Open Journal of Ecology, 2024, 14, 731-746
https://www.scirp.org/journal/oje
ISSN Online: 2162-1993
ISSN Print: 2162-1985

Salinization-Desalinization (SDS) Processes—A Linkage between Hula Valley and Lake Kinneret Ecosystem Management

Moshe Gophen

Migal-Scientific Research Institute in Galilee, Kiryat Shmone, Israel
Email: gophen@migal.org.il

How to cite this paper: Gophen, M. (2024) Salinization-Desalinization (SDS) Processes—A Linkage between Hula Valley and Lake Kinneret Ecosystem Management. *Open Journal of Ecology*, **14**, 731-746.
https://doi.org/10.4236/oje.2024.149042

Received: August 29, 2024
Accepted: September 23, 2024
Published: September 26, 2024

Abstract

The salinization process resulted in agricultural damage in the Hula Valley and water quality deterioration in Lake Kinneret. Therefore, salinization-desalinization (SDS) processes have been emphasized in the last two decades. Global and regional extreme climatological events and water scarcity strengthen the link between Hula Valley and Lake Kinneret management design. A bond between optimizing Hula agricultural maintenance and Kinneret water quality protection is conclusively suggested. Saline contribution originated from the southern Hula Valley region to the underground and surface water is higher than from the northern organic soil. The impact of eastern water Intrusion from the Golan Heights as surface waters, river discharge and underground seepage into the Hula Valley represent north-south gradient enhancement. Salinized surface water contribution from the Hula Valley to Lake Kinneret is unwanted because presently Kinneret desalinization management policy is critically required. The present salinization of surface and underground water in the Hula Valley indicates the upper limit suitable for agricultural crop optimization and the decline of salinity is crucial. Enhancement of the portion of Jordan water within the total balance in the valley is beneficial for Hula agricultural crops but serves as a disadvantage to Kinneret desalinization implementation. Therefore, the enhancement of lake water exchange is recommended.

Keywords

Hula Valley, Lake Kinneret, Salinization, Desalinization

1. Introduction

The Hula Valley drainage was completed in 1957. The objective of the drainage was the creation of agricultural infrastructure for already existing settlements, particularly for those that were established in the mid-1930s. A conspicuous consequence of the drainage was natural ecosystem devastation where highly diversified communities existed [1]. A minor response compensation was the creation of a nature reservation in the southern part of the valley. The agricultural development and initiated utilization of the new development was difficult and not without failures. Forty years later after the implementation of a reclamation project (Hula Project, HP), appropriate management procedures were successfully performed. Since 1957, scientific research and monitoring in the Hula Valley have been carried out for 70 years [2]. Partial conclusion of the documented information including the majority of nutrient migrations dynamics from the Hula Valley confirmed plausible protection of Lake Kinneret Water quality. That was the result of appropriate agricultural management. Gradual continuous increase of soil and groundwater salinization in the Hula Valley initiated the requirement for taking measures of this developmental process to be thoroughly considered. The hydrological linkage between Hula Valley and Kinneret accompanied by present lake salinization enhancement justified it. The impact of the damageable component of salinization on agricultural crops is an unwanted agent in the Hula Valley and Lake Kinneret as well. The objective of the present paper is the awareness of qualitative and quantitative, temporal and spatial expositions of salinization processes in the Hula Valley. The data set of EC documented in the Hula Valley, particularly within the Hula Project territory is incomplete and was not routinely recorded during short periods. EC values in the underground (GWT) were rarely measured. EC in the canal runoffs was routinely measured for 11 years but later the database was sporadically incomplete. Recently, in response to requirements applied by stakeholders, land owners, farmers and other agricultural-ecological managers, an EC routine monitor program in the canal runoffs, and the underground was initiated. In the present paper, routine and sporadically measured data was assembled and aimed at formulating seasonal, temporal and hypsometrical distribution of the EC feature, *i.e.* salinization and desalinization dynamics in the Hula Valley. The time frame is limited between 1994 and 2024 but not orderly completed.

2. Material and Methods

Electrical Conductivity (EC) data 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.; EC Data 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 [2]-[8]. Documented (unpublished, personal communication: D. Klein) EC values are part of the Hula Project Monitor Program (Migal-Galilee Scientific Research Institute, Jewish National Fund and Israeli Water Authority) were provided by D. Klein and O. Reichman. 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. The salinity (EC) data in water drainage migrated from the Peat Soil is therefore associated with water flows in Canal Z [2] [7].

Statistical analyses of Quadratic Regression (prediction) and Linear regression were carried out by using the software of STATA 17.0-Standard Edition, Statistics and Data Science, Copyright 1985-2021 StataCorp LLC, 4905 Lakeway Drive, 800-STATA-PC, Stata license: Single-user perpetual, Serial number: 401706315938, Licensed to Moshe Gophen, Migal. Quadratic Prediction (regression) is used for modeling relationships between variables distribution with a parabolic best-fit curve, most likely relevant to the analyses presented in this paper.

3. Results

3.1. Hula Valley

Between 2007 and 2018, the routine sampling program of surface water in the drainage canals included 10 sampling stations where water was sampled for nutrient analysis: 5 stations northern and 5 stations southern to the underground plastic barrier (located along the southern shoreline of Lake Agmon Hula) (LAH). The total means of EC in the northern and southern stations were 0.478 mS (milli Siemens) (SD 0.135; n = 73) and 0.835 mS (SD 0.585; n = 66) respectively. The EC values documented in the northern drainage canals (surface water) were lower than those measured in the southern part of the Valley. Additional saline substances are contributed along the route of flow and are therefore suggested within the total chemical north-south gradient. An intensive supply of salty substances to surface water originating in the mineral soil covering most of the southern part of the HP region is suggested.

Data given in **Table 1** indicates that the source of the majority of salty substances supplied to surface waters in the HP region is peat soil. The contribution of salty substances through the Jordan waters comprised of major headwaters and other smaller rivers northern to the HP (Stn.48) region is low (**Figure 1**).

Table 1. Multi annual (1994-2006) monthly means of EC values (mS) measured in surface water stations in Hula Project region: 48—The reconstructed Jordan River inflow into LAH; 49—The outflow of LAH; 57—The entrance of Z canal (canal 101) into LAH; and the averages of stations 48, 49 and 57 during 2021-2023.

Month	49 (1994-2006)	57 (1994-2006)	48 (1994-2006)	2021-2023 (Total mean)
1	1.37	2.084	0.57	1.117
2	1.74	2.577	0.52	1.513
3	1.67	1.697	0.42	1.318
4	1.18	1.351	0.43	0.962
5	1.08	0.826	0.48	0.651

Continued

6	0.65	0.640	0.4	0.694
7	0.79	0.660	0.69	0.681
8	0.5	0.558	0.37	0.633
9	0.54	0.506	0.395	0.625
10	0.73	0.744	0.41	0.676
11	0.76	1.014	0.57	0.676
12	0.89	1.454	0.52	0.762
Mean (SD)	0.984 (0.632)	1.157 (0.835)	0.497 (0.233)	0.866 (0.744)

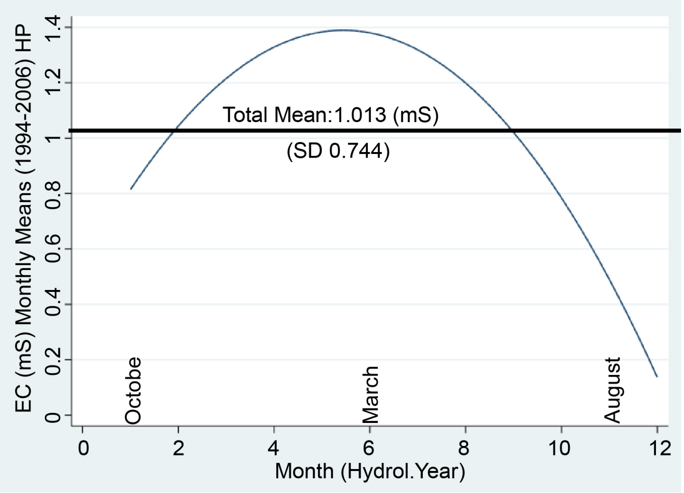

Figure 1. Temporal distribution of EC values (mS) Monthly means (Hydrological Year: 1 = October, 12-September next year) (1994-2006) in surface water stations) (total average is indicates) in the Hula Project territory: Reconstructed Jordan, lake Agmon-Hula (LAH) outlet and Canal Z (101).

Results given in **Figures 2-5** indicate a similar pattern of seasonal fluctuations of salinity: minimum summer (August-September) values, followed by a slight increase during fall-early winter (October-December) and maximal value in January. The exceptional seasonal pattern is presented in the reconstructed Jordan waters: Earlier (July) Minimal value and intensive summer (July-December) elevation. The impact of soil and bedrock infrastructure along the headwaters discharge flows outside the Hula Valley is suggested. The moderate summer elevation of surface water salinity in the Hula Valley is probably affected by runoffs, underground and seepage of low EC sources intruded influx from the Golan Height.

Results given in **Figure 6** indicate the impact of the Hula Project (HP) implementation. During HP execution an increase of low EC`s headwater supplied as surface water for irrigation through the Peat soil enhanced their wettability accompanied by documented temporal EC decline.

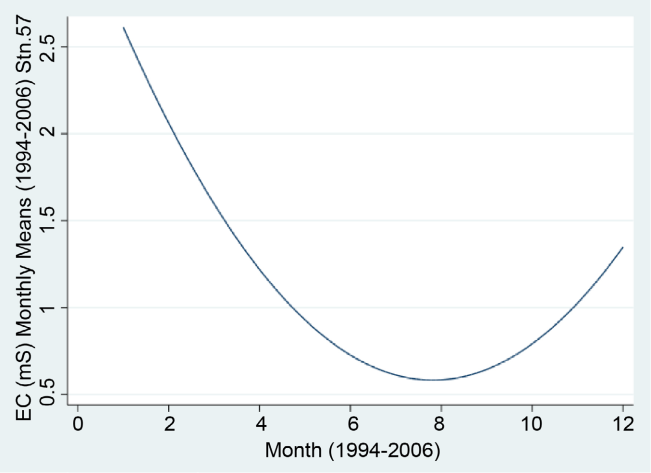

Figure 2. EC (mS) Monthly averages in Canal Z Peat soil drainage surface waters Station 57 (1994-2006).

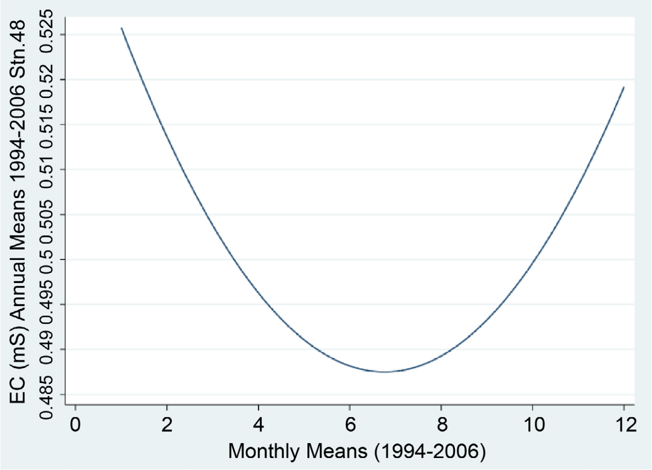

Figure 3. EC (mS) Monthly averages in reconstructed Jordan surface waters (1996-2009).

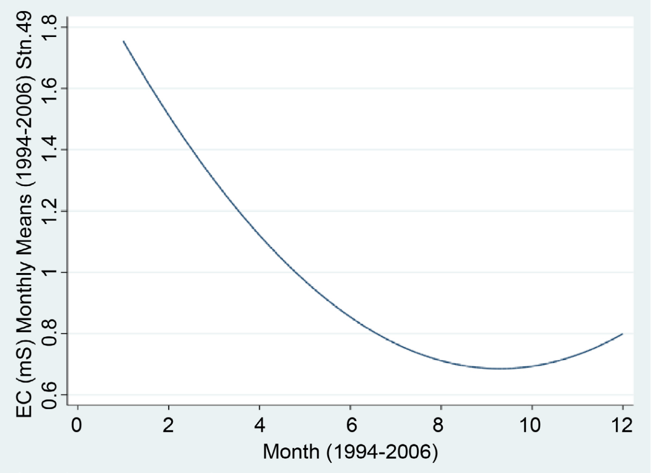

Figure 4. EC (mS) Monthly averages (1994-2006) in Lake Agmon-Hula outlet. Station 49.

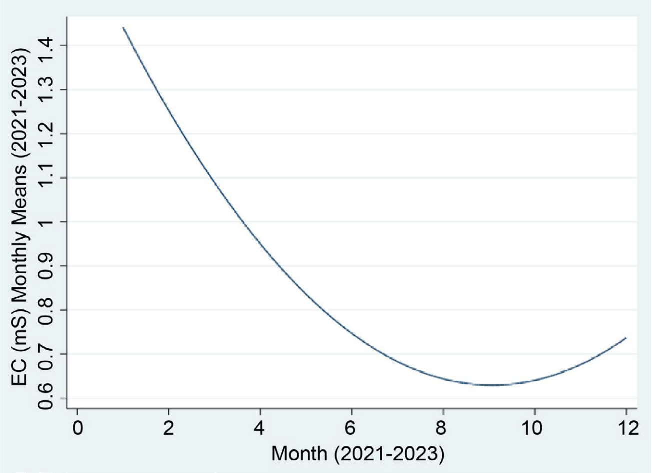

Figure 5. EC (mS) Monthly averages (2021-2023) in Lake Agmon-Hula outlet. Station 49.

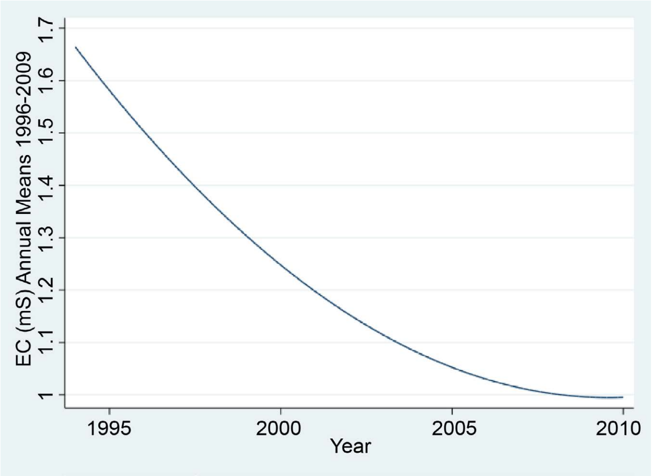

Figure 6. EC (mS) Annual averages in Canal Z Peat soil drainage surface waters Station 57. Annual averages (2009-1994) of Monthly means.

The Results given in Figure 7 indicate a significant EC decline during 1994-1998 and a slight increase later. It has to be considered that the amplitudes of EC values—Maximum-Minimum ranges, in stations 48, 49, and 57 during 1994-2006 were 0.395 - 0.69, 0.5 - 1.74, and 0.506 - 2.577, respectively. The levels of salinity (EC) in the waters of reconstructed Jordan are lower and more stable in comparison with the waters in stations 49 and 57 (Figure 8).

Results given in Figure 9 emphasize the pattern dissimilarity of the southern region of the Hula Valley: High EC level throughout winter-spring (January-May) and continuous significant decline later. The prominent elevation from December to May is probably due to the response time of the Golan Height waters penetration which significantly caused the EC to diminish later.

Results in Figure 10 indicate that within the lower EC, range of the southern stations (below 1000 μS) relations are negative (South increase - North decline), whilst within the range of above 1000 μS, the relations are positive (South increase

- North increase). These results confirm the interpretation given earlier to results shown in **Figure 9**.

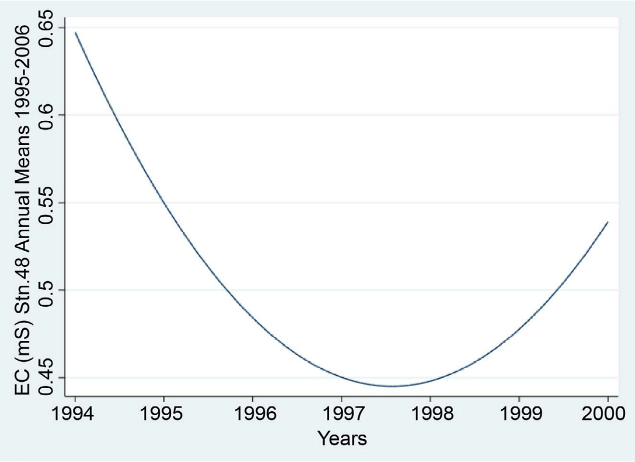

Figure 7. EC (mS) Annual (1994-2009) averages of monthly means in reconstructed Jordan surface waters (Stn. 48).

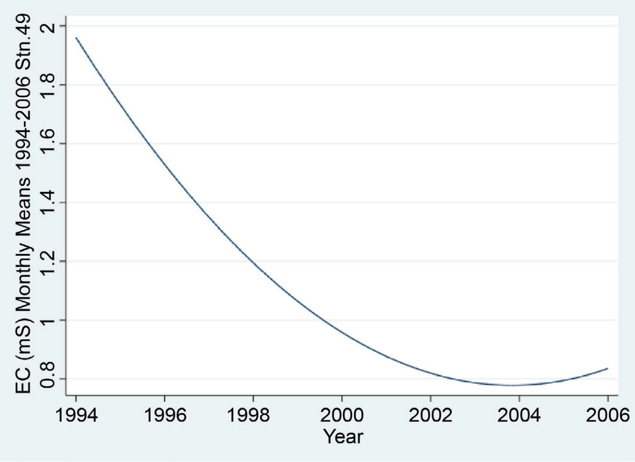

Figure 8. EC (mS) Annual averages in the Lake Agmon-Hula outlet waters (1994-2006).

3.2. Lake Kinneret

The difference in management policies of water and salt balances between two periods, 1948-1968 and 1969-1989 is presented in **Figure 11**: During 1948-1968 water storage without anthropogenic salts diversion caused salinity enhancement whilst salts removal (app. 40,000 tons/year) accompanied by heavy floods in the winter of 1968-69, and open dam caused by lake water exchange (*i.e.* natural salts removal) initiated a sharp decline of salinity. This was historically the second proven result of anthropogenic involvement succeeding Lake Kinneret management. The first case was carried out earlier, during 1933-1948 after dam construction and usage which was aimed at water storage and unintentional enhancement of salinity (**Figure 12**).

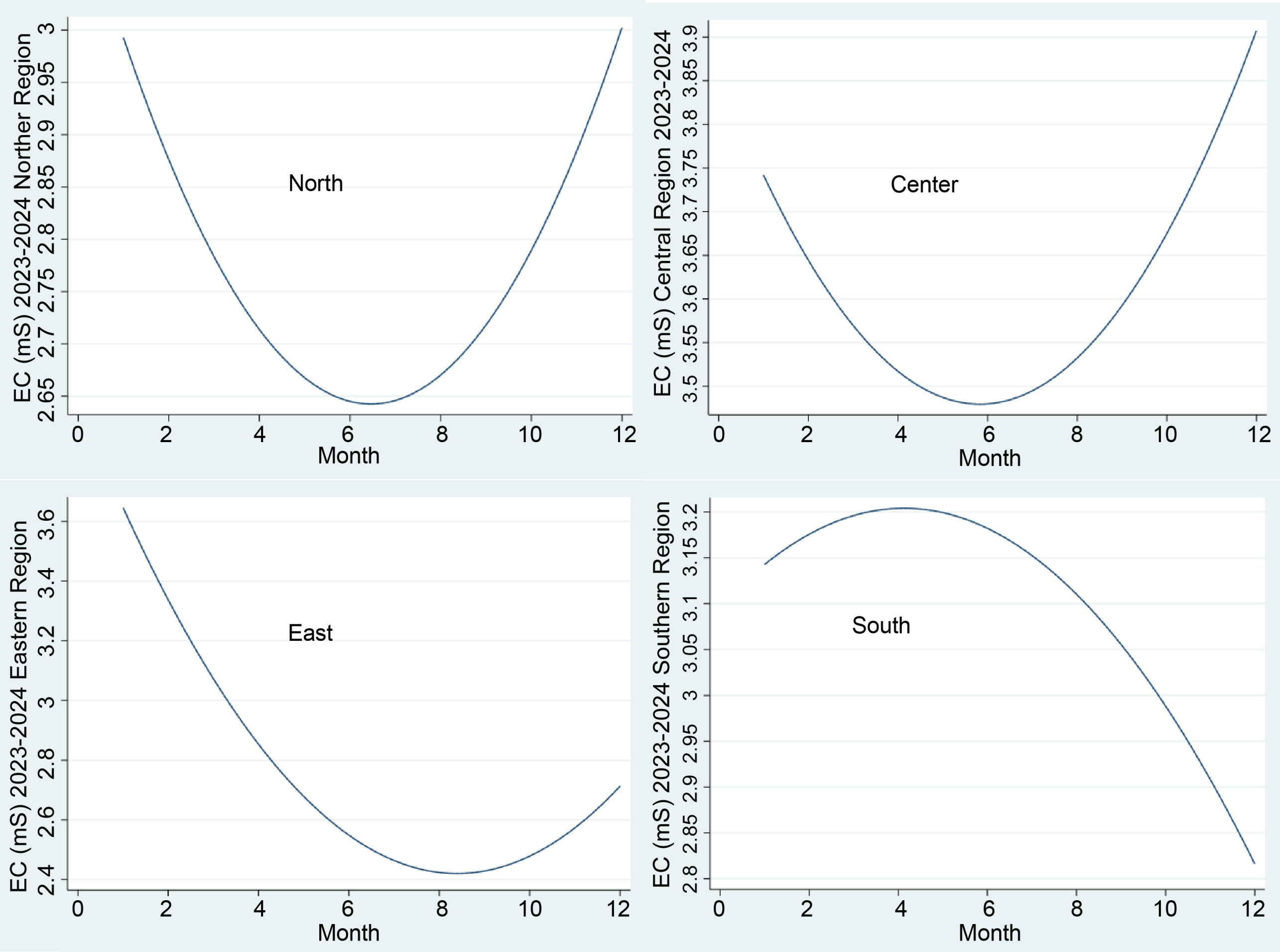

Figure 9. Seasonal fluctuations of monthly means (January 2023-July 2024) EC values in surface waters sampled in 4 different regions in the Hula Valley: 1) North—Far Northern to LAH; 2) Center—Northern-close to LAH; 3) East—East-northern to LAH; 4) South—southern to LAH.

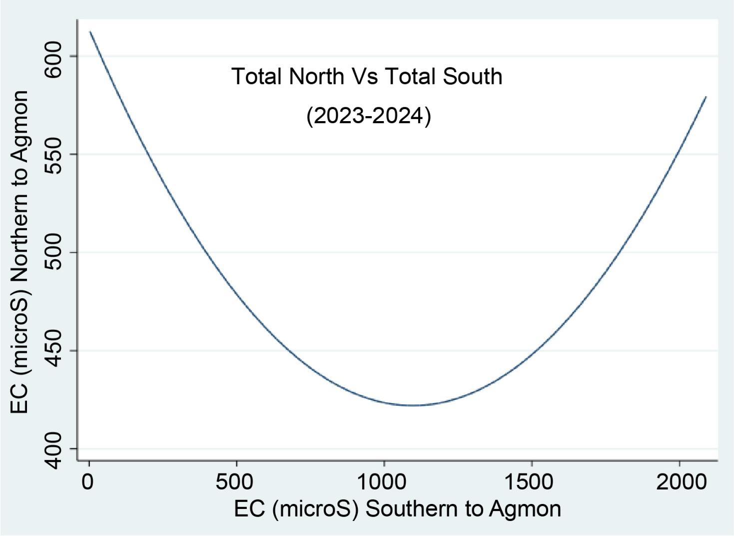

Figure 10. Quadratic regression between runoff waters EC of all northern stations Vs southern stations.

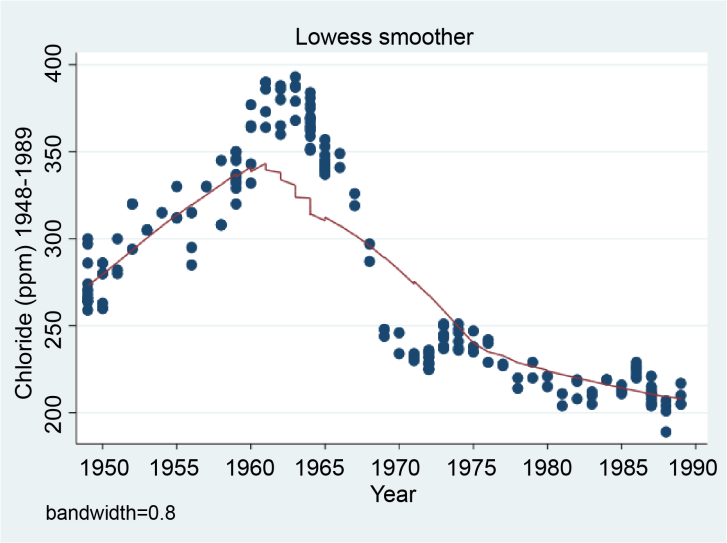

Figure 11. Lowess Smoother (Bandwidth 0.8) plot of Lake Kinneret monthly means of Chloride concentration (ppm) during 1948-1989.

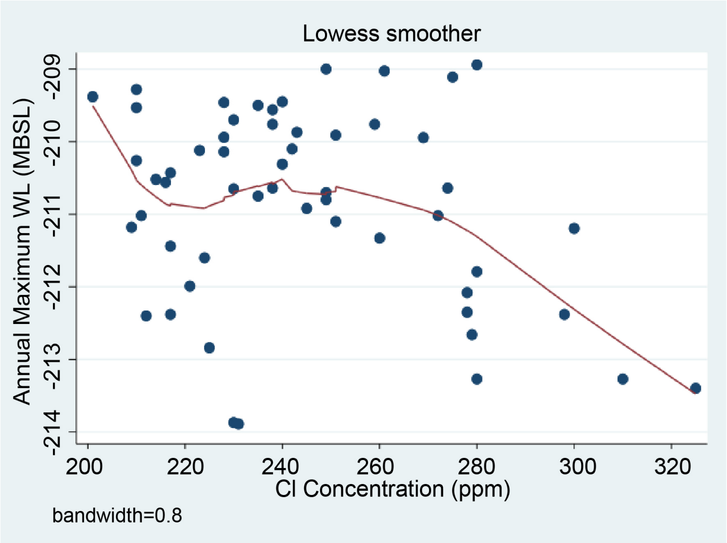

Figure 12. Lowess Smoother (Bandwidth 0.8) plot of Lake Kinneret annual means of Chloride concentration (ppm) in Lake Kinneret in relation to annual maximal WL (MBSL) during 1970-2024.

The impact of water storage policy through closed dam accompanied by WL increase initiate seasonal short-term decline of salinity (as Chloride concentration) is presented in Figure 12 and Figure 13. Nevertheless, this is long-term misleading because the total load is enhanced (Figure 14) and a comprehensive salinity level, (Chloride concentration) (Figure 15) as well. The highest WL occurs annually when freshwater input is higher than output accompanied by the closed dam and minimal pumping withdrawal (no irrigation) resulting in a decline in Chloride concentration. Exceptional conditions of drought initiate, lower WL and elevation of Chloride concentration.

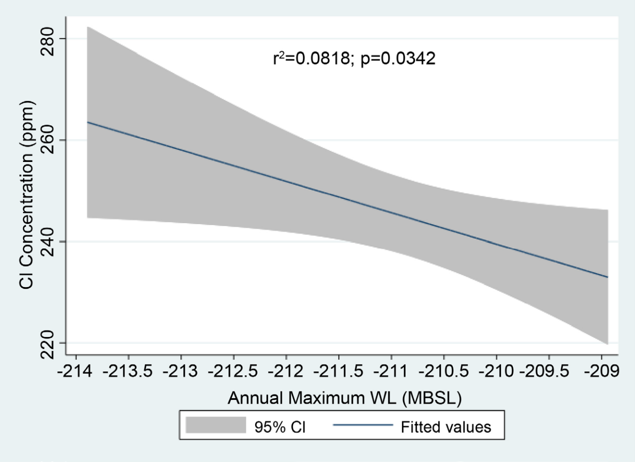

Figure 13. Linear Regression (CI 95%) (low level of significance) of fluctuations of total annual lake mean Chloride concentration (ppm) at WL changes during 1970-2024 (Significance level—low).

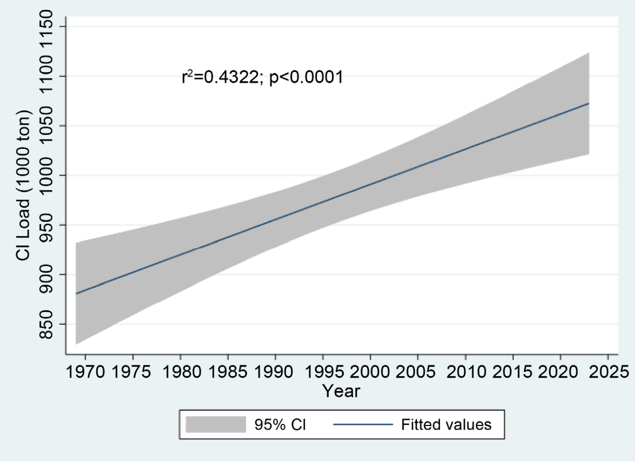

Figure 14. Linear Regression (CI 95%) of temporal changes of total annual lake salt (as Chloride) load (1000 tons) at maximal WL during 1970-2024 (Significant).

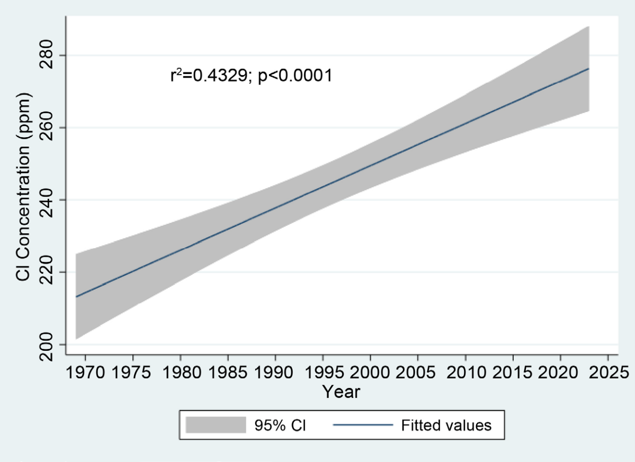

Figure 15. Linear Regression (CI 95%) of temporal changes of total annual lake mean salt (as Chloride) concentration (ppm) during 1970-2024 (Significant).

4. Discussion

The drainage of the Hula swamps and old lake was targeted at providing land for agriculture income resources. Nevertheless, shortly after drainage completion awareness of several difficulties arose and salinization was one of them [7]. Moreover, changes of climatological conditions, especially drought frequencies enhancement urged Hula soil salinization due to decline Jordan waters allocation and salts (mostly carbonates) accumulation in surface layer. For the study of salinization sources in the Hula Valley and particularly the Hula Project territory (app. 6000 ha), it was divided into 4 sub-regions:1) North-northern to Lake Agmon-Hula (LAH); 2) Center-LAH and close vicinity, 3) East-, Peat-soil blocks eastern to the Eastern major Canal; 4) South-Southern to LAH. Based on these sub-regions, the mean (14 boreholes samples, during 2010) EC (mS) values measured in the underground water (GWT) samples were 2.78, 3.59, 2.83, and 3.12 in the North, Center, East and South respectively. The total mean for the entire Hula Project region as measured during 2010 was 2.263 mS (SD 1.572). It is suggested that the inflow capacity of underground freshwater from eastern Golan Heights resources is higher in the "East" and "North" regions which are therefore more intensively affected and EC is lower in comparison with the central and southern regions. The winter impact of low-EC-rainfall and runoff waters (headwaters and small rivers, seepage and runoff fluxes) on underground EC decline continues effectively from January through August. Later on, these freshwater capacities decline significantly and EC values are therefore elevated continuously. Rainfall season continues during November-March but due to response time, underground waters EC is gradually declining from January through August. Rainfall, river discharge, runoff fluxes and seepage are enhanced in winter (November-March). Nevertheless, their impact is expressed as the EC decline of the undergrounds continues and is slightly enhanced later in summer. The hydrological delay from early winter (January) to mid-summer (August-September) is the result of time response delay.

Results given in **Table 1** accounted for surface waters indicating lower EC values than the Hula GWT: LAH outlet—0.984; Canal Z (101)—1.157, Reconstructed Jordan inlet—0.497, and total mean for 2021-2023—0.866. A clear hypsometrical gradient from surface to GWT of EC value enhancement, and salinization, is confirmed. The downward geohydrological gradient of the underground water flows from the eastern higher altitude Golan Heights towards lower altitude in the Hula Valley affecting there the EC values of the GWT. Rainfall and river discharges by infiltration and surface flow on the Golan Heights significantly enriched underground freshwater resources downwards in the Hula Valley. Since the Hula drainage (1957) the organic content in the Peat Sol declined from 75% to 10-20% and 1% - 17% and 50% - 60% in the carbonate soil in the southern part of the valley respectively [9] [10]. A biannual biweekly water sampling program (2011-2013) in drainage canals crossing the valley directed north-south, was carried out (Barnea 2008-2018) in 5 stations southern to LAH and 5 locations northern to LAH

Hula Valley. Sixteen and 73 samples were collected in the southern and northern stations respectively. Documented mean values (SD) (mS) of EC in the southern and northern stations were 0.835 (0.585) and 478 (0.135) respectively. The same as the spatial trend of EC level of the underground waters (GWT) is the difference of the runoffs in the drainage canals: significantly higher in the southern carbonates-rich soil.

Results given in **Table 1** indicate distinctively that the headwater and other small rivers located northern to the Hula Valley are marginal contributors of salinity whilst the major saline input originates in the Hula Valley. Statistical expression of this conclusion is given in **Table 2**. Linear Regression was evaluated between monthly means of the salinity measured in the reconstructed Jordan (Stn. 48), the outflow from LAH and in Canal Z Vs the total average of the three locations during 1994-2006. The results, as LR parameters (r^2, p, S, NS), are given in **Table 2**.

Table 2. Linear regression (r^2, and p,) and significance level (S-significant; NS-not significant) between monthly means during 1994-2006 of EC values in three stations of 48, 49, and 57 Vs total averages.

Station	r^2	p (S, NS)
48	0.0121	0.3993 (NS)
49	0.1780	<0.0001 (S)
57	0.1787	<0.0001 (S)

The significant dependence of station 49 and 57 waters which assembled drainage waters from peat soil drainage and the insignificance relation between Jordan waters and fluctuated salinity in drainage effluents are indicated. Conclusively, the salinization fate of the natural headwaters low EC freshwaters which are diverted into the valley and flow through the Hula valley is clear. Finally, the higher the capacity of the headwaters (reconstructed Jordan flow) within the entire valley water balance the lower the salinization (EC decline). Moreover, salinity in Lake Kinneret might be affected by diverted headwater rivers into the Hula Valley [11]. Enhancement of headwaters diversion into the valley might reduce the salinity of irrigated waters and consequently, drainage waters whilst an increase of saline substances migration from the valley into Lake Kinneret is predicted. The evaluation of a compensated model where optimization of agricultural management in the Hula Valley continues and enhanced water exchange in Lake Kinneret is likely. The salinity of the headwater rivers is affected by the soil/rocky infrastructure in the Kinneret drainage basin outside of the Hula Valley and their salinity is low and slightly seasonally fluctuated.

The salinity fluctuations within the principal headwaters and other small rivers joined into one Jordan River which partly is diverted into the reconstructed Jordan route EC is low and stable. For the prevention of soil salinization in the Hula Valley, an enhancement of Jordan water allocation for agricultural utilization is recommended. The similarity between soil salinization-desalinization in the Hula Valley and Kinarot Valley (western and southern to Lake Kinneret) initiates similar irrigation management: freshwater allocation for flushing and decline of soil salinization. In both regions, the Hula and Kinarot soil salinities are diminished resulting in crop profitability improvement but carbonates are migrated into Lake Kinneret. Salts migration from the Kinarot region became recently negligible as a result of the implemented drip-irrigation method. Nevertheless, even with the partial utilization of the drip-irrigation method for orchard and Tomato crops in the Hula Valley, the underground waters (GWT) upward capillarity and carbonates contribution by mineral soil, salinization enhanced and the increase of Jordan waters allocation is required. Research about the spatial, temporal and hypsometrical dispersion of nutrients in the Hula Valley was carried out [12]. The Chloride concentrations in the water content of the deep layer of Lignite were analyzed. The high content of chloride in the northern and central bulks of the Lignite whilst much lower in the southern and eastern boreholes were documented. The low concentrations of Chloride in the Lignite waters probably resulted from freshwater dilution originating in the eastern Hula Valley side-wall springs: Notera, Gonen, Divsha, Harofe and Dekel with additional seepage of Ein Zraot, Ein Pagim, Ein Ela, Ein Harofe, Ein Netz and Ein Dekel and flow as surface runoff, underground flows and seepage [13] [14]. Likely, a similar impact on salt content (EC value range) of the HP underground is continuously created by those fresh waters within the HP underground waters (GWT). Winter rainfall enhances freshwater surface runoff, river discharge, infiltration and seepage intrusion from the Golan Heights into HP undergrounds and later with respect to response time desalinization (EC decline) occurs. The winter precipitations are expressed as EC decline within the HP underground after an approximation of several months of delay (**Figure 1**). Results given in **Figure 1** where seasonality and months are numbered as Hydrological annual cycle, from October (1) through January (3), to September (12) of next year: EC enhancement in summer early winter time (October-March), response time is included, when freshwater contribution diminishes and the gradual decline of EC (desalinization) during winter-spring-early summer time (April-September).

Results given in **Figures 2-5** where seasonality is numbered as a calendar from 1(January) to 12 (December) confirm gradual desalinization as the decline of EC (salt content) during winter months and enhancement in summer. The impact of water salinity on agricultural crops in the Hula Valley is so acute that a specific determination of crop damage was experimentally determined for 22 field, vegetables and orchard crops (M. Peres unpublished data) (**Table 3**).

Results given in **Table 3** indicate that salinity levels above 1.7, 1.2 and 0.9 mS in irrigated waters might cause a harvest decline of 50%, 25%, and 10% for 22 different fields crops, vegetables and orchards. As shown here (**Table 1**), the reconstructed Jordan waters throughout all months are suitable for irrigation and no harvest decline is predicted when used (**Table 3**). Nevertheless, Peat soil drainage waters (Station 57) are not suitable for irrigation throughout the month unless a decline of their EC level by freshwater dilution or agricultural management improvements of the Peat soil is carried out.

Table 3. Percentage (50, 25, 10) of harvest decline resulting in salinity range (Minimum-Maximum) (mS).

Percentage Crop Decline	Minimum (mS)	Maximum (mS)
50	1.7	8.7
25	1.2	8.4
10	0.9	6.4

Recently (2020-2023) the annual total lake Chloride concentration was 264 and 266 ppm and the load of salt (as Chloride) was 1095.5 and 1048.0 × 10^3 tons of salt in 2022 and 2023 respectively [15]. Anthropogenic removal of salt from the Kinneret balance accompanied by heavy rainfall was followed by a distinct salinity decline documented during 1968-1980. Pumping withdrawal through the National Water Carrier removes annually 57 × 10^3 ton salt. Annual Salt removal of 75 × 10^3 tons, originating in Ein-Nur and Fuliye is successfully carried out [15]. Salts input through the Jordan River is 8042 tons annually which comprises 8.7% of totally measured salt fluxes inputs in Lake Kinneret. Salts' portion contributed by the Hula Valley within this Jordan input is significant. The long-term (1995-2024) record of annual means of loads in Lake Kinneret indicates that prior to 2002 it was never higher than 1 × 10^6 tons whilst since 2003 it has been enhanced continuously and was highest in 2021 (325 ppm; 1404 × 10^3 tons).

5. Conclusion

During the post-drainage period in the Hula Valley, soil salinization was recognized as a potential damageable factor for agricultural management. Lake Kinneret salinization is gradually increasing as measured by Chloride concentration and total load. The combat achievement of these two obstacles is contradicted by the increased salinization of Hula Valley soil and the desalinization aspiration of the Kinneret waters. Integrated management is likely: additional Jordan waters to the optimal maintenance of agriculture in the Hula and enhancing salt diversion and water exchange (open dam or pumping withdrawal) in Lake Kinneret. There is a hydrological linkage between the Salinization of runoff waters and soil in the Hula Valley and Lake Kinneret. Although major saline sources are different, there is a minor level of negative ecological interference overlap due to salt migration from the Hula into the lake. In both ecosystems, salinization is unwanted, and therefore saline accumulation in the Hula and migration require appropriate management. A relevant option aimed at reduction of Hula soil salinization for the improvement of agricultural crops management is enhancement of the Jordan waters within the irrigation supply. Consequently, saline component within the underground waters would probably be reduced. Saline removal in the Hula is beneficial to the long-term constructed management of desalinization in the Kinneret waters as well. The present lake management policy is aimed at the achievement of Kinneret desalinization which is operated by both salt diversion and water exchange through pumping withdrawal, dam opening and increased headwaters inputs [16] [17]. Salinization processes of underground aquifers and its impact on water supply for agricultural and domestic demand is a long term global-international issue [18] [19]. Thought, hydrological management in the Hula Valley of enhancement of headwater utilization is contradicted. The shift of irrigation method from a "flood-capillarity" water supply procedure to moveable sprinkle lines in the Hula and drip-irrigation usage, as well as in Kinarot in the southern vicinity to Lake Kinneret reduced significantly salt drainage water flux into the underground. During the 1970s-1990s about 6% of total external Kinneret salt inputs (80% are sub-lacustrine origin) were supplied through the Jordan River of which Hula's contribution is significant.

Acknowledgements

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, 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.

Conflicts of Interest

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

References

[1] Dimentman, C., Bromely, H.J. and Por, F.D. (1992) Lake Hula: Reconstruction of the Fauna and Hydrobiology of a Lost Lake. Publications of the Israel Academy of Sciences and Humanities, 170.

[2] Gophen, M. (2023) Subterranean Migration of Nutrients in the Hula Valley. In: Gophen, M., Ed., *Agriculture, Recreation, Water Quality and Nature Protection in the Hula Valley, Israel*, Springer-Geography, 39-51. https://doi.org/10.1007/978-3-031-23412-5_3

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

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

[5] Barnea, I. (2008) Hula Project Annual Report. Jewish National Fund (Keren Kayemeth

Lelsrael), MIGAL-Scientific Research Institute and Israeli Water Authority, 159.

[6] Barnea, I. and Kaplan, D. (2018) 2008-2018 Hula Project Annual Report. Jewish National Fund (Keren Kayemeth Lelsrael), MIGAL-Scientific Research Institute and Israeli Water Authority, 156.

[7] Gophen, M. (2023) Agriculture, Recreation, Water Quality and Nature Protection in the Hula Valley, Israel: 70 Years of a Mega-Ecological Project. Springer Geography, 243 p. https://doi.org/10.1007/978-3-031-23412-5

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

[9] Marish, S. (1986) Chapter: Soil Survey in Hula Valley 1984/85. In: Zemach, M.M., Ed., *Workshop on Hula Peat Management Esteem Compiled*, Kinneret Authority and Kinneret Drainage Authority, 2-6.

[10] Avnimelech, Y. (1986) Chapter: The Hula Peat Soil: Composition, Features and Conclusion. In: Zemach, M.M., Ed., *Workshop on Hula Peat Management Esteem Compiled*, Kinneret Authority and Kinneret Drainage Authority, 11-13.

[11] Gophen, M. (2016) A Review on Modeling of Kinneret Salinity with Practical Recommendations. *Open Journal of Modern Hydrology*, **6**, 129-139. https://doi.org/10.4236/ojmh.2016.63011

[12] Gophen, M. and Orlov-Levin, V. (2024) Temporal, Spatial, and Hypsometrical Dispersion of Nutrients in the Hula Valley, Israel. *Open Journal of Ecology*, **14**, 604-628. https://doi.org/10.4236/oje.2024.148035

[13] Michelson, C. (1992) Hula Valley Project, Hydrogeological Report. Final Report, TAHAL, Tel-Aviv, Ltd. 21.

[14] Michaeli, A. (1979) Hula Lignite Project, Drainage Studies. TAHAL Consulting Engineers Ltd., Institute for Petroleum Research and Geophysics, Ministry of Energy and Infrastructure, 88.

[15] Ashri-Arnon, T., Berger, D. and Rom, M. (2023) Hydrological, Salts and Energy Balances, 2021-2022, in Lake Kinneret, Mekorot. The National Water Company, Management and Maintenance Section-Kinneret Drainage Basin, Jordan Region, Annual Report. Mekorot-Nazareth Publisher, 45.

[16] Gophen, M. (2021) Correlative Relations between Salinity and Hydraulic Residence Time (HRT) in Lake Kinneret (Israel). *Geology & Geoscience Journal*, **5**, 1-9.

[17] Gophen, M. (2021) The Role of Hydraulic Residence Time in Lake Management Design: Lake Kinneret Case Study. *Journal of Biomedical Research & Environmental Sciences*, **2**, 888-889. https://www.jelsciences.com/articles/jbres1327.pdf

[18] AlMaarofi, S., Douabul, A. and Al-Saad, H. (2012) Mesopotamian Marshlands: Salinization Problem. *Journal of Environmental Protection*, **3**, 1295-1301. https://doi.org/10.4236/jep.2012.310147

[19] Mohamed, M.L., Diongue, D.M.L., Emvoutou, H.C., Mohamed, A.S., Jiddou, M. and Faye, S. (2020) Salinization Processes in the Benichab Coastal Aquifer-Mauritania. *International Journal of Geosciences*, **11**, 377-392. https://doi.org/10.4236/ijg.2020.116020