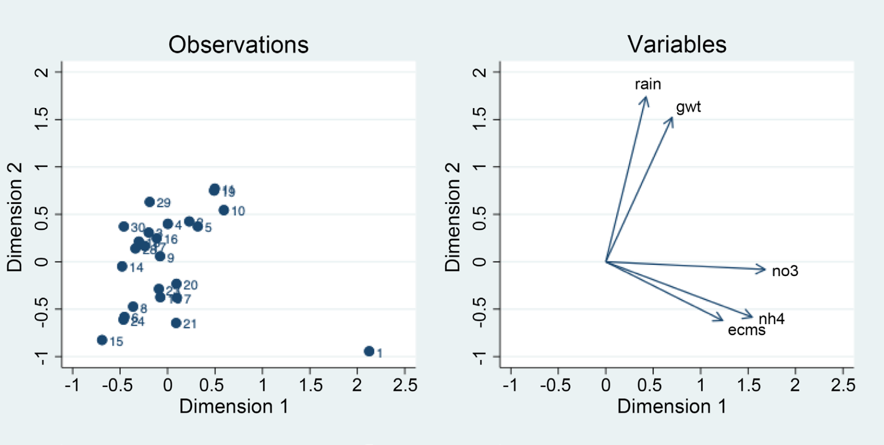

Figure 16. Graphical layout of PCA analysis/Biplot presentation of environmental variable combinations, NO_3, NH_4, Ground Water Table (total valley annual means, 1994-2024) and Annual rain (mean, Dafna).

Table 1. Principle component (Eigenvector) and explained variance by components.

Variables	dim1	dim2
EC (mS)	1.2315	−0.6198
Annual Rain(mm)	0.4241	1.7379

Continued

GWT (MBS)	0.6983	1.5201
NO_3 (ppm)	1.6780	−0.0806
NH_4 (ppm)	1.5417	−0.5839

Coordinates 1 and 2 and total, Explained variance by component 1 = 0.4535, Explained variance by component 2 = 0.3063, Total explained variance = 0.7598.

Principle components (Eigenvector): NO_3, NH_4 and EC are negatively (inversely) correlated with Dimension 2 and all other relations are positive. (**Table 1**)

4. Discussion

The Hula Valley ecosystem during the post-drainage period created environmental obstacles: efficient agricultural management without Kinneret water quality deterioration. The newly created ecosystem required a relevant management program suitable for the maintenance of agriculture, tourism and Kinneret water quality protection. The factors of nitrate migration and soil salinization are critical. Awareness of the following contradicted interests involvement within such a complicated ecosystem were: Nature protectors against natural ecosystem devastation; Agro-economical demands, such as fertilization or irrigation water allocation by the farmer's land owners; prevention of pollutants leaking into Lake Kinneret by water managers; Touristic optional attractions for recreational designers. Therefore, the relationship between NO_3 migration and soil salinization, typical Hula Valley compartments, deserves a thorough consideration. The enhancement of soil moisture, which was one of the conclusions of the Hula Reclamation Project, was successfully implemented. Nevertheless, salinization was enhanced as well, and NO_3 migration continued intensively.

Not very many Peat soil studies in the Hula Valley were carried out before drainage [9] [10]. Shortly after the Hula drainage, intensive investigations of the Peat soil texture, other edaphic features, Peat drained and porewaters and environmental impact consequences were carried out [11]-[16]. These studies documented Gypsum accumulation and dissolution resulting in SO_4, and Ca common components of Peat soil composition. Over a period of 40 years after drainage, the oxidation processes in Peat organic matter resulted in the production of nitrates in the peat soil, accompanied by sulfate (SO_4) in both the soil's porewater and drained waters [15]-[17]. During 1994-2024, the implementation of the Hula reclamation project (HP) [18]-[20] of the Peat land was carried out. A major part of the renovated hydrological management was due to the upper (5 - 7 m below surface) Peat soil layers implementing an increase in soil moisture and elevation of the Ground Water Table (GWT). Temporal and seasonal peat soil moisture enhancement, accompanied by GWT elevation, enriched NO_3, SO_4, and ALK, and increased EC in the drained water.

Calcium Carbonate (source of alkalinity) and Calcium Sulfate (Gypsum, source of Sulfate) in the Peat soil were formed as common components of the Peat soil during the post-Hula drainage period. Consequently, Gypsum dissolution enriched Ca^{2+} and SO_4^{2-} inputs into the drained waters, sourced from rainfall and irrigation. Enhancement of Ca^{2+} dissolution combined with elevation of Alkalinity (water capacity to resist acidification) resulted from organic matter decay initiated precipitation of $CaCO_3$ [17]. During the post-Hula drainage period, organic matter was oxidized, emphasizing the conversion of Ammonia to Nitrate and Sulfur to Sulfate [21]. The results presented in **Figures 2-6** (excluding **Figure 5**) (seasonal changes) and **Figures 7-9** (excluding **Figure 7**) (Annual temporal changes) indicate a similar distributional pattern: winter increase and summer decline of NO_3, EC, Alk, and SO_4 (seasonal) and EC, pH, ALK, and SO_4 (temporal). It is therefore suggested that the activation factor of Peat nutrient migration is soil moisture. The rainfall seasonality, as measured in 3 stations in the Hula valley, is a typical sub-tropical regime (**Figure 12**) which is identical to the seasonality presented in **Figures 2-6** (excluding pH, **Figure 5**). The very minor changes in seasonal pH indicate Buffer capacity done by the ALK component.

The decomposition of the high content of organic matter in Peat demands ALK buffer which is supplied through Gypsum dissolution, accompanied by enhancing EC (salinization) which is an agricultural disadvantage.

Comparative temporal distribution patterns of NO_3 and the other soluble components (ALK, SO_4) indicate discrepancy. The NO_3 pattern represents temporal stability and that of SO_4 indicates a decline during 1994-2012 and an increase later. On the contrary, the seasonal patterns of SO_4 and ALK of winter high and low in summer and that of NO_3 are similar. The seasonal and temporal distribution patterns represent the minor amplitude of pH value fluctuation. Linear Regressions of seasonal distribution of soluble components represent highly significant indication:

ALK vs SO_4: $r^2 = 0.4734$; $p = 0.0134$

EC vs SO_4: $r^2 = 0.9689$; $p < 0.0001$

NO_3 vs SO_4: $r^2 = 0.9351$; $p < 0.0001$

All linear regressions between the seasonal distribution pattern of pH and soluble components were significant.

It was reported that shortly after Peat soil moisture enhancement by sprinkle irrigation, an increase in denitrification activity and nitrate content enhancement were recorded [22]. Moreover, alternate wet-dry conditions during the summer irrigation regime enhanced nitrogen mineralization of the Peat organic matter and nitrate content increase [22]. The inorganic Peat constituents include, among others, $CaSO_4$. (Gypsum), $CaCO_3$, $Ca(NO_3)_2$, or $NaNO_3$. The solubility Products (equilibrium) and Solubility Constants (Ksp) of these salts are different. The more soluble a substance is, the higher its Ksp value. Alternate cycling of wet-dry through seasonality of rain capacity or temporal climate change or irrigation management induces significant changes in the Peat soil moisture. Consequently, soluble Peat soil products fluctuated respectively. Seasonal changes are respectively incorporated within the correlation plot curve. Despite different Ksp values for $CaCO_3$, $Ca(NO_3)_2$ and $CaSO_4$, the seasonal changes of soil moisture impact on their distributional patterns are similar. Meanwhile, the temporal distribution of NO_3 is significantly different from that of $CaSO_4$, Alkalinity, and EC. The Ksp of anhydrite ($CaSO_4$) ($10^{-4.36}$) and Hydrite ($CaSO_4 \cdot 2H_2O$) ($10^{-4.61}$) forms are significantly lower than that of $NaNO_3$ (0.804) or $Ca(NO_3)_2$ (1.2×10^{-2}). Likely, the long-term (1994-2024) evaluated record accompanied by respective Ksp values confirmed a higher temporal capacity of dissolved nitrate in comparison with sulfate (**Figure 7**). The dominant factor that effectively drains and flushes NO_3, SO_4, EC, and Alkalinity from the Peat soil into the underground waters and forwarding into Canal Z and LAH is soil moisture. The minor seasonal and temporal changes in pH (**Figure 5**, **Figure 8**) indicate high buffer capability. Soil moisture enhanced Peat soil salts migration accompanied by nitrates. About sixty years after the considered assumption, it was confirmed that salinization of the Peat soil was created not by external contributions but by internal resources within the Peat soil. The same generator creating salinization is recommended inversely to reduce salinity: summer freshwater enhancement l allocation.

The fate of nutrient migration in wetlands is a national and international issue [23]-[28]. The Hula drainage enhanced soil nitrogen oxidation, and nitrate replaced ammonium as a significant component within the Peat soil chemical composition. Ammonium migration from the unlimited stock of ammonium within the swampy wetlands was controlled by hydrological conditions. Nitrates are weakly bound to the Peat soil particles and efficiently disconnect and migrate through water flushing, rain in winter and irrigation in summer. Consequently, a hydrological regime through the Peat-soil defines the rate of nitrate migration from the Hula. The discharge capacity of the Kinneret inflow rivers is therefore the factor that controls load migration by biomass and concentration. The impact of climate change and anthropogenic involvement in the Hula Valley is affected by fluctuated wettability and consequently, soil moisture elevation which enhances NO_3 migration and consequently TN, whilst dryness enhances TP migration from the peat soil in the Hula Valley [23]-[26]. The shift of irrigation usage method from a "flood-capillarity" to moveable sprinkle lines and drip-irrigation, reduced significantly salt drainage water flux into the underground. The impacts of climate conditions (precipitation and discharge) on the nitrogen nutrient loads transportation respectively.

Water mass flow types in the Hula Valley include surface runoff as aerial flood dispersed and folded within the canal system and as underground gathered in preferential pathways (tunnels, or free space). Surface and shallow depths of underground water flows within the Hula Valley are mostly directed from north to south. Nevertheless, Artesian water migration was indicated and defined as significant underground water migration in the valley [29] and was considerable in the northern and not in the southern valley region. The hydraulic gradient oriented North-South was indicated [16]**.** Three Hypsometrical levels of underground water were defined in the Hula Valley: 1) Surface water; 2) Underground level (Ground Water Table) (GWT, 0 - 5 m below surface) [16]; 3) "Lignite waters" (5 - 150 m below surface) [30].

Downwards migrations of the Peat-Soil nutrients, including Nitrogen, Phosphorus, Carbonates, Sulfates, and others, occur continuously with seasonal fluctuations and a significant portion of those nutrients are deeply buried. Part of the nutrients within the shallow (0 - 6 m) layers are exported horizontally north-south directed. Previous geological investigations in the Hula Valley were documented [11] [31]-[35]. Nevertheless, documentation of hydrological monitor data and soil moisture conditions was not comprehensively accomplished [36]. Underground Peat-Soil water composition studies of deep and shallow depth were documented [16] [37]. Nonetheless, the monitoring program of quantitative and qualitative qualities of surface waters was routinely recorded over the long term. A comprehensive description of the upper (shallower) different soil types in the Hula Valley during the Post Drainage Era was widely documented (among others) [9] [21] [23] [29] [34]. The present study is an informative management tool for future management design. Varieties of nutrient compositions and their concentrations resulting soil and water salinization [38]. Calcium-Sulfur-Gypsum's Geochemical system plays the dominant role in the mechanisms of salinization in the Hula Valley [17] [39]. The present study emphasizes that salinization and nitrate migration processes in the Hula Valley are independent coincide phenomena driven by soil moisture. Nevertheless, a linkage factor through geochemical traits is absent.

The geochemical independence of nitrate migration and physical Peat soil ecosystem properties such as EC, pH, and alkalinity were widely documented. Nevertheless, $CaCO_3$ Cycling's impact on the buffer capacity, atmospheric CO_2 absorption, alkalinity, dissolved Ca, and EC in either aquatic or peat soil ecosystems was not correlated to NO_3 migration [40].

The dependence of Ca^{2+} Increase combined with release of alkalinity to organic matter decomposition in the sediments of LAH led to precipitation of $CaCO_3$ [17]. Nitrogen cycled (Nitrification and Denitrification, Ammonification) processes are produced independently with $CaCO_3$ cycle [17].

Environmental factors known to enhance denitrification include absence of O_2, redox potential, soil moisture, temperature, pH value, presence of denitrification bacteria, soil type, organic matter and moisture but nitrification is excluded. The impact of redox potential and pH value on denitrification in the Hula Peat soil is probably confounded by the impact of other environmental factors. Moreover, denitrification process does not commonly occur in the shallow Peat soil layer in the Hula Valley. The suggested independence of EC and NO_3 distributions is supported [41] [42]. The difference between nitrate concentrations, alkalinity, pH and EC values in drained waters from mineral [3] [43] and organic soil (this paper) is significant: pH, EC, and alkalinity values are higher and Nitrate concentration is lower in the mineral soil, whilst lower pH, alkalinity, and EC values and higher NO_3 concentrations in Organic Hula Peat soil drained waters. Independent responses to soil moisture impact by EC and nitrate concentration are therefore concluded [43].

5. Conclusion

Salinization and nitrate migration are geochemically independent coincident processes, both enhanced by elevated soil moisture, which are crucial for future management strategies. The already implemented recommendation to enhance water allocation for summer irrigation reduced soil salinity and phosphorus migration but enhanced NO_3 migration, which was indicated as not harmful to Kinneret water quality in present conditions of nitrogen insufficiency. Insufficient information about seasonal changes in the distribution of hypsometrical activity of nitrification and denitrification, emphasizing blocks of agricultural crop and bird roosting habitat, and soil sampling are included in future research perspectives.

Dedication

I dedicate this paper to the memory of Israel (Srulik) Levin, pioneer and one of the greatest researchers of the Hula Valley During Post Drainage, a brilliant scientist, devoted teacher, and beloved personality.

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Author Contributions

The author carried out data analysis, and 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.

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Conflicts of Interest

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

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