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ANALYSIS OF LONG TERM IMPACT OF CYCLONIC DISASTER ‘AILA’ ON SOIL PROPERTIES AND PADDY YIELD OF SUNDARBANS, WEST BENGAL, INDIA

Sisir Kumar Si

Vivekananda Institute of Biotechnology, Sri Ramakrishna Ashram, P.O.-Nimpith Ashram, South 24-Parganas (Sundarbans), West Bengal, 743338

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Cyclone

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ABSTRACT

A field study was conducted to evaluate the long term impact of cyclonic disaster ‘Aila’ on soil properties and paddy yield. Study was conducted during four consecutive rabi season started from 2009-10 onwards after the exposure of Aila at three highly Aila affected regions of Sundarbans viz Achintanagar (Patharprotima block), Kuemuri (Patharprotima block) and Shyamnagar (Kultali block) villages. Results of the study were compared to the adjoined non Aila affected area after soil test based fertilizer application (STNPK). Results of study revealed that Aila degraded the quality of paddy cultivation land by increasing EC 3 dSm^{-1} , ESP 18 and 2 to 2.7 times available iron over non Aila affected area along with completely failure of paddy production (average yield 0.45 t/ha) in 2009-10 season. Results of next consecutive three seasons revealed that soil pH, EC, ESP is improved and consequently paddy yield also increased naturally as compare to the yield of previous years in Aila affected area as well as yield of non Aila affected area in three villages. After third year of Aila occurrence, it was reported that paddy yield increase average 14% on application of extra $25\% \text{ P}_2\text{O}_5$, average 8% on application of extra $25\% \text{ K}_2\text{O}$ and average 15% on application of extra $25\% \text{ NPK}$ over STNPK (Soil test based NPK dose) treatment. These fertilizer treatments ultimately made yield gap between Aila affected and non Aila affected area after third year of Aila occurrence. This is perhaps due to extra P_2O_5 fulfilled the P requirement of paddy in Fe rich Aila affected soils and at the same time extra K_2O increased availability of K to paddy by maintaining the activity ratio of $\text{K} / \sqrt{(\text{Ca} + \text{Mg})}$ in saline environment of Aila affected areas.

* Corresponding author

E-mail: sisirkrsi@gmail.com (Si SK)

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1 Introduction

Salinity is an important index of low soil quality reducing crop production. The amount of salt that is to accumulate is a function of water quality (Ayers & Westcot, 1985) and evapotranspiration (Abrol, 1982). In arid and semi-arid regions, high rates of evapotranspiration and low rainfall can result in large amounts of salt accumulation near the soil surface. Whereas irrigated agriculture using saline water and ingress of sea water in land can lead to salt accumulation in soil profile, reduction in yield and deterioration in soil resource. Several researchers such as Feizi, 1993 and Garcia-Sanchez et al., 2003 reported advantageous effects of leaching by irrigation as well as rain water on improvement of soil salinity and crop yield.

Soil of Sundarban has been affected by different types of salt; characterization and distribution of soil in Sundarban coastal area was earlier described by Bandyapadhyay & Sarkar, 1987; Bandyapadhyay et al., 2001 and Bandyapadhyay et al., 2003. These soils are highly acidic as well as saline in nature (Yadav et al., 1979) and it was formed from the gangetic alluvium due to the accumulation of sulphide materials of inter-tidal sediments. Acidic and saline natures are characteristics of such soils and play a critical role in the nutrient uptake, which needs to be assessed for judicious and efficient management of sustainable agriculture.

The nature's fury 'Aila' in the form of massive sea tidal waves on 25th May, 2009 created devastation not only in terms of animal lives and loss of infrastructure in coastal Sundarban, but it also caused complete submergence of adjoining agricultural fields and rendered the soil and water resources salt affected. The cultivated land in coastal Sundarban is situated in low lying areas where drainage is often difficult due to very low slope gradient. Sea water ingress at the time of Aila led to stagnation situations in the agricultural land of Sundarban and this situation varies according to areas; in some area it was purely temporary and receded after temporary stagnation while in some are it stayed for long time and land remained stagnation with sea water for long time.

It was reported that this type of cyclones completely affect the agricultural production and in the passage of next few years farmers faced poor soil health conditions and this thing hampered crop production. Hence, there was an emergent need to assess the changes of soil characteristics and search suitable ways to reverse the degradation processes through optimal soil management measures. Therefore, present study has been undertaken to find out the impact of Aila on the characteristic of Achintanagar (Patharprotima block), Kuemuri (Patharprotima block) and Shyamnagar (Kultali block) area soil and rice yield. Furthermore, study also investigated to effect of fertilization (types and dose of fertilizers) on the retention and regaining of the soil quality and in improvement of the rice production.

Fig1: Study area map of Sundarbans, W.B., India

**1. Achintanagar and 2. Kuemuri (Patharprotima)
3. Shyamnagar (Kultali)**

Figure 1 Study area map of sundarbans, W.B. India.

2 Materials and Methods

With a view to the above objectives, collection and analysis of soil samples along with field studies of boro paddy (Lal Minikit, WGL 20471) were undertaken from selected Aila affected and non Aila affected area of three villages in Sundarbans (lies between longitude 88°10'E – 89°51'E , latitude 21°31'N – 22°30' N) viz. Achintanagar (Patharprotima block), Kuemuri (Patharprotima block) and Shyamnagar (Kultali block) in south 24 Parganas district, West Bengal (Figure. 1). Ten farmers of each Aila affected area and adjoining non Aila affected area in the aforesaid three villages were selected for present study. Surface soil samples (0-15 cm) were collected from farmers' fields of each village covering entirely three different Aila affected areas and adjoining non Aila affected areas. Soil samples were air-dried, ground and pass through 2mm sieve. Soil properties viz., pH (1:2), EC (1:2) soil: water ratio and organic carbon were determined as per the procedure giving by Jackson, 1973 and Walkley & Black's method (Black, 1965). The ESP value was calculated by determination of cation exchange capacity (CEC) of the soil by extracting with neutral 1N NH₄OAc solution and exchangeable sodium by flame photometer using standard laboratory methods (Page, 1986).

Available Fe was determined by Atomic Absorption Spectrometric (AAS) technique using DTPA extraction. Yield of boro paddy (2009-10) of selected farmers were recorded separately. Similarly next consecutive three years of Aila occurrence, soil test based fertilizer application and same agronomic management, analytical soil data as well as paddy yield (Lal Minikit) were recorded. After the third year of Aila

occurrence, to study the yield gap between Aila affected and non Aila affected areas, selected farmer's fields were divided into five equal plots of approximate size 133m² for application of five fertilizer treatments viz soil test based recommended 100% NPK dosed for boro paddy (STNPK) ; STNPK + Extra 25% nitrogen (STNPK+ 25% N); STNPK + Extra 25% phosphate(STNPK+ 25% P₂O₅); STNPK + Extra 25% potash(STNPK+ 25% K₂O) and STNPK+ Extra 25% nitrogen, phosphate and potash(STNPK+ 25% NPK) as recommended by Ali, 2005 and boro paddy yields of the five plots of each farmers of Aila affected and non affected area of three villages are recorded.

The data are presented statistically and relative productivity percentage of crops is calculated as

$$\frac{\text{Average Paddy}}{\text{Maximum average paddy yield of non Aila affected areas}} \times 100$$

3 Results and Discussion

The value of selected soil characteristics viz. pH, EC, OC, ESP and available Fe in Aila affected and non Aila affected Achintanagar, Kuemuri and Shyamnagar villages of Sundarban was recorded for 2009-10 and three consecutive years after Aila, results of these characteristics are presented in table 1. The table 1 revealed that the overall soil pH of non Aila affected Achintanagar is acidic in nature with an average pH value 5.24 where as nature of soil pH of Aila affected Achintanagar is neutral with an average pH value 6.93. It may be due to accumulation of carbonate and bicarbonate salt from sea water at the time of Aila occurrence.

Table 1 Soil properties of Achintanagar, Kuemuri and Shyamnagar village in Sundarban after Aila (value given in table is mean of ten replicates)

Time interval	pH	EC dSm ⁻¹	ESP	OC(%)	Fe(mg/kg)
Achintanagar					
Non Aila Affected area	5.24±0.49	1.23±0.46	10.40±3.82	0.40±0.13	37.97±25.23
Aila Affected area	6.93±1.04	11.02±2.56	30.72±7.86	0.46±0.20	101.64±167.82
1st. Year after Aila	6.7±0.83	2.40±0.69	17.37±6.78	0.46±0.19	102.29±171.47
2nd. Year after Aila	6.51±0.77	1.37±0.52	12.49±4.75	0.44±0.19	99.72±164.79
3rd. Year after Aila	6.55±0.69	1.30±0.38	12.00±3.00	0.42±0.16	100.51±161.41
Kuemuri					
Non Aila Affected area	5.36±0.65	1.36±0.68	8.81±2.89	0.43±0.11	46.69±26.64
Aila Affected area	6.63±1.05	12.13±3.99	31.75±8.74	0.57±0.23	126.42±207.63
1st. Year after Aila	6.47±0.93	2.61±0.96	17.26±7.52	0.55±0.20	124.21±204.23
2nd. Year after Aila	6.34±0.69	1.66±0.91	12.46±6.17	0.53±0.21	123.21±204.32
3rd. Year after Aila	6.39±0.71	1.57±0.79	11.95±3.49	0.49±0.16	121.35±201.68
Shyamnagar					
Non Aila Affected area	5.37±0.55	1.19±0.89	11.69±1.89	0.43±0.13	32.66±22.97
Aila Affected area	6.98±0.93	10.33±4.38	40.71±8.09	0.45±0.20	59.10±84.92
1st. Year after Aila	6.71±0.72	2.19±1.17	24.59±5.72	0.44±0.19	58.61±82.52
2nd. Year after Aila	6.51±0.52	1.43±1.12	18.66±5.19	0.42±0.18	56.84±80.01
3rd. Year after Aila	6.60±0.48	1.34±0.80	17.59±3.90	0.39±0.15	55.73±76.89
CD(P= 0.05)	0.127	0.496	1.96	...	17.22

Value given in table is mean of ten replicates; value give after ± represent SD

It is also reported that after first year, in successive years of Aila, the soil pH has slowly come down. The soil pH of Aila affected Kuemuri and Shyamnagar was also showing similar trends to Achintanagar with respect to non Aila affected areas. The average soil EC of non Aila affected Achintanagar is 1.23 dSm^{-1} and the average values of ESP is 10.40 (Table 1). While the average EC 11.02 dSm^{-1} and ESP 30.72 is attained after Aila occurrence at Achintanagar. With passage of first, second and third year after Aila, the mean EC value come down in 2.4 dSm^{-1} , 1.37 dSm^{-1} and 1.30 dSm^{-1} respectively. Whereas the mean ESP value come down in 17.37, 12.49 and 12.00 respectively at Achintanagar. The reason of improvement of soil salinity on passage of time is the effect of salt leaching i.e. desalinization by rainwater infiltration (Mostafazdeh-Fard et al., 2008). The same trend of EC and ESP values are observed in Kuemuri and Shamnagar village at different time intervals with respect to non Aila affected area.

The average OC percentage of the non Aila affected Achintanagar soils is recorded 0.40 whereas in Aila affected area, it is 0.46. It is also found a decreasing tendency of means OC values after passing of first, second and third year may be due to effects of rain water leaching as well as land use for paddy (Kolahchi & Jalali, 2007). Similar patterns are also observed in others two Aila affected areas (Table 1). Analysis of the results presented in the table 1, suggested that about 40% samples are in safe limit ($\text{ESP} < 10$) and 60% samples are moderate safe limit ($\text{ESP} 10-18$) in non Aila affected area of three localities. Whereas after Aila only 3% samples are moderately safe limits ($\text{ESP} 10-18$) and the rest are in higher ESP ($\text{ESP} > 18$) which are unsafe for cultivation (Richards, 1954). The passage of first, second and third year after Aila 64%, 40% and 23% samples became unsafe ($\text{ESP} > 18$) respectively in the aforesaid areas. It is also found that about

3% samples are at injury level ($> 3 \text{ dSm}^{-1}$) in non Aila affected areas whereas in Aila affected areas 100% samples are at injury level with respect to EC values (Ali, 2005). After first, second and third year of Aila the injury level have become 30%, 10% and 3% samples respectively. On encountering the whole three villages, the status of soil pH are 53% samples are strong acidic ($\text{pH} < 5.5$), 37% samples are moderately acidic ($\text{pH} 5.5-6.0$) and 10% slightly acidic ($\text{pH} 6.0-6.5$) in non Aila affected area, whereas in Aila affected areas the status of soil pH are 30% alkaline ($\text{pH} > 7.5$), 26% neutral ($\text{pH} 6.5-7.5$), 20% slightly acidic ($\text{pH} 6.0-6.5$), 20% moderate acidity ($\text{pH} 5.5-6.0$) and rest are strong acidic. After first year of Aila occurrence the pH status are almost unchanged but in second and third year about 40% and 54% samples have neutral ($\text{pH} 6.5-7.5$) and rest soils are slightly to moderate acidity ($\text{pH} 5.5-6.5$). There are no soils in alkaline range ($\text{pH} > 7.5$) in second and third year after Aila.

On the other hand, 73% collected samples shows presence of low OC while 27% samples shows the presence of medium OC in non Aila affected areas, whereas in Aila affected areas, the status of OC had became 53% low, 27% medium and 20% high. These changes in the status of OC may be due to deposition of fresh organic matter during the flood. After first year of Aila occurrence the OC status are unchanged but in second year only 13% OC are high level ($\text{OC} \% > 0.75$) and in third year the OC status are almost equal to non Aila affected areas i.e. 64% low and 36% medium. Higher analytical values of OC leads the blackish coloration of soils in some fields after Aila which may be resulted by the dissolution and dispersion of organic matter at high pH and ESP (Table 1), which is also the agreement of the observation of Bandyapadhyay et al. (2001).

Table 2 Yield of boro paddy at farmers' field in Sundarban after Aila

Time interval	Mean $\pm$ SD	Relative productivity (%)
Achintanagar		
Non Aila Affected area	5.18 ± 0.23	100.0
Aila Affected area	0.48 ± 0.37	8.80
1 st . Year after Aila	2.89 ± 0.38	55.74
2 nd . Year after Aila	3.58 ± 0.41	69.20
3 rd . Year after Aila	3.66 ± 0.43	70.63
Kuemuri		
Non Aila Affected area	4.91 ± 0.26	94.90
Aila Affected area	0.48 ± 0.27	9.33
1 st . Year after Aila	2.75 ± 0.33	53.01
2 nd . Year after Aila	3.43 ± 0.41	66.22
3 rd . Year after Aila	3.49 ± 0.50	67.44
Shyamnagar		
Non Aila Affected area	5.04 ± 0.26	97.40
Aila Affected area	0.38 ± 0.26	7.30
1 st . Year after Aila	3.00 ± 0.41	57.94
2 nd . Year after Aila	3.51 ± 0.47	67.73
3 rd . Year after Aila	3.55 ± 0.50	68.54
CD(P= 0.05)	0.09	

Value given in table is mean of ten replicates

Table 3 Yield of boro paddy on different fertilizer treatments at farmers' field in Sundarban after third years' of Aila occurrence

Different treatments	Mean $\pm$ SD	Relative productivity (%)
Achintanagar		
STNPK	3.66 $\pm$ 0.43	70.63
STNPK+ 25% N	3.71 $\pm$ 0.46	71.73
STNPK+ 25% P ₂ O ₅	4.29 $\pm$ 0.36	82.85
STNPK+ 25% K ₂ O	3.93 $\pm$ 0.45	75.84
STNPK+ 25% NPK	4.42 $\pm$ 0.46	85.40
Kuemuri		
STNPK	3.49 $\pm$ 0.50	67.44
STNPK+ 25% N	3.52 $\pm$ 0.36	67.90
STNPK+ 25% P ₂ O ₅	4.39 $\pm$ 0.35	84.70
STNPK+ 25% K ₂ O	4.06 $\pm$ 0.45	78.33
STNPK+ 25% NPK	4.52 $\pm$ 0.41	87.20
Shyamnagar		
STNPK	3.55 $\pm$ 0.50	68.54
STNPK+ 25% N	3.60 $\pm$ 0.45	69.52
STNPK+ 25% P ₂ O ₅	4.26 $\pm$ 0.40	82.33
STNPK+ 25% K ₂ O	3.96 $\pm$ 0.35	76.54
STNPK+ 25% NPK	4.37 $\pm$ 0.53	84.36
CD(P= 0.05)	0.09	

Whereas: STNPK (100% NPK dosed for boro paddy); STNPK+ 25% N (STNPK + Extra 25% nitrogen); STNPK+ 25% P₂O₅(STNPK + Extra 25% phosphate);STNPK+ 25% K₂O(STNPK + Extra 25% potash)and STNPK+ 25% NPK(STNPK + Extra 25% nitrogen, phosphate and potash).

The average DTPA-Fe content in three non Aila affected Achintanagar; Kuemuri and Shyamnagar villages are 37.97, 46.69 and 32.66 mg/kg (Table 1). Whereas in these three Aila affected villages the average Fe content increases remarkably and their values are 101.64, 126.42 and 59.10 mg/kg respectively. There is no remarkable change in average value of Fe with passage of first, second and third year after Aila.

The yield of boro paddy and their average value along with their relative productivity percentage in Aila affected and non Aila affected areas of Achintanagar; Kuemuri and Shyamnagar villages in consecutive four seasons are presented in table 2. Considering total non Aila affected areas of three villages, the average yield of boro paddy lie between 4.91 and 5.18 t/ha, whereas considering total Aila affected areas of three villages lie between 0.38 and 0.48 t/ha. Next successive three boro seasons the average yield of total Aila affected areas of three villages have increased naturally and their average values lie between 2.75 and 3.00 t/ha in first year, 3.43 and 3.58 t/ha in second year, 3.49 and 3.66 t/ha in third year (Table 2) respectively.

Table 2 shows that the relative productivity percentage in three Aila affected villages and these are 8.80, 9.33 and 7.30. It is also observed that relative productivity percentage of boro paddy in total three Aila affected areas of three villages have been increased (ranged from 53.08 to 57.94) after first year of Aila occurrence. After passage of second and third years, the range became 66.22 to 69.20 and 67.44 to 70.63 respectively. Through the average paddy yield in third year increased slightly in compare to the yield of second year after Aila, yet

there found a yield gap between Aila affected areas and non Aila affected areas after third year (Table 2). It may be due to the high concentration of iron and comparatively higher value of EC and ESP in compare to non Aila affected areas (Table 1) has still hampered the paddy production in Aila affected areas.

Based on five fertilizer treatments i.e. STNPK, STNPK+ 25% N, STNPK+ 25% P₂O₅, STNPK+ 25% K₂O and STNPK+ 25% NPK in Aila affected areas of three Villages, the average paddy yield in rabi season, after third year of Aila are recorded in table 3. The Paddy yield of Aila affected Achintanagar, Kuemuri and Shyamnagar villages are remarkably increased of an average 4.29, 4.39 and 4.26 t/ha by application of STNPK+ 25% P₂O₅, 3.93, 4.06 and 3.96 t/ha by application of STNPK+ 25% K₂O, 4.42, 4.52 and 4.37 t/ha by application of STNPK+ 25% NPK over the average yield 3.66, 3.49 and 3.55 t/ha based on STNPK treatment in three respective villages. On the other hand,, STNPK+ 25% N treatment increases slightly paddy yield of an average 3.71, 3.52 and 3.60 t/ha with respect to STNPK treatment in three respective villages.

Table 3 also shows that the relative productivity percentage 82.85, 84.70, 82.33 on treatment STNPK+ 25% P₂O₅ and 85.40, 87.20, 84.36 on treatment STNPK+ 25% NPK in Aila affected areas of Achintanagar, Kuemuri and Shyamnagar villages are very close to non Aila affected areas of respective three villages and simultaneously it is agreement with the same land suitability class for paddy according to Sys et al. (1993). From the results of five fertilizer treatments (Table 3), it may be said that recommended phosphate are less available to paddy perhaps due to high concentration of Fe in Aila affected

soils (Adhikari & Si, 1994) which fixed most of recommended phosphate. When extra phosphate over recommended dose is applied then paddy response and yield is increased. On the other hand, saline environment of Aila affected soils with high amount of Ca and Mg decrease the activity ratio $K / \sqrt{(Ca + Mg)}$. So, plant face problem to uptake available K (Joshi, 1992). Extra K over recommended dose (STNPK+ 25% K₂O) lead increases the activity ratio $K / \sqrt{(Ca + Mg)}$ and consequently increases the uptake of available K as well as significantly paddy yield.

Conclusions

Present study shows that cyclone Aila affected the lands of Sundarban by making various types of degradation like high salinity, alkalinity and Fe content and it resulted poor crop performance. Result of study indicated that poor growth of paddy is due to high salinity ($>3 \text{ dSm}^{-1}$) and high alkalinity (ESP >18) which gradually reduced by leaching with rain water in passage of consecutive three years. The yield of boro paddy is further improved by application of extra phosphate and extra potash over soil test based fertilizer dose that enhance phosphorous and potassium availability to paddy in Fe richer saline environment.

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Conflict of interest

Authors would hereby like to declare that there is no conflict of interests that could possibly arise.

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