21 Faulty Waste Water Usage Versus Agricultural Sustainability: An Assessment of East Kolkata Wetlands

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Abstract

In recent times, excessive population growth and increasing demand for habitation continue to drive rapid urbanization, illegal construction, and modification of land cover in the surrounding areas of East Kolkata Wetlands. These expansions lead to the disruption of basic physiochemical and hydrological functioning, excessive silting, pollution and heavy metal concentration, overexploitation of fragile ecosystems, loss of biodiversity coupled with the change of soil properties and drop in both quality and quantity of sewage indirectly affecting both agriculture and pisciculture. This study aimed to identify the linkage of urban expansion and wastewater usage as non-sustainable agricultural practices in East Kolkata Wetlands. The data from different fields of geospatial and earth observatory technology (satellites and Google View), laboratory testing (from field samples) along with empirical observations have been used. Here, the boundary of EKW for 1968, 1977, 1990, and 1998 has been drawn based on the same visualizing characteristics of the EKW and considering seven parameters: tone, texture, size, shape, pattern, shadow, and site situation. This area was a marshy land around 30–40 years ago, which gradually transformed into agricultural areas and later resulted in an urban scape due to illegal construction. The food and feeding habits of the fishes are one of the detrimental factors regarding bioaccumulation of heavy metals. A decrease in organic carbon concentration indicates an interruption in the biogeochemical cycle. Leaf area index value has been analyzed to identify the light energy interception. The gross and net primary productivity values are examined for the survival level of crops. The results obtained show unsustainable wastewater usage in agricultural practice in the East Kolkata Wetlands area, thus adversely influencing human food grain. This study further suggests more influences of empirical research on the ground of scientific correlation between the water quality parameters and adverse human health impact.

Keywords

Agriculture · Pisciculture · Wetlands · Vegetation · Productivity · Sustainability

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21.1 Introduction

A wetland is often considered an unwanted swampy area, but sometimes as history states, it has been of great use in maintaining the homeostasis of an ecosystem. East Kolkata Wetlands, a distinct wetland of West Bengal, has varied uses for Kolkata and its adjoining areas. This wetland was the epitome of pisciculture and often acted as an agricultural hub for the adjacent areas. However, the faulty water usage methods have led to havoc, creating less opportunity for sustainable agriculture. This paper tries to investigate this core problem with the help of an analytical study. Various eminent hydrologists and environmentalists have discussed this issue in their working papers. Various authors have evaluated this problem, extensively studied it, and tried to provide an empirical conclusion of the abovementioned situation.

Roy et al. (2016a), in their study, entitled 'Water Quality Index (WQI) of East Kolkata Wetlands using dissolved oxygen as proxy' has tried to investigate the reason for declining WQI by considering various factors and also has tried to provide a concrete solution regarding the issue. In contrast, Roy et al. (2016b) have tried to identify the causes of spatiotemporal variations of surface water temperature, pH, dissolved oxygen, nitrate, phosphate, and silicate on chlorophyll concentration in three water bodies meant for fish culture (locally known as Bheries) in East Kolkata Wetlands. Chattopadhyay et al. (2002) have extensively studied the toxic concentration of metal in the East Calcutta Wetlands. Haque (2020) also has tried to evaluate the spatiotemporal changes in the wetland's water. Similarly, Ghosh and Das (2019) stated about the recent anthropogenic interference, which acted as an obstacle and a threat to wetlands conservation.

Thus, a wetland denotes a distinct ecosystem, flooded by water at regular intervals (permanently or temporarily), where oxygen-free processes are common. East Kolkata Wetlands (henceforth EKWs) is no exception. The wetlands acted as a sewage treatment area in Kolkata and the nutrients harnessed from there helped to withstand agriculture. The preliminary hydrological functioning of the canals and fishing ponds has been severely affected by a huge mass of siltation, along with lower levels of sewage quality that the wetlands used to receive, thus wholly affecting the production of crops. The circumstances described above pose a serious threat to the water treatment systems. So it is a prerequisite to study the changes over time to ameliorate the ill effects until it gets too late. The studies regarding single-parametric analysis of agricultural sustainability in East Kolkata Wetlands are many years old. Still, it is necessary to carry out researches on multi-parametric analysis based on non-sustainable agricultural practices. Hence, this particular problem is the prime target in the selected study area. Thus, this research has been of great interest as there is very less evidence of such researches in the past. This study is a small step toward the above lacunae. Moreover, this research's prime objective is to identify the extremely vulnerable zones regarding agricultural sustainability.

In this chapter, the methodology is planned with the identification of certain selected parameters evaluating their purpose and the techniques used in such evaluation. An empirical study has been conducted in East Calcutta Wetlands to identify the various changes like chlorophyll concentration, the concentration of carotenoids, leaf area index, inability to perform photosynthesis, low energy, and gas exchange rate. Moreover, the above analysis concludes along with the identification of ecologically vulnerable zones.

21.1.1 Relevance

East Kolkata Wetlands is the most important wetland and has received an extensive response as various environmentalists, geologists, hydrologists, and geographers have studied in detail this particular wetland. However, the constant implementation of faulty techniques of wastewater conservation has created an inverse effect on the various types of agricultural practices and their allied activities in the EKW. The paper tries to evaluate the exact reason behind such an anomaly which has resulted in gradual disruption and has prevented from using sustainable agricultural techniques. This paper is significant as no such initiative has been taken so far to examine the details and the existing relationship between the usage of wastewater and agricultural practices that are being carried out in East Calcutta Wetlands.

21.2 Data and Methodology

21.2.1 Data Source

As per the prime objective of this chapter, the data from different fields of geospatial and earth observatory technology (satellites and Google View), along with the empirical observations, have been used to understand the extremely vulnerable zones in terms of agricultural sustainability. Datasheet details have been furnished below (Table 21.1). Here, the boundary of EKW for 1968, 1977, 1990, and 1998 has been drawn based on the same visualizing characteristics of the EKW and considering seven parameters: tone, texture, size, shape, pattern, shadow, and site situation.

21.2.2 Methodology

A literature review from different articles has been prepared along with the collection of satellite images from different sources; the sample is prepared in the laboratory for digestion. Tests have been prepared using different instruments, and a pilot survey has been conducted to have a clear glimpse of the area. Samples have been collected from Dhapa, Topsia DPS, Chowbaga DPS, Tannery site, Palmer Bazar DPS, and Kulti lock gate) for ground truth verification, and locations have been detected by the trilateration method with GPS. Testing of samples using different methods (Walkley–black acid digestion method, spectrophotometer method, ascorbic acid method, electrical conductivity method, gravimetric analysis, iodometric method; chlorophyll extraction method and fluorometric technique), calibration of ground truth with satellite for data analysis have also been carried out. Findings and solutions have been provided in the following Table 21.2.

21.2.3 Study Area

East Kolkata Wetlands (22°25′N to 22°40′N; 88° 20′E to 88°35′E) is located in the districts of North and South 24 Parganas of the Indian state of West Bengal, occupying a total surface area of 12,500 hectares. It consists of salt marshes, agricultural fields, sewage farms, and settling ponds and also serves as a natural sewage treatment plant for Kolkata. The name East Kolkata Wetlands (EKW) was propounded by Dhrubajyoti Ghosh (Special Advisory, Commission on Ecosystem Management, IUCN). The EKW is a kind of human-induced ecosystem involved in resource recovery practices. It has transformed itself from 'nona-bheris' (salty swamps) to a sound sewage-fed fish farm in 250 years, leading to a typical livelihood pattern as per a set of interdependent vocations in the area. EKW is a peri-urban wetland supplying a multifaceted perspective in terms of both fish criteria and waterfowl habitats. It also hosts a large variety of flora and fauna. The aquatic vegetation mainly comprises of floating microphytes. There are also about 100 plant species in EKW. It also serves as a home to various indigenous animal species and snakes. Several fish species are farmed in sewage-fed ponds called 'bheris' (Fig. 21.1).

21.3 Results and Discussion

21.3.1 Lack of Chlorophyll Concentration

Poor drainage, damaged roots, high alkalinity [deficiency of iron or manganese, both of which are present but unavailable in high pH soils (pH > 7.2)], and nutrient deficiencies in the plant have caused a huge amount of chlorophyll destruction (Baker 2008) in the northeastern and northwestern part of the wetlands region from 1977 to 2020.

Table 21.1 Catalogue of different types of data sources

Data type	Sub-type		Nature	Source	Purpose
Earth observatory images (secondary data)	Sensor	MSS	r = 148, p = 45 December 1975	https://earthexplorer.usgs.gov/	Image classification for land cover change detection, NDBI, NDMI, LST, BSI, NDVI, NPCRI, habitat fragmentation, and disturbance mapping
		TM	r = 138, p = 44 November 1990		
		OLI-1	r = 128, p = 45 February 2020		
		MODIS	MOD17A2H V-6	NASA LPDAAC collection	Determining average evapotranspiration value
		MODIS	MOD16A2 V-6		Determining GPP value
		ALOS PALSAR	r = 138, p = 45 2009 and 2020	https://earthdata.nas a.gov/	For preparing a 3d urban model and to detect topographic wetness
Maps (secondary data)	Toposheets	79B/6 on 1:50,000 (surveyed in 1958-59) toposheet on inch map (surveyed on 1922–1924)		SOI-1973 SOI-1968	The base map for assessing the previous land resources, infrastructures, and settlements
	Other thematic maps	Gross biomass, surplus biomass, and bioenergy potential map		ISRO Bhuvan portal	To visualize gross biomass, surplus biomass, and bioenergy potential
		Dry matter productivity map, FAIR, COVER, leaf area index, soil water index, surface soil moisture map, VCI, VPI		Copernicus Global Land Service	For determining dry matter productivity rate, spatial variation of photosynthesis rate, fraction of green cover, leaf area, presence of surface water, surface soil moisture content, vegetation condition and vegetation productivity

In 1977, through an archival study, comparatively dense vegetation cover was found in almost all the wetlands regions like Gharal, Tardaha Kapasati, Samukpota, Tardaha, Pratapnagar, Tihuria, Nayabad, Kantipota, Ranabhutia, Atghara, northern part of Dhapa Manpur, northern part of Panchuria, Hadia, Jagatipota, and Bhagabanpur, while low-dense vegetation cover was found in Boinchtala, Dhalenda, Paschim Chaubaga, Nonadanga, the northern part of Dhapa, the eastern part of Beonta, the northeastern part of Tardaha Kapasati, and very low vegetation cover was found in the middle part of Dhapa.

In 1990, very high dense vegetation cover was observed in the eastern part of Boinchtala, Dhapa, the middle eastern part of Dhapa Manpur, the western part of Hadia, Beonta, Karimpur, the eastern part of Bhagabanpur, the western part of Deara, a small part of Hatgacha and middle part of Tardaha Kapasati. On the contrary, high dense vegetation cover was found in Ranabhutia, Nayabad, Gharal, Samukpota, Bhagabanpur,

Table 21.2 Detail description of methodology

Parameters			Purpose	Methods
Primary productivity	GPP	Net	To find the food-web	(Data collected from NASA LPDAAC Collection)
		Nano		
		Total		
	NPP	Net		
		Nano		
		Total		
	TP	Net		
		Nano		
		Total		
Normalized difference vegetation index			To detect the Chlorophyll concentration	(B4-B3)/(B4 + B3) (LANDSAT-5) (B5-B4)/(B5 + B4) (LANDSAT-8)
Normalized pigment chlorophyll ratio index			To identify the status of plant stability	(B3-B1)/(B3 + B1) (LANDSAT-5) (B4-B2)/(B4 + B2) (LANDSAT-8)
Leaf area index			To measure the amount of light energy interception	Copernicus Global Land Service
Fraction of absorbed photosynthetically active radiation index			To measure the amount of photosynthesis and to detect the presence of dead leaves	Copernicus Global Land Service
Amount of top of canopy reflectance index			To detect the state of ecophysiological condition	Copernicus Global Land Service
Vegetation productivity index			To measure the respiration rate and growth rate and detect vegetation state	Copernicus Global Land Service
Amount of dry matter productivity			To measure the stability of the base of trophic structure, energy flow, and bioenergy potentiality	Copernicus Global Land Service
Amount of average evapotranspiration			To measure the rate of transpiration	NASA LPDAAC collections
Amount of gross biomass			To measure the stability of the base of the trophic structure, the energy flow	ISRO Bhuvan portal
Amount of surplus biomass			To measure the stability of the base of the trophic structure, the energy flow	ISRO Bhuvan portal
Amount of bioenergy potential			To measure the bioenergy potentiality	ISRO Bhuvan portal

Jagatipota, Atghara, Karimpur, the northeastern part of Tardaha Kapasati, Tardaha, Tihuria, and Beonta. Bongtala, Dhalenda, Paschim Chaubaga, Nonadanga, North Dhapa Manpur, North Hatgacha, Eastern Beonta, North Panchuria, South Tardaha Kapasati, and Hatgacha had a low vegetation cover. Whereas, very low vegetation cover was found in the middle part of Dhapa Manpur, the western and eastern parts of Hadia, the southern part of Dhapa, the western part of Khodhati, the middle and northwestern part of Tardaha Kapasati, the southwestern part of Tihuria, Deara, and the southeastern and northeastern part of Bhagabanpur. In 2020, very dense vegetation cover is absent in any part of the wetlands. In the meantime, high vegetation cover

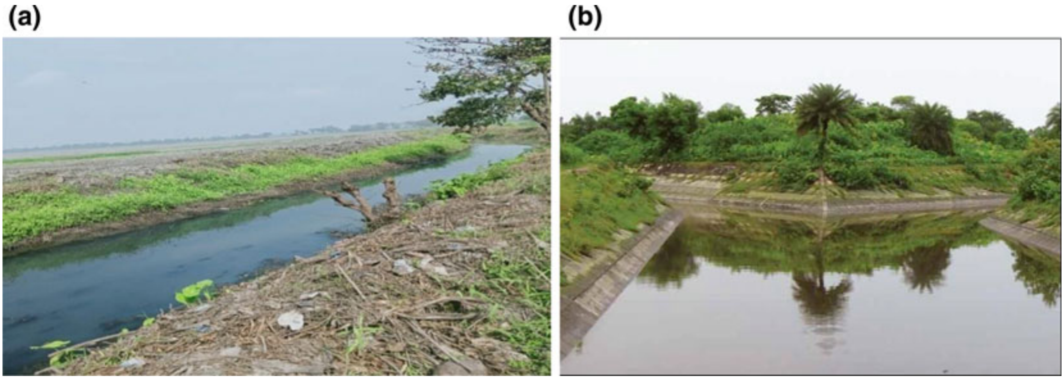

Fig. 21.1 View of surveyed wetland, **a** inlet of wetland, **b** outlet of wetland

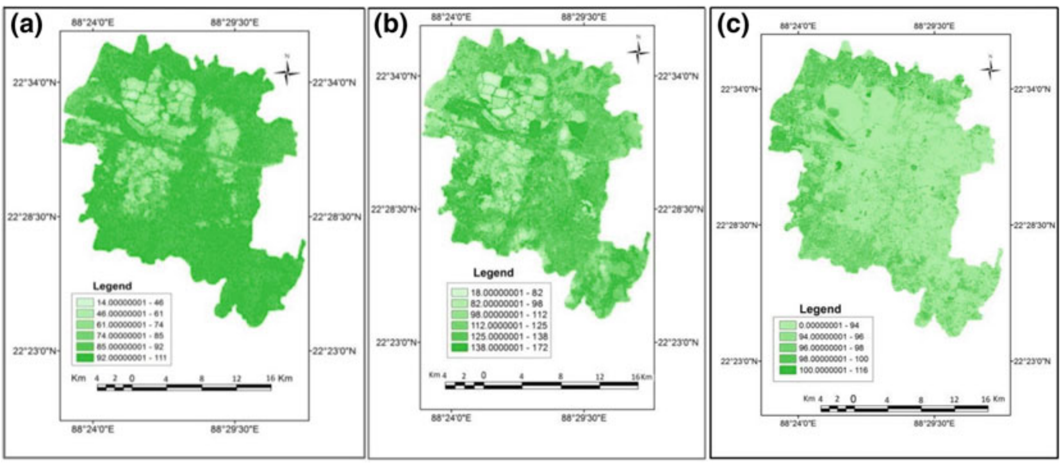

Fig. 21.2 Normalized difference vegetation index **a** 1977, **b** 1990, and **c** 2020

is limited to some blocks like West Dhapa Manpur, northeast Dhapa, southwest Dhapa, Paschim Chaubaga, Nonadanga, west Chaubaga, and west Dhalenda. Medium and dense vegetation cover prevails in Boinchtala, north Dhapa Manpur, north Hatgacha, north Nanchuria, north Kulberia, Karimpur, Bhagabanpur, Jagatipota, Algarah, Ranabhutia, Kantipota, Nayabad, Tihuria, middle and western Tardaha, a small part of Samukpota, and a small patch in south Tardaha Kapasati, and low vegetation cover in the middle and southern part of Dhapa Manpur, Hadia, Beonta, south Pachuria, and the south-western Kulberia, middle and southeastern part of Dhapa, Tardaha Kapasati, the eastern part of Tardaha, Deara, Kheadaha, Kumar Pukuria, Goalpara, and south Chaubagha (Fig. 21.2).

21.3.2 Lack of Amount of Carotenoids

On the western side, metal pollution affects the transfer of carotenoids (Sillanpää, et al., 2008) across the trophic levels. Although the plant's growth rate is high there due to the presence of sufficient amount of nitrogen, the stability is low due to the presence of a few carotenoids. There is

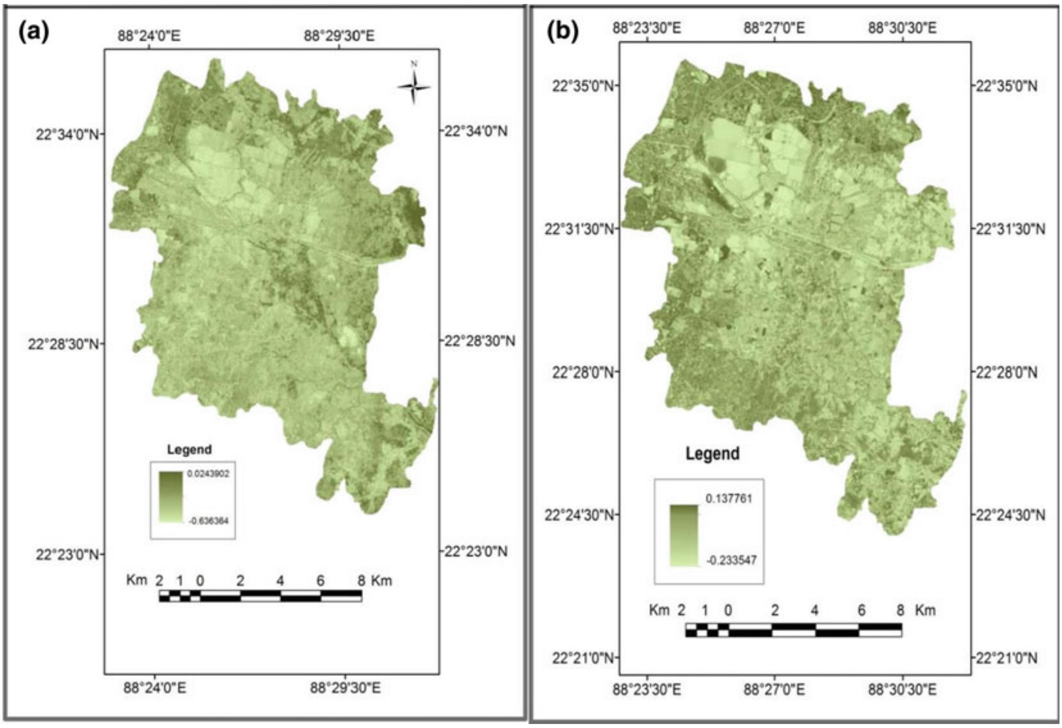

Fig. 21.3 Normalized Pigment Chlorophyll Ratio index **a** 1990, and **b** 2020

a low survival response of plants due to non-photo-protection and low energy absorption, which is used in photosynthesis. From Normalized Pigment Chlorophyll Ratio Index, it is evident that stable ecosystem conditions have shifted from the north and eastern sites to the southern and northern sites in the wetlands region from 1990 to 2020. In 1990, a very high value was found in East Beonta (0.0243902), and a high value was seen in North Dhapa, Chaubaga, Nonadanga, east Khodhati, a small patch near North Goalpara, northwestern part of Tardaha Kapasati and a very small patch near South Ghara, South Samukpota, and southeast Tardaha Kapasati, indicating more stable ecosystem because the large survival response of plants due to photo-protection via non-photochemical quenching and high amount of energy absorption which is used in photosynthesis. Despite the low presence of nitrogen, large amounts of carotenoids are responsible for a long stability (Swapnil, 2021). It has been found that very low value was found in the middle and southern part of Dhapa Manpur, Dhapa, Hatgacha, south Bonchtala, south Panchuria, west Beonta, Hadia, Kharki, Kaarimpur, Kalikapur, Deara, Bhagabanpur, Jagatipata, Atghara, Ranabhutia, Kantpota, Nayabad, west Khodhati, Kheadaha, Tihuria, Tardaha, and the middle part of Tardaha Kapasati. From the Normalized Pigment Chlorophyll Ratio Index, it is clear that a stable ecosystem has shifted from the north and eastern sites to the western, southern, and northern sites in the wetlands region from 1990 to 2020 (Fig. 21.3).

21.3.3 Increase of the Shortage of Leaf Area

Climatic factors (mainly temperature), light intensity, nutrient availability, soil moisture, N supply, and the air humidity regime can influence leaf size and shape. Due to the lack of those ideal conditions, a very low leaf area index value

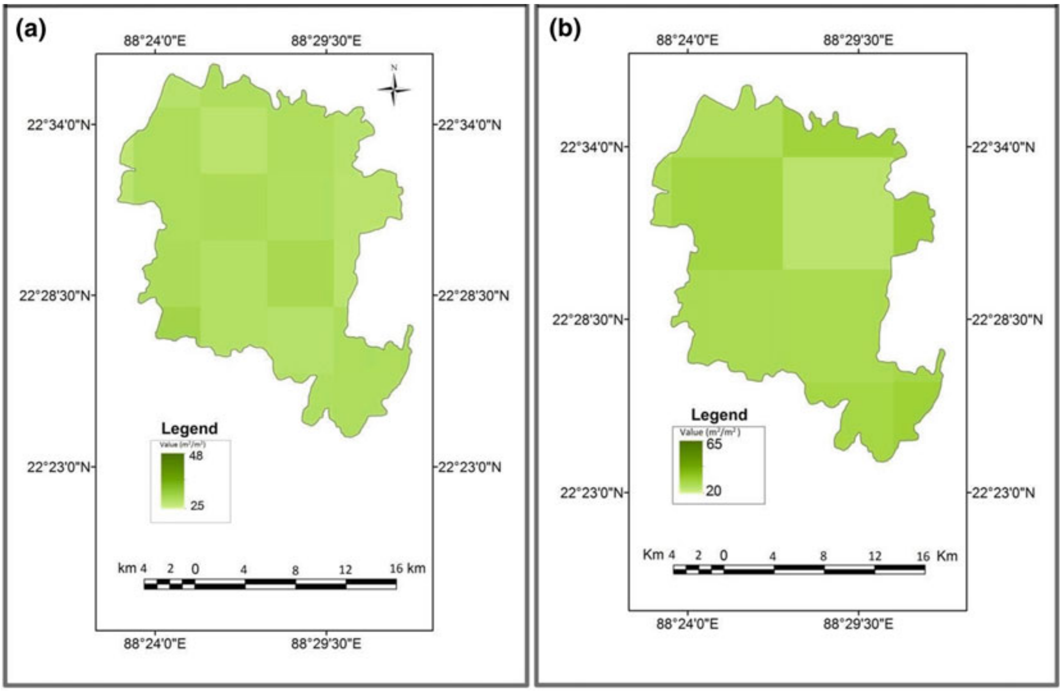

Fig. 21.4 Leaf area index **a** 1999, and **b** 2020

(almost $20m^2/m^2$) is found in Hadia, east Beonta, north Khodhati, south Panchuria, south Hatgacha, southeast Dhapa, Manpur which indicates a small amount of light energy interception. As a result, the primary production is also very negligible (due to the small leaf area per unit of ground area) (Srinivasan et al. 2017). Primary production and light energy absorption have changed in the wetlands region's northern, southern, and western sites from 1990 to 2020. Gross Primary Productivity is very high (33,000 g C m^{-2} $year^{-1}$) in the middle and northwestern part of Dhapa Manpur, north Dhapa, Bonchtala, Dhalenda, Paschim Chaubagha, Nonadanga, northwest Chaubagha, south Chaubagha, west Kalikapur, northwest Beonta, and south Dhapa. In comparison, maximum Gross Primary Productivity regions are located in the northwestern and middle part of the wetlands, indicating a high metabolism rate, cellular respiration, and high rate of tissue building. Very low Gross Primary Productivity (10 g cm-$year^{-2}$ $year^{-1}$) is found in Pratapnagar, Gharal, Samukpota, Tardaha, Tihuria, Nayabad, Kantipota, Beonta, Khodhati, Goalpara, Kumar Pukuria, Kheadaha, Deara, Bhagabanpur, Kharki which points out low metabolism rate, low cellular respiration and low rate of tissue building (Fig. 21.4).

21.3.4 Lack of Photosynthesis and Increase in the Number of Dead Leaves

Leaf spectral properties are the main analyzing factor for light composition within the plant communities. The photosynthetic pigments absorb sunlight in the upper part of the plant (top spectrum). The leaves often function as a filter for blue and red wavelengths. The resultant transmitted wavelengths mainly consist of green and far red (bottom spectrum). The greener tissue in the plant sometimes reflects far red, thus reducing the R/FR ratio. In a forested area, a high reflection of far red light is noticed, especially from the

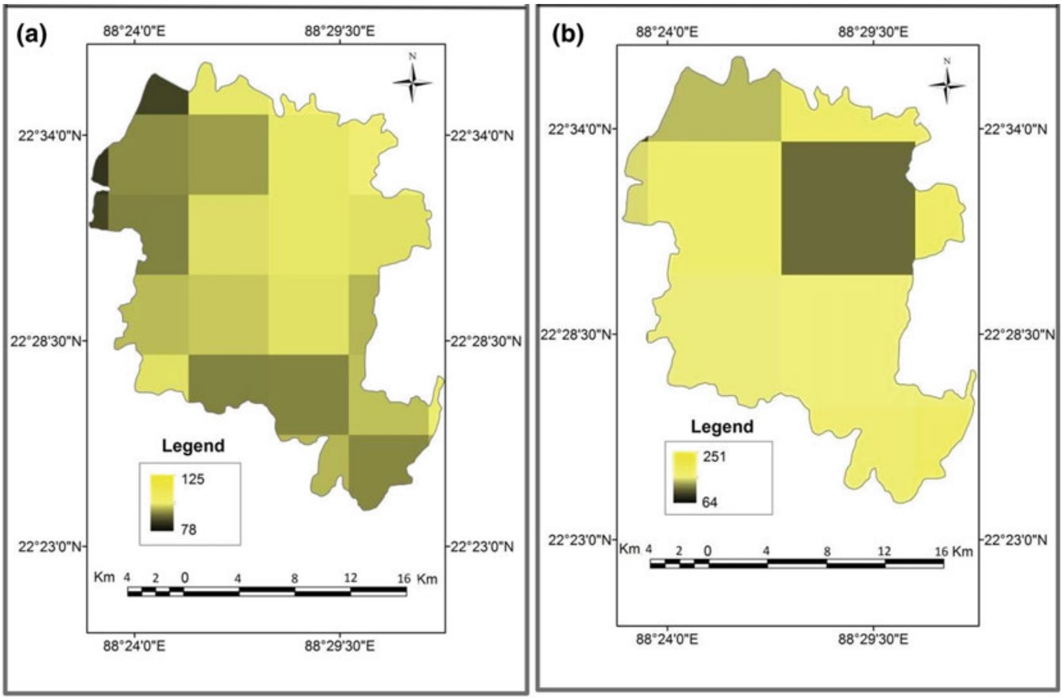

Fig. 21.5 Fraction of absorbed photosynthetic active radiation **a** 1990, and **b** 2020

neighboring plants, to indicate a strong competitive environment under an evergreen canopy; light is filtered by the presence of leaves at a higher level and lower parts that are the understoey forests receives a low light intensity. Under a canopy, light is strongly filtered by high tree leaves, and the understory receives a much lower light intensity, characterized by low UV-B, low photosynthetic active radiation, and low R/FR. FAPAR value becomes very low (1990–2020) in the northeastern and northwestern parts, which indicates not only a low amount of photosynthesis but also the presence of dead leaves (Fig. 21.5).

21.3.5 Very Low Energy and Gas Exchange Rate

Due to water-logging (rainy season), high temperatures, and inadequate mineral content of the soil, the presence of phytotoxic compounds with high reflectance is found in the northwestern, southeastern, northern, and western parts, which indicates less presence of pigments (including chlorophyll a & b) and canopy water content. The above said phenomenon shows poor ecophysiological conditions (where CO_2 consumption, O_2 release, and the energy exchange rate is improper). Low reflectance is found in East Kharki, Deara, southeast Bhagabanpur, Goalpota, west Kheadaha, north Nayabad, and north Tihuria, which indicates more presence of pigments (including chlorophyll a & b) and canopy water content (Fig. 21.6). The above-stated situation is a sign of better ecophysiological condition (where CO_2 consumption, O_2 release, and the energy exchange rate is proper).

21.3.6 Decrease in the Amount of Vegetation Productivity

Despite the high value of Gross Primary Productivity, low Net Primary Productivity value is found in northwestern and western parts due to

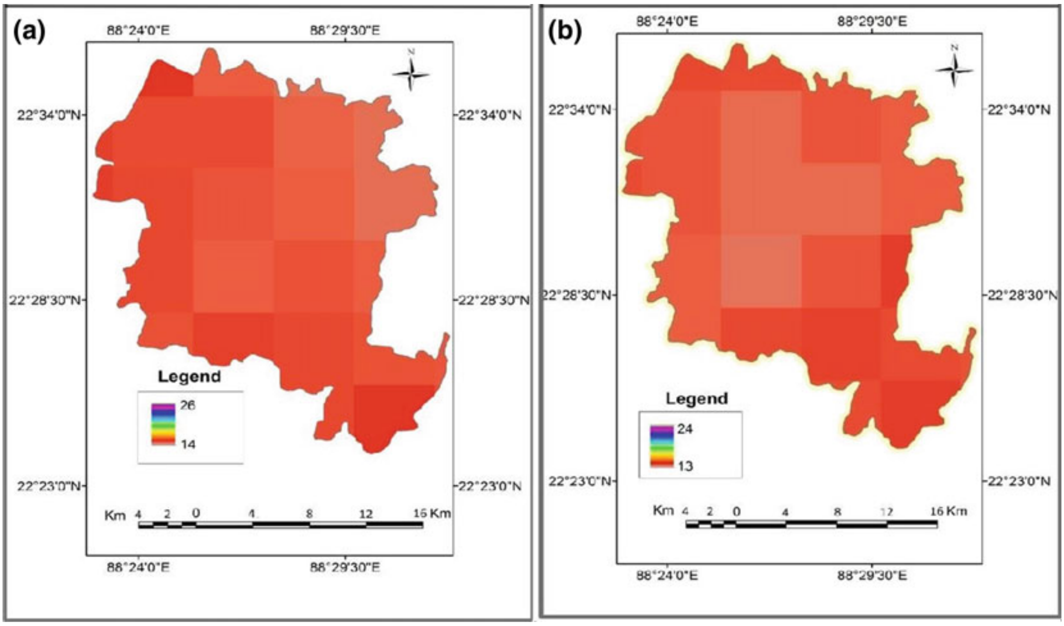

Fig. 21.6 Amount of top of canopy reflectance **a** 1999 and **b** 2005

huge anaerobic respiration, which is essential for plants' cellular activities, growth and maintenance of all plant tissues, carbon balance of individual cells, and to get the energy to stay alive and creating the ability to survive by fighting various diseases (Ward et al. 2019) It indicates that the worst vegetation state has a low growth rate. The average evapotranspiration rate is also very high (32,766 mm) there. High Net Primary Productivity in other sites indicates a more or less good vegetation state (Figs. 21.7 and 21.8).

21.3.7 Spatial Variation of Amount of Gross, Surplus Biomass, and Bioenergy Potential

Low Gross Biomass (<0.15 Kilo tons Km^{-2}) in the middle part of the wetlands reflect poor ecological process (less control of plants on nutrients, water, and solar resources), and the base of the trophic structure is very weak (Table 21.3). Low surplus biomass (<0.02 kilo tons Km^{-2}) in the southeastern site indicates interrupted energy flow through different trophic levels (Rapport et al. 1985) in an ecosystem. Low bioenergy potentiality (0–0.4 Giga Joule Km^{-2}) is found in the middle part of the wetlands, but the northwestern part has a huge bioenergy potentiality (Figs. 21.9, 21.10, 21.11, 21.12, and 21.13).

21.3.8 Identification of Ecologically Vulnerable Zone

This study indicates that the various 'mouza' (demarcated areas under a community development block) in the vicinity of Kolkata megacity and Salt Lake City are at high risk and under a higher vulnerable zone, and the southern part that is including the Sonarpur municipality area is also at a high-risk zone. On the other hand, as the distance increases from the Kolkata municipality

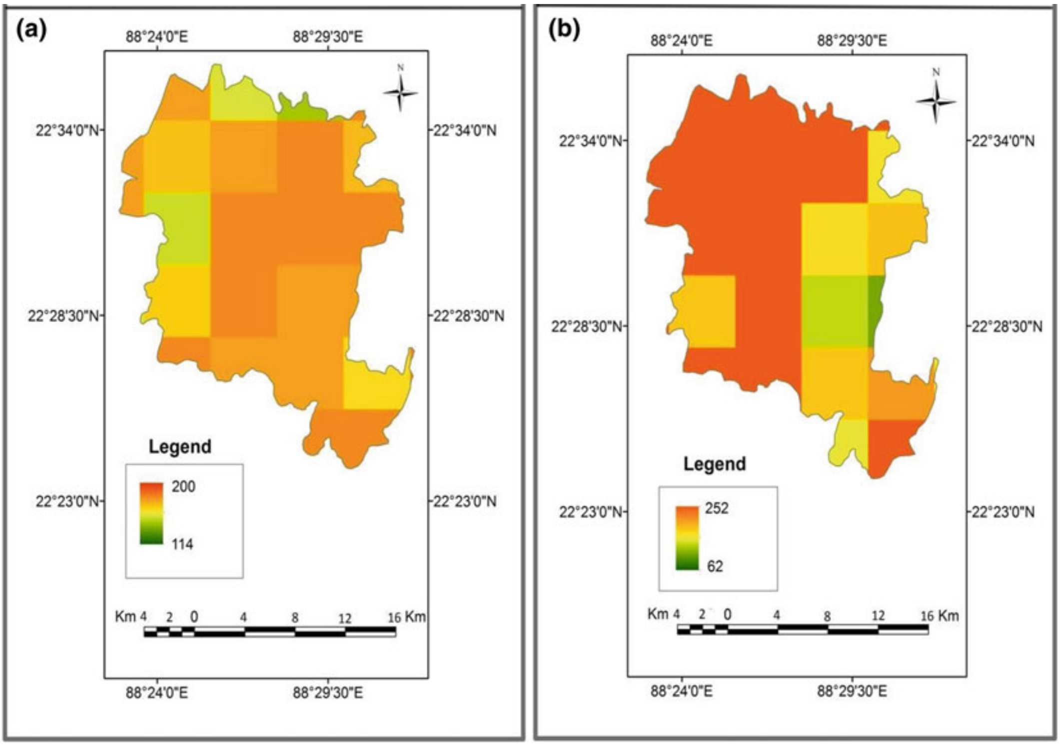

Fig. 21.7 Vegetation productivity index **a** 2013, and **b** 2020

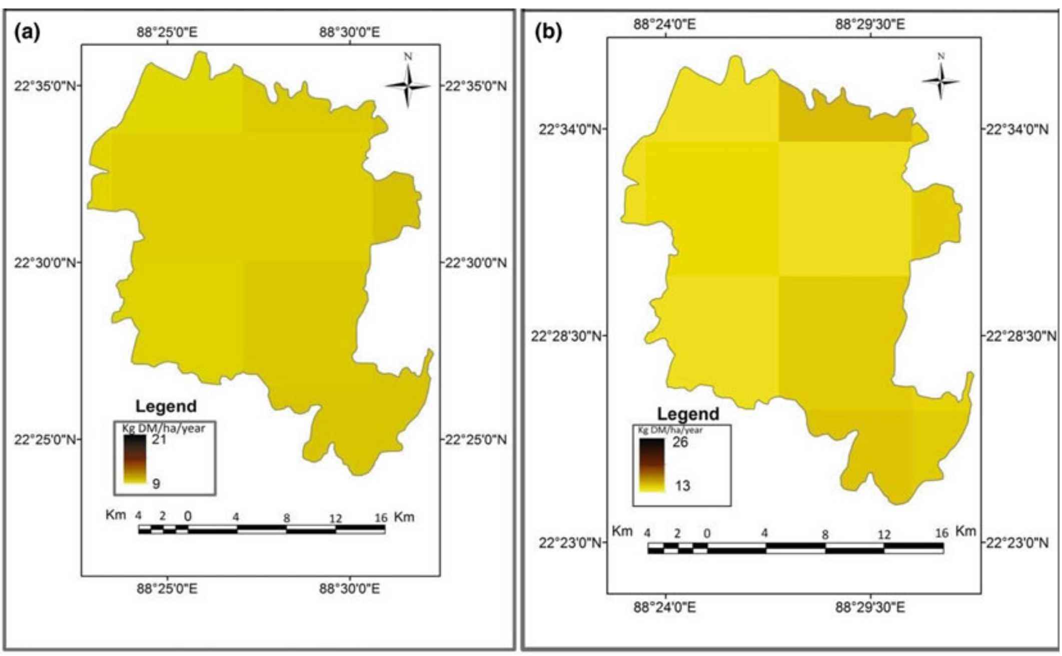

Fig. 21.8 Amount of dry matter productivity **a** 2014 and **b** 2020

Table 21.3 Biomass data of different crops, 2020

Biomass	Kharif rice	Rabi rice	Wheat	Cotton	Sugarcane	Total
Gross biomass	0.37	11.54	0	0	0	–
Surplus biomass	0.02	0.57	0	0	0	–
Bioenergy potential	0.28	8.86	0	0	0	9.14

Source ISRO Bhuvan portal

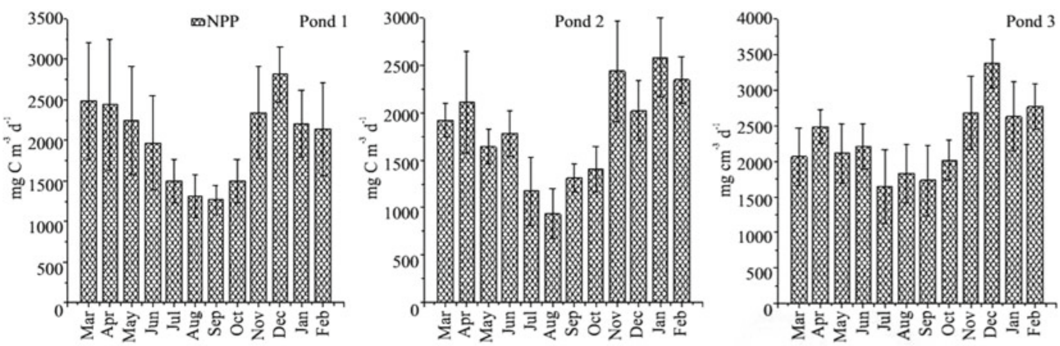

Fig. 21.9 Net primary productivity

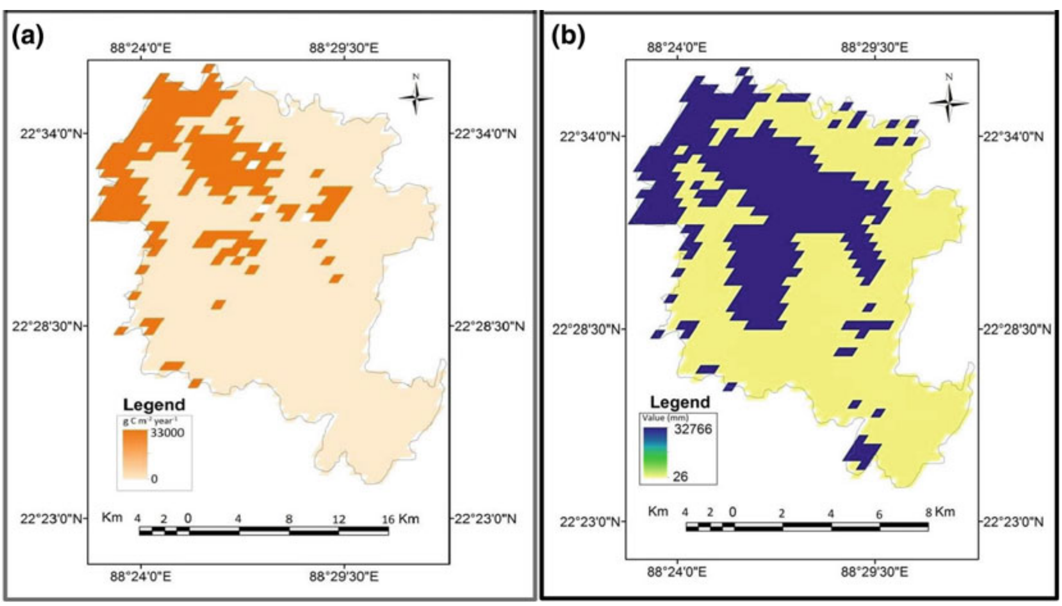

Fig. 21.10 Spatial scenario EKW **a** Gross Primary Productivity (2020) and **b** average evaporation (2020)

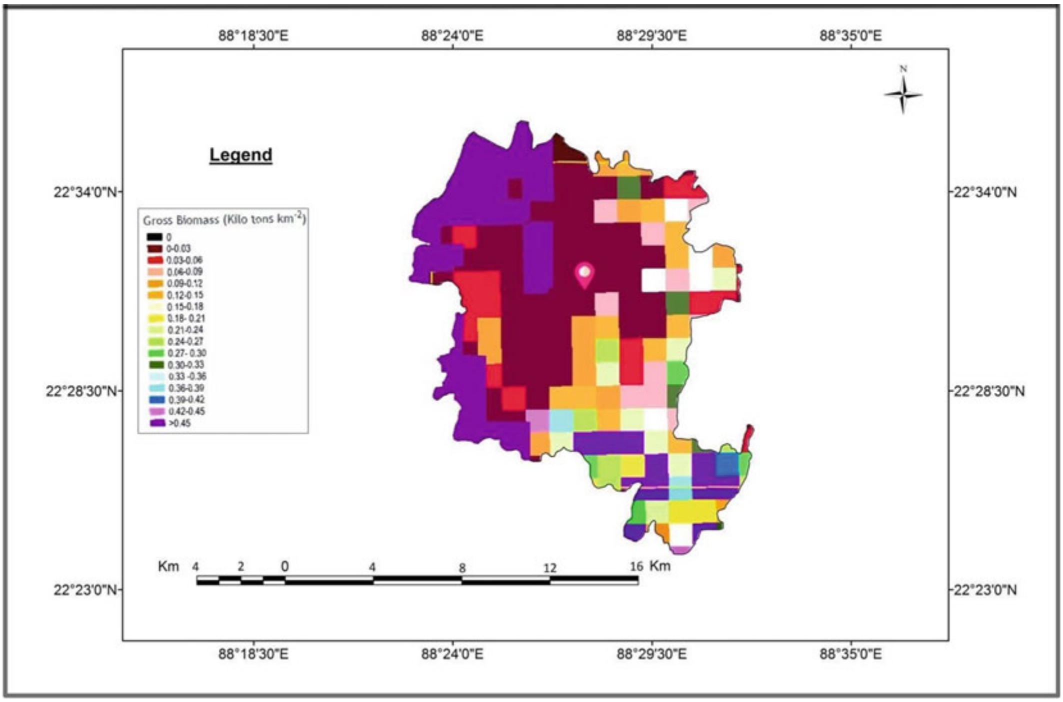

Fig. 21.11 Spatial distribution of gross biomass in EKW (2020)

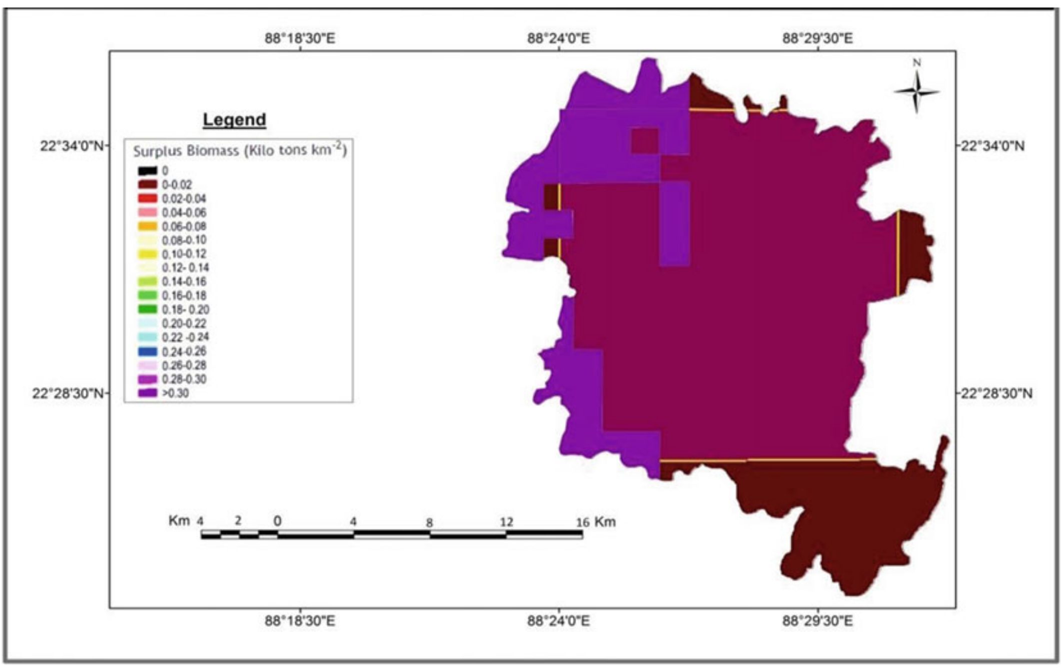

Fig. 21.12 Spatial distribution of surplus biomass in EKW (2020)

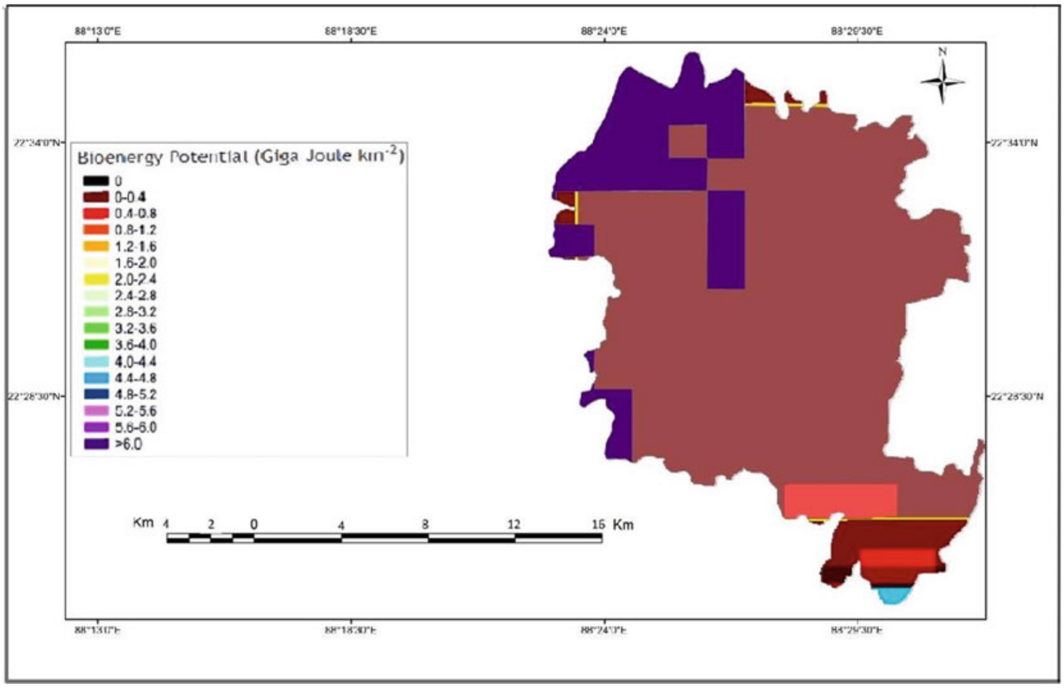

Fig. 21.13 Spatial distribution of bioenergy potential in EKW (2020)

area and other urban areas, the vulnerability magnitude also decreases, indicating the high impact of urban areas on wetland reduction.

21.4 Conclusion

The western side of East Kolkata Wetlands (EKW) is ecologically more sustainable than the eastern side. The ecosystem was most sustainable in the northwestern, and the most fragile was in the southeastern side. Recently, rapid urbanization has started on the western side, which is responsible for destroying this healthy ecosystem. Therefore, it is imperative to control this rapid urbanization in the interest of the environment and retain Kolkata as a subsidized city. Relevant and proper policies should be implemented to maintain ecological balances which are as follows: an appropriate buffer zone should be made surrounding the small but valuable wetlands, with the help of guideline provided by the East Kolkata Wetlands Authority. Secondly, to maintain the health of these concerned wetlands of east Kolkata there is an earnest need to allow biological movements, and interconnections (through small cannels) among the wetlands. Thirdly, to restrict the adverse impacts of urbanization on the wetlands and its micro-ecology, specific management is necessary to ban littering, vegetation destruction, etc. Other than these, for making the aforementioned recommendations fruitful for the purpose of wetland conservation, for its future agricultural sustainability, stimulating public awareness is a prerequisite. Nothing is possible without bottom-up approach. Sustainability and ecological conservation of the area can be restored through public awareness about the problems faced, and it can be mitigated by teaching the daily life attitude and behavioral modification of local residents, supplying them with necessary articles and providing them with assistance for enjoying a better living.

References

Baker NR (2008) Chlorophyll fluorescence: a probe of photosynthesis in vivo. Annu Rev Plant Biol 59:89–113. https://doi.org/10.1146/annurev.arplant.59.032607.092759

Bhattacharyya A, Sen S, Roy PK, Mazumdar A (2008) A critical study on status of East Kolkata Wetlands with special emphasis on water birds as bio-indicator. In: Proceedings of Taal 2007: The 12th World Lake Conference, Vol 1561, p 1570

Bhattacharya S, Ganguli A, Bose S, Mukhopadhyay A (2012) Biodiversity, traditional practices and sustainability issues of East Kolkata Wetlands: a significance Ramsar site of West Bengal, (India). Res Rev Biosci 6 (11):340–347

Bose PC (1944) Calcutta sewage and fish culture. Proc Natl Inst Sci India 10:443–450

Chattopadhyay B, Chatterjee A, Mukhopadhyay SK (2002) Bioaccumulation of metals in the East Calcutta wetland ecosystem. Aquat Ecosyst Health Manage 5(2):191–203

CPCB (1997) Standards for liquid effluents, gaseous emissions, automobile exhaust, noise and ambient air quality.Central Pollution Control Board, Parivesh Bhawan, Delhi

Ghosh S, Das A (2019) Urban expansion induced vulnerability assessment of East Kolkata Wetland using Fuzzy MCDM method. Remote Sensing Appl: Soc Environ 13:191–203

Haque M (2020). Assessing infrastructural encroachment and fragmentation in the East Kolkata Wetlands. In: Water management in South Asia. Springer, Cham, pp 233–257

Hussan A (2016) Threats to fish diversity of East Kolkata wetlands and conservation needs. Aquaculture times 2(6):10–15

Rapport DJ, Regeir HA, Hutchinson TC (1985) Ecosystem behavior under Stress. Am Nat 125(5):617–640

Roy A, Amin G, Agarwal SK, Pramanick P, Banerjee A, Roy M, Mitra A (2016a) Water Quality Index (WQI) of East Kolkata Wetland using dissolved oxygen as proxy. Int Adv Res J Sci, Eng Technol 3(2): 22–24

Roy A, Roy R, Sarkar D, Roy M, Mitra A, Lake Campus S (2016b) Hydrological parameters of east Kolkata wetlands: time series analysis. Int J Life Sci Scient Res 2(6):692–699

Roy AS, Gorain PC, Paul I, Sengupta S, Mondal PK, Pal R (2018) Phytoplankton nutrient dynamics and flow cytometry based population study of a eutrophic wetland habitat in eastern India, a Ramsar site. RSC Adv 8(17):9530–9545

Srinivasan V, Kumar P, Long SP (2017) Decreasing, not increasing, leaf area will raise crop yields under global atmospheric change. Glob Change Biol 23(4):1626–1635

Swapnil P, Meena M, Singh SK, Dhuldhaj UP, Marwal A (2021) Vital roles of carotenoids in plants and humans to deteriorate stress with its structure, biosynthesis, metabolic engineering and functional aspects. Current Plant Biol 26:100203

Ward LM, Rasmussen B, Fischer WW (2019) Primary productivity was limited by electron donors prior to the advent of oxygenic photosynthesis. J Geophys Res: Biogeosciences 124:2. https://doi.org/10.1029/2018JG004679