Open Journal of Ecology, 2024, 14, 331-342
https://www.scirp.org/journal/oje
ISSN Online: 2162-1993
ISSN Print: 2162-1985

The Peat-Organic-Soil in the Hula Valley

Moshe Gophen

MIGAL, Galilee Research Institute, Kiryat Shmona, Israel
Email: Gophen@Migal.org.il

How to cite this paper: Gophen, M. (2024) The Peat-Organic-Soil in the Hula Valley. *Open Journal of Ecology*, **14**, 331-342.
https://doi.org/10.4236/oje.2024.144020

Received: March 18, 2024
Accepted: April 20, 2024
Published: April 23, 2024

Abstract

The main soil type, principle contributor of nutrients and available agricultural land in the Hula Valley is the organic Peat. Nevertheless, the relative contribution of Phosphorus from the Hula Valley to the Lake Kinneret inputs is lower than regional outsourcing. The Nitrogenic matter, mostly Nitrate migration from the Peat soil is significant. The implementation of efficient development is the key factor of Hula Land use. The financial beneficial success of the Hula land use is therefore dependent of Peat soil properties. The porosity of the Peat Soil is high and preferential pathway volume is low and Hydraulic Conductivity is therefore low. Consequently, the Mobile Spray Irrigation line was found as most suitable for cultivation in Peat Soil. Enhancement of Summer irrigation creating moisture elevation reduces Phosphorus migration from Peat Soil and is therefore recommended and recently implemented.

Keywords

Peat, Wetting, Dryness, Alternate, Hula, Kinneret

1. Introduction

The drainage of the Hula swampy wetland and the old shallow lake was completed in 1957 and consequently, the very high variability of soil properties was indicated [1] [2] [3] [4] and a study of the soil properties became an essential demand. The newly created unfamiliar ecosystem resulting from the drainage was aimed at the development of agricultural land utilization. Consequently, agronomical research was required to ensure the prevention of water quality deterioration in Lake Kinneret and efficient cultivation. From the beginning of the research, it became clear that the Peat Soil area creates a critical part of the ecosystem that deserves special attention. The implementation of cultivation and irrigation methods which were carried out immediately after drainage was initiated suffered from lack of experience and the initiated research supported insufficient guidance. Therefore, crop cultivation on peat soil was partly inappropriate and was followed by damageable consequences such as underground fire and insufficient plant supply of irrigated water through unsuitable methods. During the second half of the 1990s, the Hula Project (HP) implementation was completed and agronomical utilization was significantly improved [5] [6]. Moreover, a comprehensive contribution capacity of nutrient migration by the Hula Valley into Lake Kinneret is presently known. One of the HP conclusions was to increase summer moisture of the cultivated land in the valley by higher Ground Water Table (GWT) and in the Peat Soil apart [7]. The dynamics of Nitrogen and Phosphorus contribution by Peat Soil worthwhile additional moisture in summer and a supplement of irrigated water was allocated. This paper is an attempt to analyze the uniqueness of the Peat Soil and the benefit value of additional summer irrigation to agriculture as well as to prevent Kinneret water quality deterioration.

2. Methods

The data of nutrient concentrations and loads and river discharges were taken from periodical and annual reports published by the Monitor Unit Jordan Districts, Mekorot Ltd., and Kinneret Limnological Laboratory, IOLR Ltd.; Data about nutrient concentrations in the runoffs in the Hula Valley from Hula Project, Migal, annual reports. Headwater River Discharges from interim and monthly and annual reports published by Israeli Water Authority, Hydrological Service Department [8] [9] [10] [11] [12].

Under the present renovated construction of the Hydrological system that was implemented by the HP operation drained water from the Peat Soil block is conveyed through Canal Z (synonym: Canal 101) into Lake Agmon Hula [5]. The analysis of the Nutrient migration from the Peat Soil is therefore associated with water flows in Canal Z [5].

Statistical evaluation and data presentation 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. Four statistical methods were utilized: Linear Prediction with Confidence Limit of 95% (w/Cl 95%); Quadratic Prediction (w/Cl 95%); Lowess Smoother and Linear Regression.

3. Results

Results given in **Table 1** indicate significant seasonal (month: from 1 to 12) decline of all parameters in the two periods, except significant seasonal increase of TP.

The seasonal (winter, summer) concentration of all nutrients, except Phosphorus in Canal Z, is significantly lower in summer whilst the opposite is for TP. These declines (whilst TP enhancement) are statistically significant. Moreover,

Table 1. Results of Linear regression (r^2 and significant value, p) between nutrient (TN, NO_3, NO_2, NH_4, TP, SO_4, $CaCO_3$, DO), concentrations, (ppm), and Electrical Conductivity (EC; mS) and months in Canal Z during two periods: 1995-2010 and 2007-2012. ALK-Alkalinity, as $CaCO_3$ (ppm). A temporal trend of decline or increase is indicated. The presented results indicate how much the seasonal (monthly) trend are related to changes (decline or increase) of the environmental conditions.

Parameter	r^2 (1995-2010)	p (1995-2010)	r^2 (2007-2012)	p (2007-2012)
TN	0.5725	0.0135	0.5371	0.0103
NO_3	0.5037	0.0097	0.5281	0.0074
NO_2	0.4725	0.0135	0.5112	0.0090
NH_4	0.4716	0.0136	0.4376	0.0191
TP	0.2460	0.1010	0.4599	0.0153
SO_4	0.4991	0.0171	0.4220	0.0222
Alk.	0.5304	0.0072	0.5965	0.0032
EC	0.4501	0.0169	0.6403	0.0029
DO	0.5552	0.0054	0.5583	0.0052

no difference was indicated between the two periods, 1995-2010 and 2007-2012. Consequently, the management policy of supplemental summer Peat Soil moisture enhancement by irrigation is justified. The DO concentration is temperature dependent and soil moisture enhancement might cause diminishment of soil temperature. The higher temperature in summer consequently declines DO concentration as the result of lower Oxygen solubility. It is suggested that increased moisture might decrease soil temperature and consequently elevate DO concentration. Results given in figures and **Table 1** indicate a summer decline of Nitrogenic nutrients, TN, NO_3, NO_2, NH_4, carbonates (and consequently EC) and Gypsum (SO_4) with an increase in TP concentrations. It is suggested that summer moisture enhancement might induce invertible development, decline of TP and increase of nitrogenic and carbonate substances. The level of the Correlation Coefficient (r^2) is high in both periods whilst that of the 2007-2012 period is higher: The total mean of r^2 for the 2007-2012 and 1995-2010 periods is 0.5212 and 0.4779 respectively. It is therefore suggested as an indication of a continuous developmental promotion of nutrient migrations from the Peat Soil during post-Hula Project implementation.

Results presented in **Figures 1-4** indicate higher nitrogenic nutrient migrations during winter time, from November through October next year, and continuous diminishment in summer when soil moisture declines.

The TP migration (**Figure 5**) from the Peat Soil is the opposite, low in winter and high in summer [13].

The migration dynamics of Carbonates and Gypsum from the Peat Soil are presented in **Figures 6-8**. When soil moisture is high in winter, Gypsum and Carbonate dissolution is intensive causing enhancement of SO_4, Alkalinity and EC. In the summertime, moisture decline induces lower levels of dissolution and therefore, their migration.

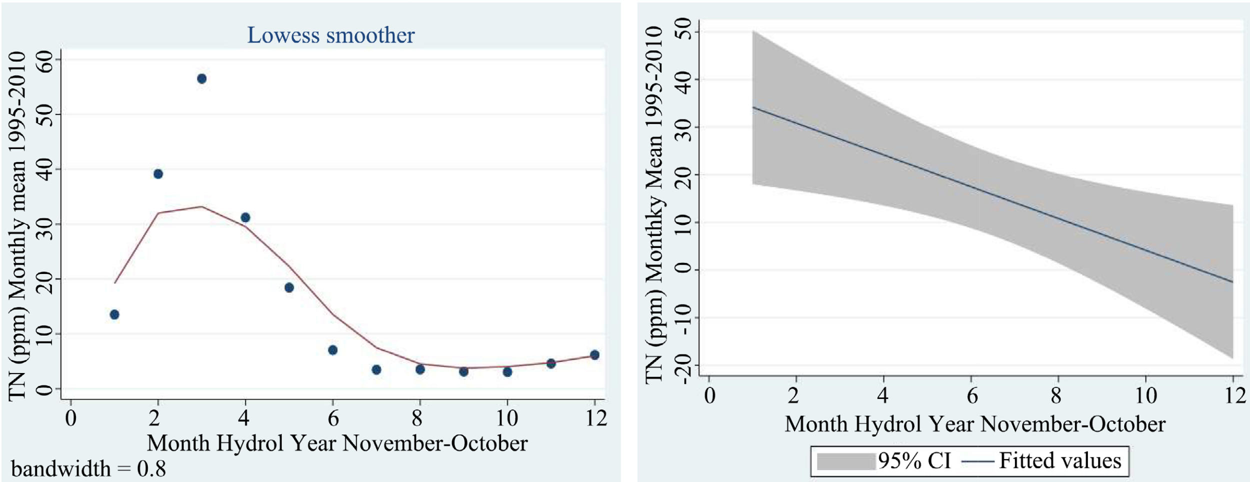

Figure 1. Monthly mean changes of TN concentration (ppm) in Canal Z during 1995-2010: Left Panel: Lowess Smoother; Right Panel: Linear Prediction w/Cl, 95%.

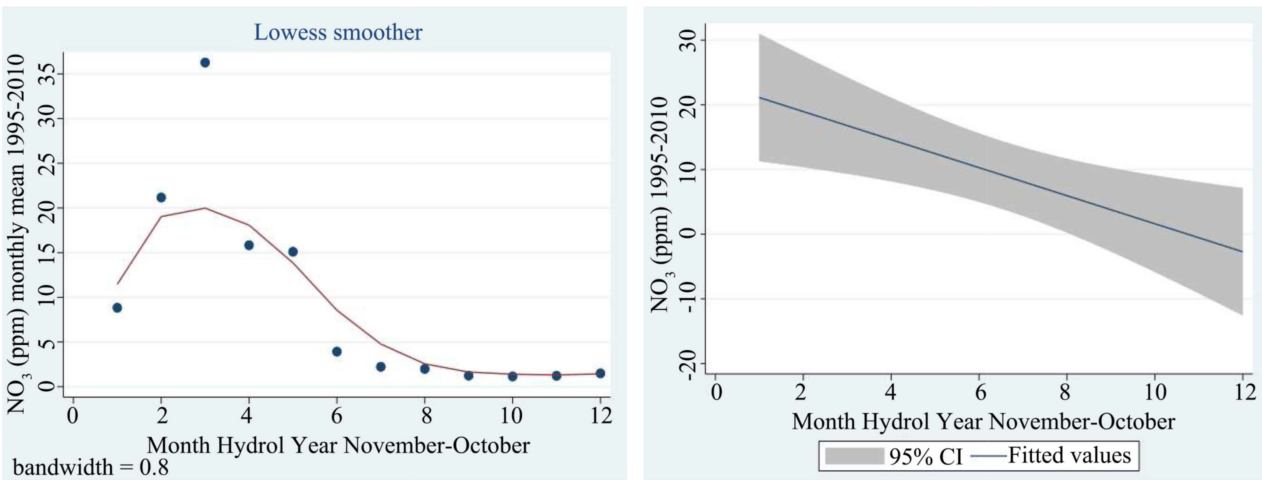

Figure 2. Monthly mean changes of NO_3 concentration (ppm) in Canal Z during 1995-2010: Left: Lowess Smoother; Right: Linear Prediction w/CI, 95%.

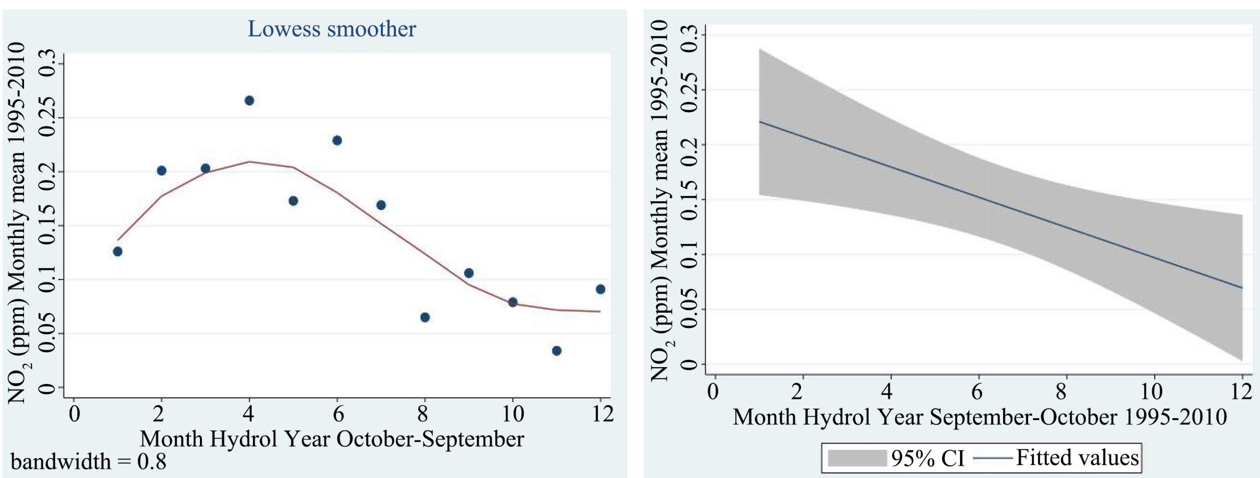

Figure 3. Monthly mean changes of NO_2 concentration (ppm) in Canal Z during 1995-2010: Left: Lowess Smoother; Right: Linear Prediction w/CI, 95%.

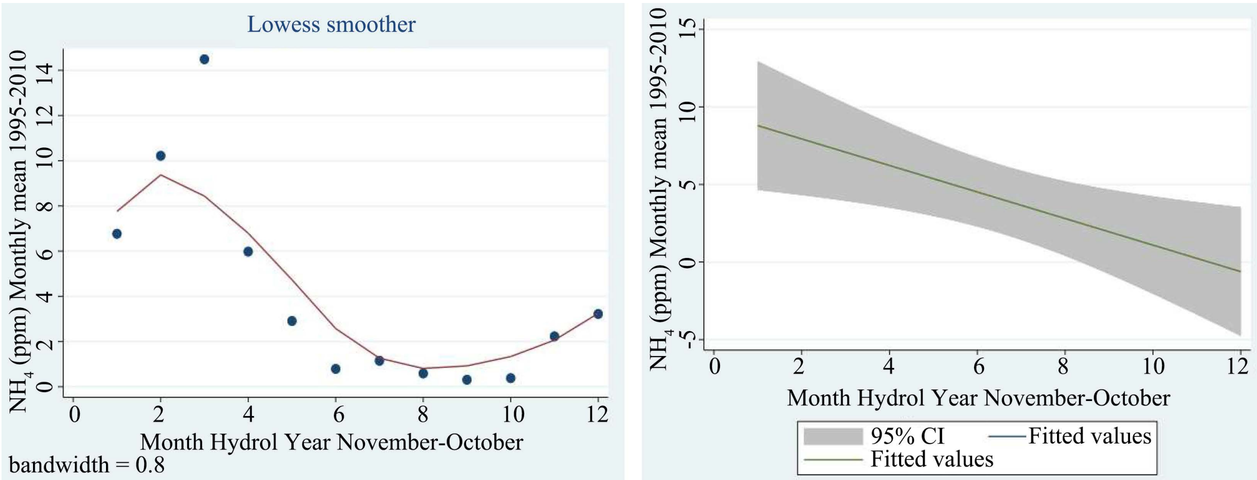

Figure 4. Monthly mean changes of NH_4 concentration (ppm) in Canal Z during 1995-2010: Left: Lowess Smoother; Right: Linear Prediction w/CI, 95%.

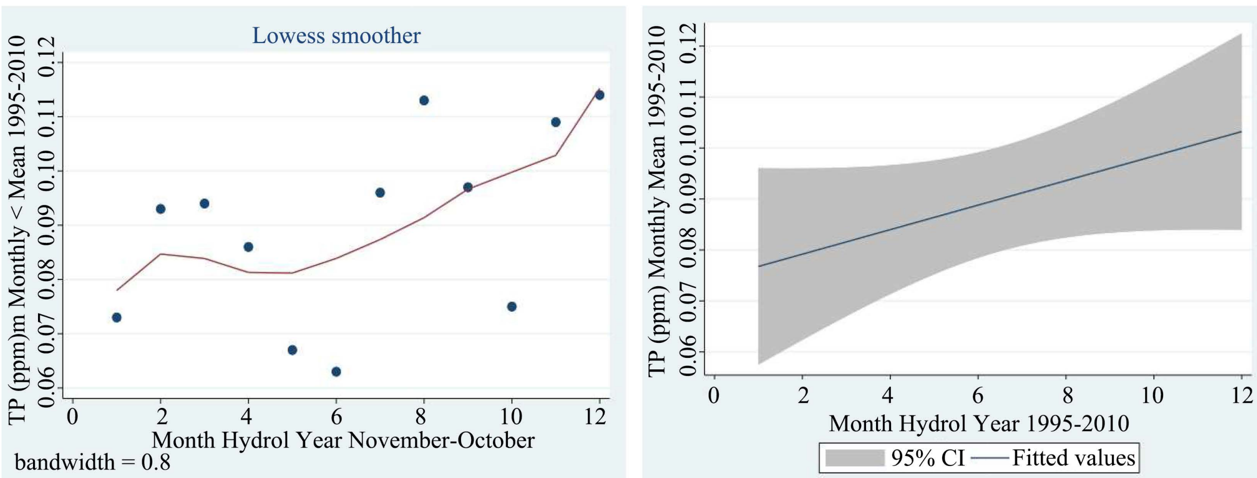

Figure 5. Monthly mean changes of TP concentration (ppm) in Canal Z during 1995-2010: Left: Lowess Smoother; Right: Linear Prediction w/CI, 95%.

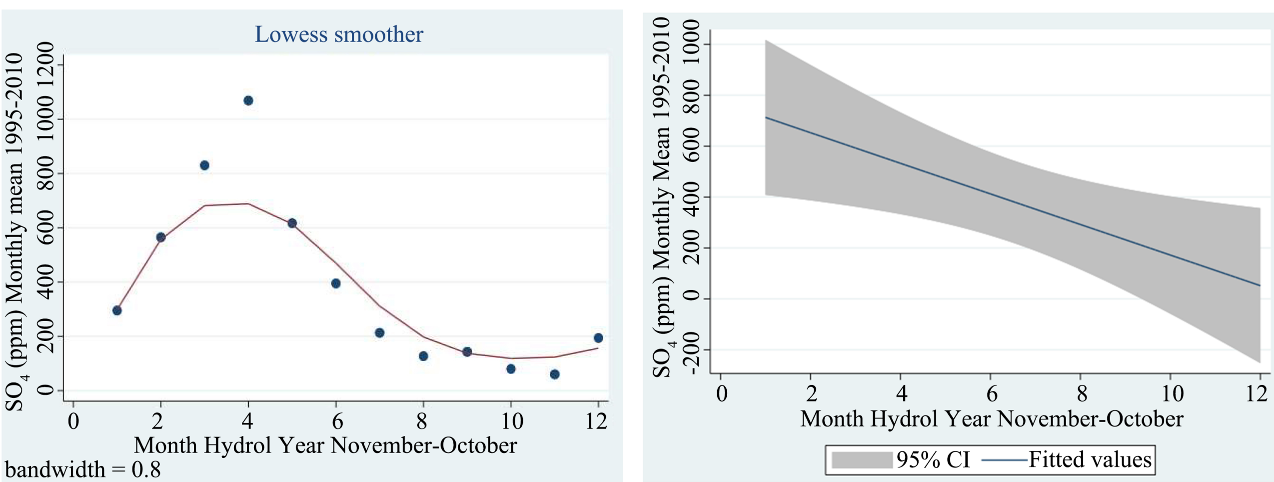

Figure 6. Monthly mean changes of SO_4 concentration (ppm) in Canal Z during 1995-2010: Left: Lowess Smoother; Right: Linear Prediction w/CI, 95%.

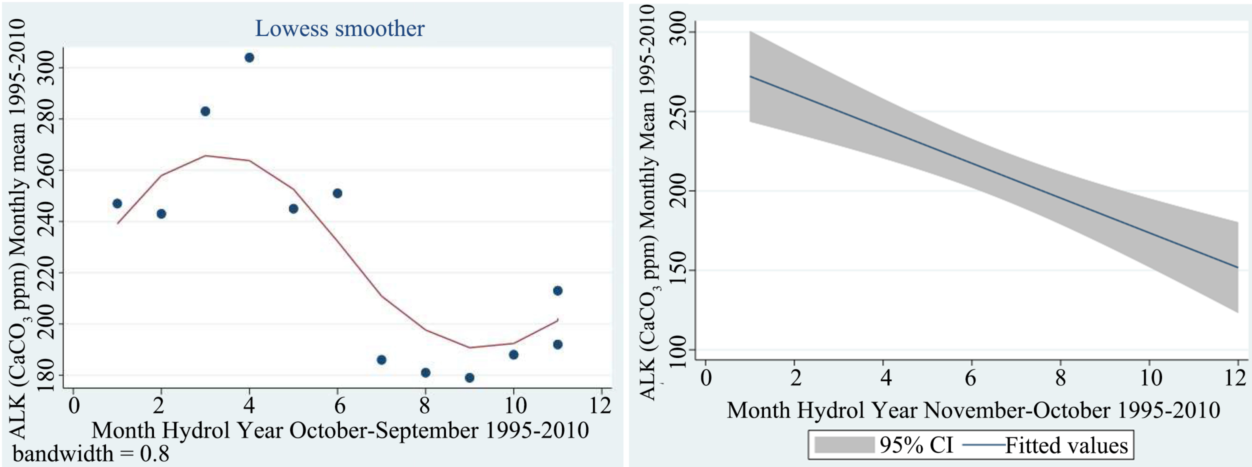

Figure 7. Monthly mean changes of Alklinity as $CaCO_3$ concentration (ppm) in Canal Z during 1995-2010: Left: Lowess Smoother; Right: Linear Prediction w/CI, 95%.

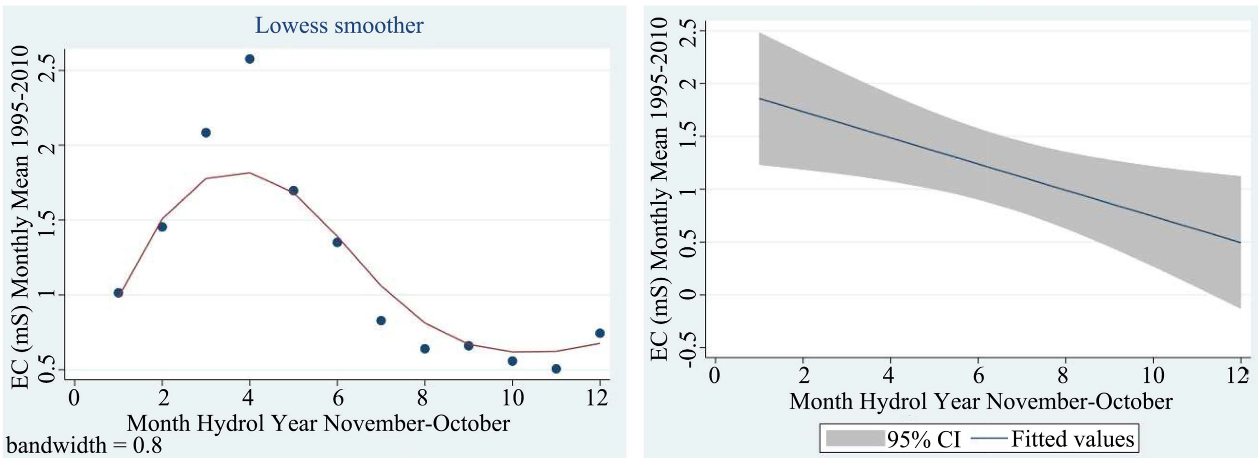

Figure 8. Monthly mean changes of Electrical Conductivity (EC) (mS) in Canal Z during 1995-2010: Left: Lowess Smoother; Right: Linear Prediction w/CI, 95%.

Sub-tropical climate features comprised within the summer regional condition in Hula Valley creating the moisture decline: Lack of precipitation and therefore low river discharges, high air temperature (**Figure 9**) and low relative humidity, high solar radiation and high wind velocities and tough policy of legislated water allocation for agricultural irrigation [4] [6]. Drought conditions include water scarcity, high temperature wind regime throughout most of the time resulting lower relative humidity.

4. Discussion

4.1. Organic Matter Content

The high diversity of soil types in the Hula Valley was widely documented [2] [3] [4] [14] [15] [16]. Three major soil types were recognized: Peat, Transition Peat-Mineral and Mineral. Significant features of those soil types are given in **Table 2**.

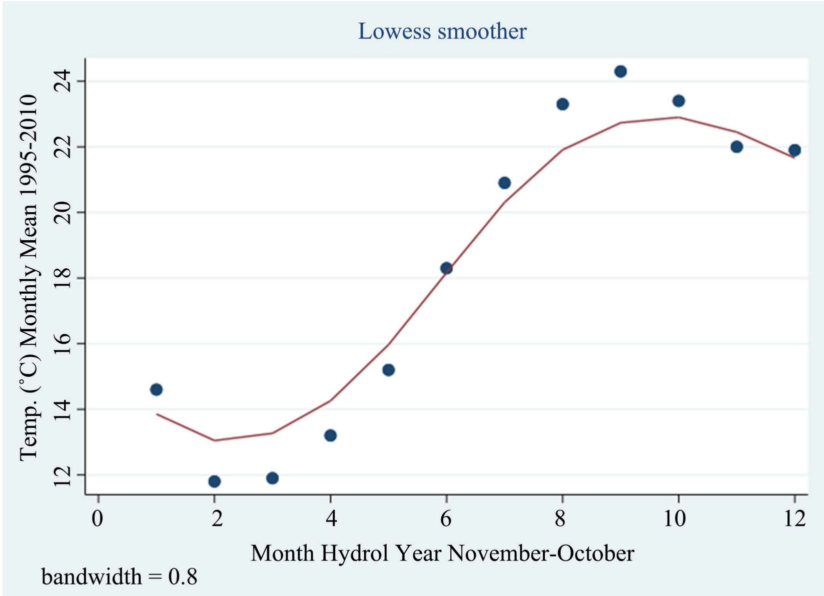

Figure 9. Canal Z water temperature (˚C), monthly mean changes 1995-2010.

Table 2. Percentage composition range (Max. Min) by weight of lime, organic matter, moisture, and Bulk Density as measured 13 years after drainage (Harpaz 1971).

Soil Type	Lime	Organic Matter	Moisture	Bulk Density (g/cm^3)
Peat	0 - 16	46 - 75	260 - 700	0.07 - 0.25
Transition	16 - 65	16 - 46	140 - 260	0.25 - 0.42
Mineral	65 - 90	0 - 16	60 - 140	0.42 - 1.10

A major part of the Peat-Organic soil is located in the middle-northern part of the Hula Valley. Consequently, and supported by placing a Vertical plastic barrier a subterranean Hydraulic gradient was created of which, the northern is a higher altitude. This gradient was accompanied by lower amplitude of underground Water Table seasonal fluctuations in comparison with the seasonal changes in the southern mineral soil [5] [6] [7] [16]. Evaluation of the documented information on the Hula Valley soil varieties clearly indicates the wide range of dissimilarity in soil properties (**Table 2**) and the uniqueness of the Peat Soil. A significant ($r^2 = 0.8739$) correlation between BD (Bulk Density) and the content of organic matter was indicated. The organic content property predominantly affected the low BD. Moreover, lime and organic matter contents are inversely related. The typical peat soil properties include a high content of organic matter and negligible content of lime which induce enhancement of porosity and low BD. Moreover, the high Peat Soil porosity creates a decline of preferential pathways and consequently low level of hydraulic conductivity of the peat soil. That Peat Soil Hydraulic property was the reason for the inadequacy of the earlier usage of irrigation method that was based on capillary water movement. Irrigated water usage was significantly improved after the implementation of the Hula Project conclusion to the use of Mobile Spray Irrigation technology. Due to the low hydraulic conductivity of peat soil, wetting process in is slow and space limited, and water dispersion is insufficient. Therefor, low capacities at high frequency of water support through top-down spray was indicated as most suitable. Optimal revenue as crop per water volume was found to be optimal. Water linkage to Peat-Organic soil-particles is more efficient than to the mineral soil. Therefore, groundwater table fluctuations are smaller than those within the mineral soil particles. The higher carbonates content in the mineral soil in the Hula Valley results in high measured values of EC (Electrical Conductivity) in drained waters due to Gypsum and Carbonates dissolution. The high content of organic matter besides the very low content of mineral substances initiated different levels of surface subsidence. The range of surface subsidence of the Peat-organic soil is higher than that of the Mineral soil [4] [17] [18].

The Peat Soil factors of Bulk Density (BD) were measured as 0.5 - 0.7 g/cm^3 [2]. Field Capacity (FC) of 75% - 85% and 48% by weight and volume respectively (Levin 1970) and a lower value of 0.07 - 0.25 g/cm^3 was indicated [2]. FC (%) of the Hula Peat Soil ranged between 50% - 70% and BD of 0.6 g/cm^3 and organic matter content of 56% - 77% were also documented [4] [19] [20]. Southern to the Hula Peat Soil bulk within the drained area in the Hula Valley soil type is mineral and their BD value is much higher. The drainage of the Hula Valley enhanced the reduction in water availability and elevation of water gravity migration [15]. Intensive nutrients mediated water migration through preferential pathways in the peat soil was enhanced during the post-drainage period. Moreover, the preferential pathways creation and consequently free space for the nutrient-mediated water migration capacity is available in summer whereas soil moisture, the nutrients water transporter, capacity is lower. Surprisingly, phosphorus migration is enhanced due to the geochemical properties of its linkage to peat soil particles. These geochemically bound types are more breakable under dry conditions. Therefore, enhanced peat soil moisture in summer is recommended.

BD measure indicates the level of soil porosity and is inversely related to preferential pathways volume whilst Field Capacity (FC) defines soil wetness level and water migration by gravity. During winter, soil wetness and consequently FC value are continuously maximal whilst in summer an alternate between high and low levels exists. Therefore, the seasonal differences of nutrient mediated water migration through the Peat Soil in winter and summer are dissimilar.

A direct positive correlation that exists between FC and soil moisture [3] indicates that the lower the moisture the higher the FC. Available water capacity for plants in soil ranges between FC and WP (wilting point) whilst nutrient migration is significantly enhanced when moisture exceeds FC. Summer management of the available water regime in the Peat Soil between WP and FC is therefore recommended for optimization of beneficial contribution for both agricultural crops and the decline of Phosphorus migration. Such management of moisture increase by additional irrigation enhances the geochemical reduction of Phosphorus and diminished migration of other nutrients resulting from seasonal moisture depletion.

4.2. Peat Soil Nitrogen and Phosphorus Dynamics

The temporal decline of TN (mostly NO_3) migration from the Peat Soil through Canal Z is mostly due to the precipitation decline whilst the summer decline of nitrate in Lake Agmon-Hula is due to denitrification and particulate Nitrogen sedimentation. Consequently, TN (mostly NO_3) fluctuation in Canal Z is a result of winter enhancement and summer decline. On the contrary, the summer decline of nitrate in Lake Agmon-Hula is due to denitrification and particulate Nitrogen sedimentation. Enhancement of TP migration from the Peat soil [21] is due to summer dryness whilst in Lake Agmon-Hula similar increase is due to seasonal degradation of submerged vegetation. On the other hand, a major part of the phosphorus within the river discharges input into Lake Kinneret originates outside the Hula Valley [13]. The summer decline of Nitrate concentration in the Peat Soil drained waters conveyed through Canal Z is due to dryness conditions whilst enhancement of NO_3 migration in winter due to rain wetting and the high soil moisture.

The Peat soil in the Hula Valley contains a high content of Nitrogen and part of it is Ammonium, a Pre-drainage dominant component. The Ammonium is transferred to Nitrate through the process of Nitrification where Nitrite (NO_2) is temporarily accumulated. The temporary existence of anoxic conditions enhances the denitrification process [14] which eliminates nitrogen as a volatile gas (N_2) in the atmosphere. DO concentration (**Figure 10**) indicates a high level in winter and a decrease in summer. The DO fluctuation is suggested to be temperature dependent which increases when temperature declines in winter and declines in summer when temperature elevates. The rate of nitrification and denitrification processes, the rate of Nitrate and Nitrite production in the Peat Soil were documented by [4] [14] [15] [19] [20]. Conclusively, the presence of Nitrite in winter is mostly due to Nitrification and Denitrification in summer.

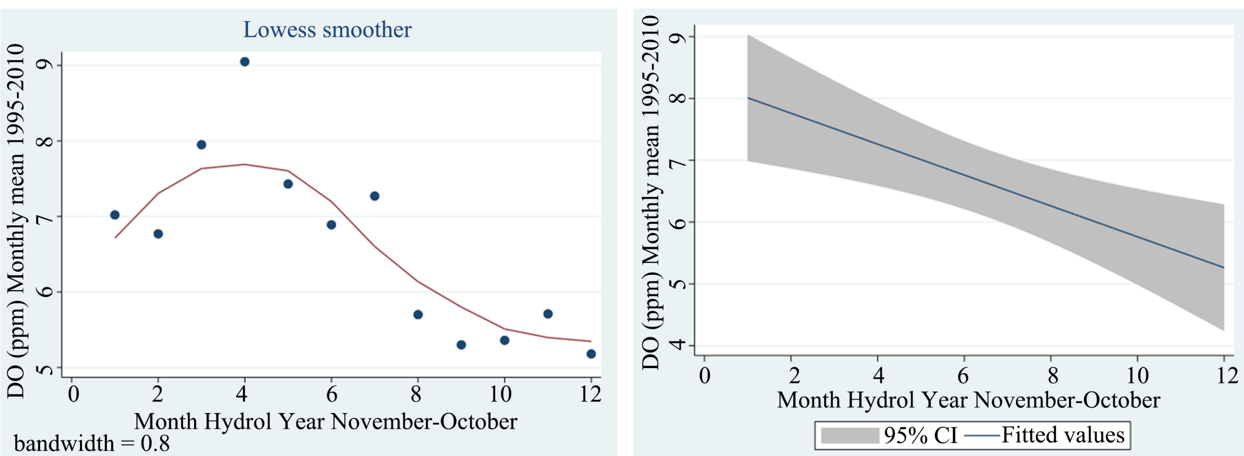

Figure 10. Monthly mean changes of Disslved Oxygen (DO) concentration (ppm) in Canal Z during 1995-2010: Left: Lowess Smoother; Right: Linear Predictiuon w/CI, 95%.

The summer decline of Ammonium (NH_4) concentration in drained waters from the Peat Soil (Canal Z) is due to moisture-redox complex interaction. Enhancement of denitrification under high moisture in winter and increase of summer oxidation under dryness. Moisture increase in summer is therefore advantageous as denitrification reduces Nitrogen capacity in the Peat Soil.

The seasonal fluctuation of Sulfate (SO_4) and Carbonates concentration in the Peat Soil (Canal Z) is due to the natural winter moisture-enhanced dissolution of Gypsum and Carbonates (high EC values) and the decline of dissolved substances during summer dryness.

5. Summary

The main soil type in the Hula Valley is the organic Peat comprising significant available management components for agriculture and ecotourism. The Peat Soil in the Hula Valley is the major contributor of Nitrogenic and Phosphorus nutrients. Nevertheless, the relative contribution of Phosphorus from the Hula Valley to the Lake Kinneret inputs is lower than regional outsourcing. The Nitrogenic matter, mostly Nitrate from the Peat soil is significant. The implementation of efficient development is the key factor of Hula Land use. The financial beneficial success of the Hula land use is therefore dependent on Peat soil properties. Peat soil contains a high content of organic matter and Nitrogenic substances, the porosity is high and preferential pathway volume is low and Hydraulic Conductivity is therefore low. Consequently, the Mobile Spray Irrigation line was found as most suitable for cultivation in Peat Soil. Enhancement of Summer irrigation creating moisture elevation reduces Phosphorus migration from Peat Soil and is therefore recommended and recently implemented.

Acknowledgements

Sincere appreciation is given to T. Natanson, and E. Yasur for field sampling assistance.

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.

References

[1] Schallinger, K.M. (1970) Investigation of the Agricultural Problems Concerning Peat Soil of the Hula Valley. Report No. 673. Volcani Institute for Agricultural Research, Bet Dagan, 33 p. (In Hebrew)

[2] Litaor, M.I., Reichman, O. and Shenker, M. (2011) Genesis, Classification and Human Modification of Peat and Mineral-Organic Soils, Hula Valley, Israel. *Mires and Peat*, **9**, 1-9. http://www.mires-and-peat.net

[3] Harpaz, A., Moses, G., Paldi, C. and Yaari-Cohen, G. (1971) Part A: A Survey of Peat Soils in the Hula-Valley, Israel. Ministry of Agriculture, Department of Soil Conservation, Water and Drainage Authority, Upper Galilee Kiryat Shmona, 53 p. (In Hebrew, English Summary)

[4] Levanon, D. (2023) Chapter: Forward: Agricultural Development and Soil Deterioration after the Hula Drainage. In: Gophen, M., Ed., *Agriculture*, *Recreation*, *Water Quality and Nature Protection in the Hula Valley*, *Israel*, Springer, Cham, 7-19. https://doi.org/10.1007/978-3-031-23412-5

[5] Gophen, M. (2023) Nutrient Export from the Hula Valley. In: *Agriculture*, *Recreation*, *Water Quality and Nature Protection in the Hula Valley*, *Israel*. *Springer Geography*, Springer, Cham, 161-178. https://doi.org/10.1007/978-3-031-23412-5__11

[6] Gophen, M. (2023) Subterranean Migration of Nutrients in the Hula Valley. In: *Agriculture*, *Recreation*, *Water Quality and Nature Protection in the Hula Valley*, *Israel*. *Springer Geography*, Springer, Cham, 39-51. https://doi.org/10.1007/978-3-031-23412-5__3

[7] Gophen, M. (2023) Chapter: Climatological Conditions in the Hula Valley. In: *Agriculture*, *Recreation*, *Water Quality and Nature Protection in the Hula Valley*, *Israel*. *Springer Geography*, Springer, Cham, 13-37. https://doi.org/10.1007/978-3-031-23412-5_2

[8] LKDB (1970-2022) Kinneret Limnological Laboratory, IOLR, Ltd., Annual Reports. Haifa.

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

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

[11] Barnea, I. (2008-2018) Hula Project Annual Report. Jewish National Fund (Keren Kayemet LeIsrael), MIGAL-Scientific Research Institute and Israeli Water Authority, 156 p.

[12] Gophen, M. and Levanon, D. (1994-2006) Hula Project Annual Reports. MIGAL and JNF (KKL). (1994-2005 in Hebrew, 2006 in English)

[13] Gophen, M. (2021) Effects of Climate Conditions on TP Outsourcing in Lake Kinneret (Israel). *Climate*, **9**, Article 142. https://doi.org/10.3390/cli9090142

[14] Avnimelech, Y. (1971) Nitrate Transformation in Peat. *Soil Science*, **111**, 113-118. https://doi.org/10.1097/00010694-197102000-00006

[15] Levin, I. (1970) Improvement of Soils Affected by High Nitrate Concentration. *Israel Journal of Agricultural Research*, **20**, 15-20.

[16] Gophen, M. (2023) Chapter: Climatological Dryness and Water Loss in the Hula Valley. In: *Agriculture*, *Recreation*, *Water Quality and Nature Protection in the Hula Valley*, *Israel*. *Springer Geography*, Springer, Cham, 147-160. https://doi.org/10.1007/978-3-031-23412-5_10

[17] Shoham, D. and Levin, I. (1968) Subsidence in the Reclaimed Hula Swamp Area of Israel. *Israel Journal of Agricultural Research*, **18**, 15-18.

[18] Levin, I. and Shoham, D. (1971) Observation and Field Experiments on Hula-Peat, 1965-1970. Volcani Institute for Agricultural Research and TAHAL, Water Planning for Israel, 58 p. (In Hebrew with English Summary)

[19] Levanon, D. (1979) The Effect of Plant and Plant Substances on Microorganisms Involved in Nitrogen Transformations in the Soil. Ph.D. Thesis, Hebrew University, Jerusalem.

[20] Levanon, D., Henis, Y., Okin, Y. and Dovrat, A. (1982) Alfaalfa Saponins and Microbial Transformations, of Nitrogen in Peat. *Soil Biology and Biochemistry*, **14**, 501-504. https://doi.org/10.1016/0038-0717(82)90110-9

[21] Barnea, I. (2009) Reexamination of Phosphorus Fertilization Practices in the Al-Tered Wetland Soil of Hula Valley, Israel. Master's Thesis, Hebrew University of Jerusalem, Rehovot.