Temporal assessment of Soil Quality Index (SQI) for Ujjani Wetland, Maharashtra

Pooja Ramanuj[1*], Shankar Laware[2], and Nitin Karmalkar[3]

[1] Department of Environmental Sciences, Fergusson College, Savitribai Phule Pune University, Pune, Maharashtra, India
2: Principal, Arts, Commerce & Science College, Sonai, Ahmednagar, Maharashtra, India
3: Ex-Vice Chancellor and Professor of Geology, Savitribai Phule Pune University, Pune, Maharashtra, India

[*] *Corresponding Author: pooja21may@gmail.com*

Abstract

Wetland facilitates in balancing the ecosystem equilibrium by bestowing human livelihood and environment sustainability. The soils of Ujjani wetland in the state of Maharashtra, are experiencing gradual but significant threat in the form of infertility, pollution, and degradation resulting in loss of land as well as crop productivity. In the current study, temporal evaluation of soil quality index is attempted using critical chemical indicators in order to evaluate the large-scale effects of water pollution, massive urbanization, and exhaustive use of fertilizers/pesticides for higher crop production. SQI obtained shows variation on a temporal scale and displays different results. In general, most of the sites reported medium SQI, suggesting potential suitability for agricultural use. However, on a temporal scale the SQI estimated for the year 2017 was significantly better in comparison to SQI for 2018, with around 1% decrease yoy^{-1}. The results also point that the unwarranted application of fertilizers to different crop varieties for faster and higher crop yield has relegated the SQI significantly.

Keywords: *Maharashtra, Wetland, Chemical Indicators, Soil Quality Index*

1. Introduction

Wetlands are the carbon pools which provide services that contribute in balancing the ecosystem and alleviating human well-being (MEA, 2005). Wetlands provide sustenance and livelihood to humans by contributing directly to agricultural production, water source for crops, aquaculture, and livestock. Spatially, the Indian sub-continent encompasses plenteous wetlands covering an area of 75,81,871 ha, classified mainly as inland and coastal types (Garg & Patel, 2007). The wetland area in the state of Maharashtra accounts for more than 13% (10,14,522 ha), with 58% (5,86,418 ha) area occupied by artificial inland wetlands (SAC, 2011).

From the historical assessment between 1970 and 2015 globally, wetlands have declined by 35% (Darrah et al., 2019), with regions in Asia displaying higher levels of loss and the inland wetlands contributing consistently greater and faster rates than the coastal wetlands (Davidson, 2014). Based on the Ramsar Information Sheet (2019), recent practices for agricultural production have caused pressure on 50% of wetlands of international importance. Global estimates for the 20th century suggest that the total natural land area has decreased around 1.5%, while crop and grazing lands increased by 1.7% (UNCCD, 2017). Degradation in water quality has been reported in most Asian rivers, lakes, streams and wetlands, resulting from agricultural run-off of pesticides and fertilizers, and industrial as well as municipal wastewater discharges (Liu & Diamond, 2005; Prasad et al., 2002). Voluminous application of fertilizers and pesticides elevates the nutrient concentrations in the soil and water, which stimulates undesirable algal growth, eutrophication, and soil erosion.

The Ujjani wetland is a potential Ramsar site in the state of Maharashtra, experiencing the extreme effects of water and soil pollution resulting in soil degradation, declining crop productivity, and ecosystem loss yoy^{-1} (Kalekar et al., 2022; Khumbhar & Mhaske, 2020; Shinde et al., 2020; Karikar et al., 2019; Pawar & Jagdale, 2019; Dede, 2016; Sangpal et al., 2014; Samant, 2012; Todkari et al., 2010; Islam & Rahmani, 2008). The untreated wastewater effluents from industries and the sewage discharge from urban agglomeration upstream have resulted in heavy metal contamination and loss of soil fertility. The cultivation in the study area is known to produce different varieties of crops/fruits/vegetables annually on a vast scale, and hence incessant application of fertilizers and pesticides happens to be a conventional practice. Due to the coalesced blend of oversaturated macro- as well as micro-nutrients and toxic effluents from the industries upstream, significant deterioration in the soil health of the wetland is inevitable. In order to monitor the level of temporal changes and degradation in the soils of Ujjani wetland, the current study is an endeavor through estimation and comparison of the soil quality index (SQI).

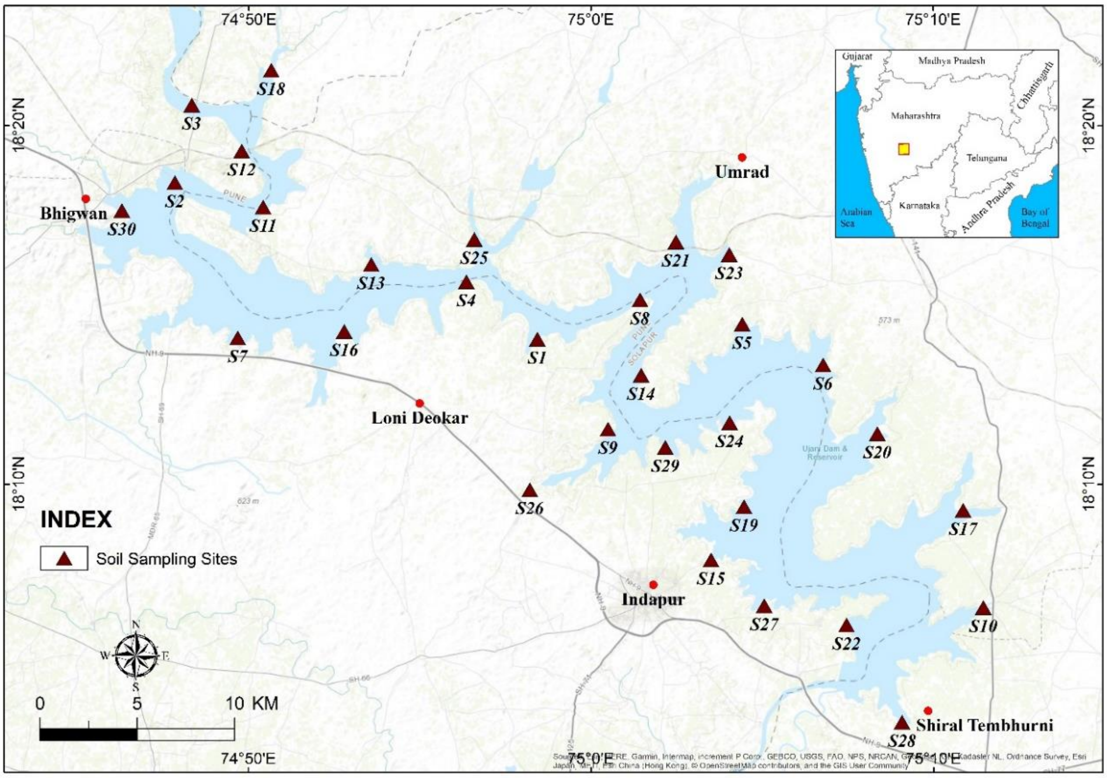

Fig. 1: Location map of the study area with sampling locations

2. Study Area

The study area covers the entire Ujjani wetland in the state of Maharashtra, which came into existence after the construction of an earthfill-cum-masonry gravity dam on the Bhima River, a tributary of River Krishna. The upstream rivers Mula-Mutha, Indrayani and Pawana (tributaries of Bhima River) transecting through the Pune city and its industrial hubs contribute most of the water to the Ujjani wetland. The Ujjani wetland expanses for more than 200 km^2 area and covers the parts of Karmala and Madha Tehsils of Solapur District as well as parts of Indapur Tehsil of Pune District. Fig. 1 shows the location map of the study area. The soils in the study area are mainly characterized by *inceptisols/vertisols*, *isohyperthermic* soil temperature regimes, with moderate salinity and slight sodicity (NBSLLUP, 1996). The climate is semi-arid (dry) with annual mean rainfall around 500 mm. Prime source of irrigation for agriculture is from the wetland, however tube well/dug well as well as rain-fed cultivation is also quite common. Dominant crop varieties grown in the study area include sugarcane (*Saccharum officinarum*), jowar (*Sorghum bicolor*), maize (*Zea mays*), and wheat (*Triticum aestivum*), with 90-120 days as the length of growing period (LGP).

3. Materials and Methods

Boundary of the Ujjani wetland was prepared using temporal comparison between the google imageries and freely-available remote sensing satellite data. Based on the fluctuations in the drained areas, buffer area was determined for soil sampling. A total of thirty (30) sites were finalized and soil samples were collected from the undisturbed buffer zones at a depth of 0-15 cm, during the pre-monsoon periods (Apr-May) for the years 2017 and 2018. The collected samples were packed in an air-tight plastic bags with proper labelling and stored in the ice box for transportation to chemical lab. Before conducting the physio-chemical analysis, all the samples were air-dried, thoroughly mixed and passed through a 2-mm mesh sieve. Analysis was carried out in two phases, firstly the pH and electrical conductivity (EC) were determined using electrometric method (IS:2720-26) and conductivity meter (IS:14767). In the second phase, analysis of available nitrogen by alkaline permanganate method (Subbiah and Asija, 1956), available phosphorus by sodium bicarbonate method (Olsen and Dean, 1965), and available potassium by flame photometer method were carried out.

In the current study, to estimate the soil quality index for the study area ratings of essential nutrients estimated by ICAR, New Delhi were considered. The suitability range for various chemical indicators in soil is provided in Table 1.

Table 1: Framework guidelines of physio-chemical indicators for soil fertility

Sr. No.	Physio-chemical Indicators	Low (Rating 1)	Medium (Rating 2)	High (Rating 3)
1	pH	<4.0 & >8.5	4.0 to 5.5 & 7.2 to 8.5	>5.5 & <7.2
2	Electrical Conductivity (dS m^{-1})	>2.0	1.0 to 2.0	<1.0

3	Available Nitrogen (kg ha^{-1})	<280	281 to 560	>560
4	Available Phosphorus (kg ha^{-1})	<12.5	12.5 to 25	>25
5	Available Potassium (kg ha^{-1})	<135	135 to 335	>335

The soil quality index methodology follows by assigning equal weightages to the chemical indicators as shown in Table 1. It is based on the linear combination of five chemical indicators, which greatly dictate the crop growth and yield. All the parameters are combined in the form of a single index value, which is finally used for determination in the suitability of soil for cultivation.

The SQI index is calculated by the following equation:

$$\text{SQI Index} = \sum_{i=1}^{6} Gi$$

where, 'i' is an incremental index and G represents the contribution of every chemical indicator important for assessment of soil quality index. The contribution of each chemical indicator is calculated based on the rating values of parameters ranging from 3 (High) to 1 (Low) as shown in Table 1. Based on the rating values for each chemical indicator, the total sum of value is estimated as three different values, viz., 15, 10 and 5 respectively. Using the median of these values upper and lower limits are categorized and are shown in Table 2.

Table 2: Soil quality index suitability for cultivation

Soil Quality Index (SQI)	**Class**
<7	Low
7-12	Medium
>12	High

4. Results and Discussions

Based on the framework guidelines of soil quality indicators for agricultural use provided in Table 1 and SQI in Table 2, the following observations are determined for the study area.

Table 3: Descriptive statistics of soil analysis for SQI

Variables	**2017**					
	Min.	**Max.**	**Mean**	**Std. Dev.**	**CV**	**Skewness**
pH	7.82	8.67	8.22	0.21	0.04	0.03
EC (dS m^{-1})	0.16	1.56	0.65	0.39	0.16	0.91
Available N (kg ha^{-1})	90.31	689.00	229.06	126.01	15877.75	1.70
Available P (kg ha^{-1})	4.39	15.13	12.14	2.79	7.80	-1.60
Available K (kg ha^{-1})	168.90	654.80	336.86	109.44	11976.80	0.93
Variables	**2018**					
pH	7.14	8.10	7.76	0.23	0.05	-0.66
EC (dS m-1)	0.18	1.98	0.69	0.38	0.15	1.56

Available N (kg ha^{-1})	56.00	158.00	98.13	26.58	706.38	0.85
Available P (kg ha^{-1})	5.48	13.16	10.40	2.09	4.37	-0.94
Available K (kg ha^{-1})	191.10	2084.00	701.24	419.88	176295.16	1.59

i) pH: For the year 2017, all samples (n=30) fall in medium category (4.0 to 5.5 & 7.2 to 8.5), similarly all samples from 2018 fall in the medium category except one sample (S-18) which falls in the high category (>5.5 & <7.2).

ii) EC: For the year 2017, 80% (n=24) of the samples fall in high category (<1.0 ds m^{-1}) category, while 20% (n=6) fall in the medium category (1.0 to 2.0 ds m^{-1}). For 2018, 83% (n=25) of the samples fall in high category, while remaining samples (n=5) fall in medium category respectively.

iii) Available Nitrogen (kg ha^{-1}): For the year 2017, 67% (n=20) of the samples fall in low category (<280 kg ha^{-1}), 30% (n=9) in medium category (281 to 560 kg ha^{-1}), and only one sample (S-17) in high category (>560 kg ha^{-1}). For the year 2018, all the samples (n=30) fall in the low category.

iv) Available Phosphorus (kg ha^{-1}): For the year 2017, 33% (n=10) samples fall in low category (<12.5 kg ha^{-1}), while remaining samples (n=20) fall in medium category (12.5 to 25 kg ha^{-1}). For the year 2018, 83% (n=25) samples fall in the low category, while remaining samples (n=5) in the medium category respectively.

v) Available Potassium (kg ha^{-1}): For the year 2017, 47% (n=14) samples fall in medium category (135 to 335 kg ha^{-1}), while remaining (n=16) samples fall in high category (>335 kg ha^{-1}). In the year 2018, only four samples (S-8, S-17, S-21 and S-24) fall in medium category, while remaining (n=26) fall in high category.

Comparison of SQI between years 2017 and 2018:

All samples display medium soil quality index for both the years. However, there appears to be 40% (n=12) decrease in SQI from 2017 to 2018 with sites S-17, S-11, S-1, S-2, S-14, and S-28 displaying highest levels in the decreasing order. In addition, 20% sites (n=6) displayed marginal increase in SQI and remaining 40% (n=12) remained neutral and reported no change. In addition, the study also reveals that temporally the SQI gradually decreased yoy^{-1} (Fig. 2).

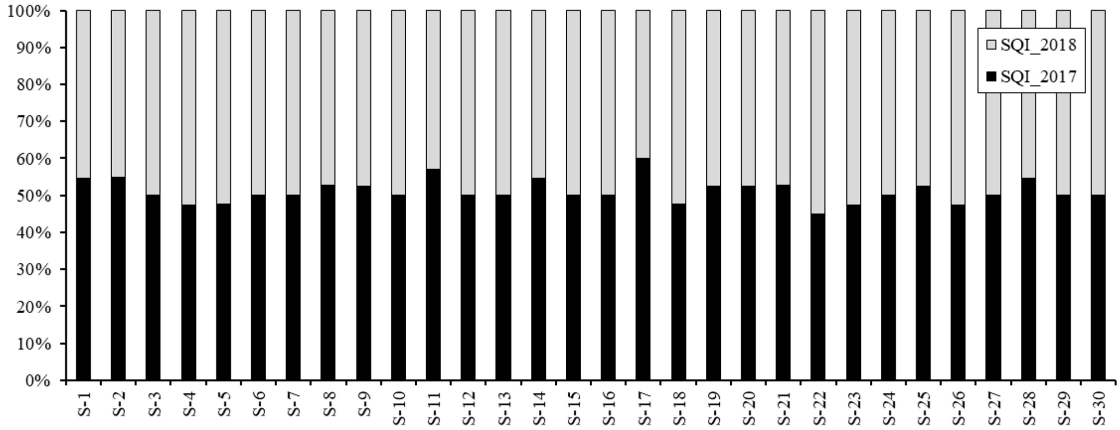

Fig. 2: Graph showing the temporal variation of SQI for the years 2017 and 2018

5. Conclusions

The SQI was calculated using the most fundamental chemical indicators, viz., pH, EC, N, P, and K, which constitute the physical and macro-nutrients components of the soil. The study reveals that these chemical indicators were found to greatly influence the SQI on a temporal scale. Variation in these chemical indicators was recorded from low to high categories. Out of the five indicators, nitrogen and phosphorus contributed the highest weightage in controlling the higher SQI levels, followed by potassium, pH and EC. All the sampling sites on temporal scale reported medium suitability index for the study area. In terms of spatial distribution of SQI variability, there appears to be no well-defined regions in the study area, however decrease in SQI is mostly clustered around the urban agglomerations utilizing the land for cultivation. The average deterioration in SQI between the years is estimated to be around 1% yoy^{-1}.

References

MEA (2005). Ecosystems and human well-being: Wetlands and Water Synthesis. A report of the Millennium Ecosystem Assessment

Garg, J. K. and Patel, J. G. (2007). National Wetland Inventory and Assessment - Technical guidelines and procedure manual. Space Applications Centre, Indian Space Research Organization, Ahmedabad

Space Applications Centre (SAC) (2011): National Wetland Atlas. SAC, Indian Space Research Organization, Ahmedabad

Darrah, S. E., Shennan-Farpon, Y., Loh, J., Davidson, N. C., Max Finlayson, C., Gardner, R. C., Walpole, M. J. (2019). Improvements to the Wetland Extent Trends (WET) index as a tool for monitoring natural and human-made wetlands. Ecological Indicators, 99, pp. 294-298

Davidson, N. C. (2014). How much wetland has the world lost? Long-term and recent trends in global wetland area. Marine and Freshwater Research, 65(10), 934-941

Convention on Wetlands. (2019). Ramsar Information Sheets (RIS). Ramsar Site Information Service (RSIS). Retrieved October, 2019, from www.rsis.ramsar.org

UNCCD (2017). The Global Land Outlook. First Edition, Germany, pp. 30-50

Liu, J. G., Diamond, J. (2005). China’s environment in a globalizing world. Nature, 435 (June), pp. 1179-1186

Prasad, S. N., Ramachandra, T. V., Ahalya, N., Sengupta, T., Kumar, A., Tiwari, A. K., Vijayan, V. S., Vijayan, L. (2002). Conservation of wetlands of India – a review. Tropical Ecology, 43(1), pp. 173-186

Kalekar, P., Kamble, P., Chakraborti, S., Dev, P., Alvarez E., Laware, S. (2022). Heavy metal contamination in surface sediments of the Upper Bhima Basin, Maharashtra, India. Environmental Sustainability, Vol. 5, pp. 507-531

Kumbhar, D. S., Mhaske, D. K. (2020). Study of waders diversity in the catchment area of Ujani Reservoir, Solapur District (MS), India. International Journal of Biological Innovations, 2(2), 287–294

Shinde, D., Kamble, P., Mahajan, D. M., Devkar, V., Chakane, S. (2020). Analysis of accumulated heavy metal concentrations in various body parts of Chillapi (*Oreochromis mossambicus*) fish from Ujjani Reservoir of Maharashtra, India. Advances in Zoology and Botany, 8(2), pp. 37-44

Karikar, S. P., Mali, S. V., Prasad, K. Priti, A. (2019). An assessment of bird communities across Ujjani and its five satellite wetlands in Solapur District of Maharashtra, India. Journal of Threatened Taxa, 11(5), pp. 14989–14997

Pawar, R. R., Jagdale, A. N. (2019). Study on water quality parameters of Ujjani dam backwater in Pune District (M.S.) India. International Journal of Science and Research, Vol.8(12), pp. 501-508

Dede, A. N. (2016). Study on fish diversity indices in Bhima River from Ursale village, Dist. Solapur (India). International Journal for Scientific Research & Development. Vol. 4, Issue 05, pp. 1675-1678

Sangpal, R. R., Kulkarni, U. D., Sayyed, M. R. G. (2014). Impact of point and nonpoint sources of pollution on drinking water quality within Yeshwantsagar Reservoir (Ujjani Dam), District Solapur, Maharashtra (India). International Journal of Environmental Sciences, 3(4), pp. 236-242

Samant, J. (2012). Wetland conservation in Maharashtra: Need, Threats, and Potential. Proc. of Int. Conf. SWRDM-2012, Dept. of Env. Science, Shivaji University, Kolhapur

Todikar, G. U., Suryawanshi, S. P., Suryawanshi, M. V., Patil, B. D. (2010). Agriculture landuse pattern in Solapur District of Maharashtra. International Journal of Agriculture Sciences, Vol. 2(2), pp. 1-8

Islam, M. Z., Rahmani, A. R. (2008). Potential and existing Ramsar sites in India. Mumbai: Bombay Natural History Society, Bird Life International and Royal Society for the Protection of Birds, Oxford University Press, pp. 1-18

National Bureau of Soil Survey and Land Use Planning, NBSSLUP (1996). Maharashtra Soils. The Soil Map of Maharashtra, Sheets 1-4

Indian Standards 2720 (Part 26): Determination of pH value (Second Revision). In: Method of test for soils, BIS, New Delhi (1987)

Indian Standards 14767: Determination of specific electrical conductivity of soils. In: Method of test for soils, BIS, New Delhi (2000)

Walkley, A., Black, I. A. (1934). An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Rothamsted Experimental Station, England, pp. 29-38

Subbiah, B. V., Asija, G. L. (1956). A rapid procedure for the estimation of available nitrogen in soils. Current Science, Vol. 25(8), pp. 259-260

Olsen, S. R., Dean, L. A. (1965). Phosphorus. In: Methods of Soil Analysis. American Society of Agronomy. Madison, Wisconsin, Vol. 9, pp. 920-926

ICAR (2019). Soil Fertility, Fertilizers and Integrated Nutrients Use. In: Handbook of Agriculture. Indian Council of Agricultural Research, New Delhi, pp. 516