Consecutive 2-year data analysis to assess the soil quality and ecological risk of heavy metals in Tobacco field: a case study in Northern Bangladesh

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Abstract

A successive 2-year (2019 and 2020) field experiment was conducted in northern Bangladesh (Rangpur district) to observe the status of soil quality and heavy metal risk due to tobacco cultivation in this area. Soil samples were collected randomly from four major sub-districts (Rangpur Sadar, Badargonj, Gangachara, and Mithapukur Upazila) where Mithapukur was a non-cultivating tobacco field and the rests were tobacco-growing fields. Along with heavy metal concentrations, physicochemical parameters were analyzed to observe the progressive change in the soil. Results depicted that values of bulk density, particle density, porosity, soil organic matter (SOM), and major nutrients (N, P, K, S) were decreased in the tobacco-growing field from 2019 to 2020, whereas significant improvement was observed in non-tobacco-growing field at successive year analysis. However, exchangeable bases were raised in the tobacco cultivated field from 40.86 to 52.98% compared to the non-tobacco cultivated field which was in a declining trend (43.66–34.33%). Overall, the soil pollution index depicted that Pb was shown a moderate risk of contamination in 2020. The ecological risk analysis also stated that the tobacco field in Rangpur Sadar was at a moderate risk of soil pollution (RI = 126.16), although the non-tobacco field in Mithapukur was at no risk of pollution (RI = 45.23). So, it can be recommended that tobacco cultivation harms the soil health, and thus, it should be prohibited from the agricultural field.

Keywords Physicochemical parameters · Heavy metals · Ecological risk index

1 Introduction

The plant tobacco is cultivated natively in North and South America. The scientific name of the tobacco plant is *Nicotiana tabacum* or less widely used *Nicotiana rustica* [1]. During the “1980s” and “1990s”, the tobacco industry started trading heavily in out of the USA specifically Asia’s developing countries. Since the mid-1960s of the last century, tobacco has been introduced into the Bangladeshi fields where food crops were grown. It elongated more widely after liberation in 1971 by the British American Tobacco Company in Teesta silt in the Rangpur area [2]. Rangpur is a district that is situated in the northern part of the country. Agricultural soils of Rangpur are very fertile

and rice-based. According to the Bangladesh Agricultural Research Council (BARC) [3], here major cropping patterns are Potato/Wheat-T.Aus (HYV)-T.Aman (HYV), Wheat-Jute-T.Aman (HYV), Boro-Fallow-T.Aman. Most renowned rice varieties are grown in boro season where tobacco is being cultivated by replacing boro seasonal rice. Bangladesh is one of the greatest tobaccos uptaking countries in the world. Totally, 0.5% of people are directly related to tobacco cultivation to their employment. Tobacco is grown throughout the country, with the largest tobacco cultivating areas including Rangpur, Kushtia, and Chatogram Hill [4]. The total cropped area in the Rangpur region is 696,420 ha, whereas 14,221 ha lands are now being tobacco cultivated [3]. Traditionally, the area is one

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of the most tobacco-growing areas in the country that is why the Rangpur district was chosen as the study area. Tobacco is an alien species in this area, and this non-local species adversely impacts on the habitats and bioregions environmentally or ecologically. They crumble up an agro-ecological system by forcing over other cultivated and uncultivated crops essential for the life and livelihood of a community [5]. Tobacco cultivation greatly influences the environment, such as deforestation, environmental pollution due to the utilization of agrochemicals and soil fertility inanition. Tobacco plants take soil nutrients more heavily and consume soil nutrients very fast compared to other crops, thereby making such soils unsuitable for healthy plant growth for the following crops [6]. Therefore, tobacco plants require more chemical fertilizers and pesticides thus lead to potential loss of soil health [7]. The excess use of agrochemicals such as insecticides and herbicides is another factor that contributes a lot to the accumulation of heavy metals in the soil [8]. Tobacco farming contributes to large accumulation of heavy metals in soils especially Pb and Cd that has a carcinogenic effects on human body [9]. Apart from that, heavy metals in soil harms soil quality. Especially soil microbial community is strongly suppressed due to the destruction of soil enzymatic activities [10]. So, a comparative research was conducted at tobacco-growing fields and seasonal crops growing field (noted as a non-tobacco field) in Rangpur district to assess the impact of tobacco cultivation on soil

health as well as analyze the ecological risk of heavy metals based on two successive years soil physicochemical and heavy metals loading data.

2 Materials and methods

2.1 Study area

The study was carried out at 4 Upazilas (sub-districts) (Mithapukur, Badarganj, Gangachara, and Rangpur Sadar) of the Rangpur district in Bangladesh (Fig. 1). Tobacco cultivation elongated more widely after liberation in 1971 by the British American Tobacco Company in Teesta silt in the Rangpur area [2]. According to the Bangladesh Bureau of Statistics (BBS) [11], in 2017–2018, the tobacco cultivation area of Rangpur division was 37,142 acres while in the Rangpur district it was 7883 acres. The farmers of this area are being motivated to produce tobacco by the tobacco manufacturing companies and for this reason, Rangpur district was selected as the studied area to assess the soil quality which might play a potential factor in ensuring long-term soil health.

Rangpur district is situated in the north of the country with an indigenous environment that differs from other parts of the country. The Annual temperature of the Rangpur district varies from “51°F” to “95°F” and sometimes temperature rarely gets below “46°F” and above “102°F”. In Rangpur, almost 80% precipitation has been received from May to August

Fig.1 Location of the study area

and < 20% precipitation has been received from December to February. In the wet season (March to November), average rainfall occurs about 11.0 inches wherein dry season (November to March), average rainfall occurs about 0.1 inches [12].

During the experiment, loamy textured soil was found in Mithapukur, Gangachara, and Rangpur Sadar, as well as silty loam texture was identified in Badargonj. Mithapukur was chosen as control and designed as a non-tobacco field due to not cultivating tobacco in the agricultural soils whereas Badargonj, Gangachara, Rangpur Sadar were designed as the tobacco field due to intensive tobacco cultivation in the agricultural soil. Soil samples were taken in successive years of 2019 and 2020. Locations (GPS) of the study area with site coding are presented in Table 1.

2.2 Soil sample collection and processing

Composite soil samples (0–15 cm) were collected from selected sites for consecutive 2 years in April, 2019, and 2020 respectively. Soil sampling was carried out by composite sampling method as suggested by the Soil Survey Staff of the USDA [13]. All samples were replicated thrice and stored in clean polythene packets, receptively. Then, samples were carried to the laboratory of Soil, Water and Environment discipline, Khulna University, and kept them in the air. After air drying, samples were crushed and sieved by using 2-mm-diameter sieve and finally preserved in plastic containers for further physical and chemical analysis.

2.3 Analysis of physicochemical properties

For physical analysis of soil, the bulk density of the soil samples was determined by the core sampling method followed by Blake and Hartge [14]. Porosity (%) of the samples was determined using Eq. (1) below consists of the value of bulk density (BD) and particle density (PD) [15].

$$\% \text{Porosity} = \left\{ 1 - \left(\frac{BD}{PD} \right) \right\} \times 100 \quad (1)$$

For chemical analysis of soil, pH was measured followed to the glass electrode pH meter method by calibrated pH meter (soil/water = 1:2.5 by volume) and electrical conductivity

was measured by a calibrated conductivity meter [16]. Soil organic matter was determined by Walkley and Black wet oxidation method [17] whereas soil organic matter (SOM) was calculated using organic carbon data [18]. Total nitrogen was determined by the Kjeldahl method [19]. Available phosphorus was analyzed by the Bray-1 extraction method following bluecolorimetry [20]. Available sulfur was determined by the turbidimetric method [21]. Exchangeable potassium (K^+) and sodium (Na^+) were determined by flame photometry [22] while exchangeable magnesium (Mg^{2+}) and calcium (Ca^{2+}) were determined by atomic absorption spectrophotometer [23]. Cation exchange capacity (CEC) was measured by ammonium acetate (NH_4OAc at pH 7.0) method [24]. BSP, SAR, and ESP were also analyzed. The base saturation percentage (BSP) was determined using Eq. (2). Sodium adsorption ratio (SAR) was determined by using Eq. (3). The exchangeable sodium percentage (ESP) was calculated by using Eq. (4) given below:

$$BSP(\%) = \left\{ \frac{[Ca^{2+}] + [Mg^{2+}] + [K^+] + [Na^+](\text{cmolc/kgsoil})}{CEC(\text{cmolc/kgsoil})} \right\} \times 100 \quad (2)$$

$$SAR = \frac{[Na^+]}{\left\{ \sqrt{1/2}([Ca^{2+}] + [Mg^{2+}]) \right\}} \quad (3)$$

$$ESP(\%) = \left(\frac{[Na^+]}{CEC} \right) \times 100 \quad (4)$$

2.4 Micronutrient and heavy metal analysis

For the determination of micronutrient (Fe and Zn) and heavy metals (Mn, Co, Cr, Ni, Pb), sieved (2 mm) soil samples (0.5 g) were put into a 100-mL beaker and were digested with nitric-perchloric acid (2:1) as described by Piper [25]. After digestion, digested solutions were diluted to 50 mL using distilled water and the total Fe, Zn, Mn, Co, Cr, Ni, and Pb concentration were analyzed by inductively coupled plasma optical emission spectrometry (ICP-OES) [26].

Table 1 Location (GPS) and site code of the study area

SL no	Study area	Site code	Location (GPS)
1	Mithapukur (Non-tobacco Field)	A (NTF)	89°17'7" E, 25°31'49" N
2	Badargonj (Tobacco Field)	B (TF)	89°4'48" E, 25°43'30" N
3	Gangachara (Tobacco Field)	C (TF)	89°11'33" E, 25°49'20" N
4	Rangpur Sadar (Tobacco Field)	D (TF)	89°8'21" E, 25°49'8" N

2.5 Measurement of soil pollution index (SPI) and ecological risk index (ERI)

Soil pollution index (SPI), a simple well-known pollution evaluation tool, was applied to identify single element contamination indices. SPI was calculated using the following Eq. (5):

$$SPI = \frac{Ci}{Cbi} \quad (5)$$

where SPI is the soil pollution index, C_i is the concentration of the i th heavy metal in the soil, and C_{bi} is its reference level Alloway [27] and WHO [28]. Based on the SPI values, pollution can be classified into five categories: unpolluted ($SPI \leq 1$), slightly polluted ($1 < SPI \leq 2$), mildly polluted ($2 < SPI \leq 3$), moderately polluted ($3 < SPI \leq 5$), and highly polluted ($SPI > 5$) [29].

The ecological risk index (RI) was calculated by using the following formula to assess the ecological risk (ER) of heavy metals [30]:

$$RI = \sum_{i=1}^n ERI \quad (6)$$

$$ERI = Ti \times \left(\frac{Ci}{Cbi} \right) \quad (7)$$

where ERI is the ecological risk index for the heavy metal i , and Ti is the toxicity response coefficient for the metal i . The toxic response factors for Mn, Co, Cr, Ni, and Pb are

10, 5, 2, 6, and 5, respectively, [31]. Standard grading of potential ecological risk are given in Table 2 [32].

2.6 Statistical data analysis

Generated soil sample data were subjected to analysis of variance (One way ANOVA) and Pearson correlation coefficient with computer package software SPSS 16, and general calculations were conducted by using Microsoft Office Excel 13. Data generated from the tobacco cultivated field was compared with the non-tobacco field's data. Group comparison of the means was carried out by Duncan's multiple range test (DMRT) at 95% confidence level ($p \leq 0.05$) using SPSS 16.

3 Results and discussion

3.1 Physical parameters

A comparison of soil physical properties for the successive year's data is presented in Table 3. Results revealed that bulk density was the highest at site A (1.57 gcm^{-3}) in 2019 that was decreased in the following year. In other sites, bulk density was slightly increased (average $1.44\text{--}1.5 \text{ gcm}^{-3}$) from 2019 to 2020. In 2020, among the four different sites, no significant differences were found. In the study of particle density; Site B illustrated the highest value between the years (2.76 gcm^{-3}) that was diminished the following year (2.59 gcm^{-3}). Except for site B, all other sites values were augmented in the following year

Table 2 Classification of potential ecological risk index (Xia et al. 2020)

ER value	Grade of ecological risk of single metal	RI value	Grade of potential ecological risk of the environment
$ER < 40$	Low risk	$RI < 112.5$	Low risk
$40 \leq ER < 80$	Moderate risk	$112.5 \leq RI < 225$	Moderate risk
$80 \leq ER < 160$	Considerable risk	$225 \leq RI < 450$	Considerable risk
$160 \leq ER < 320$	High risk	$RI > 450$	Very High risk
$ER \geq 320$	Very high risk	–	–

Table 3 Summary statistics for surface soil physical parameters

Sites ¹	Bulk density (gcm^{-3})		Particle density (gcm^{-3})		Porosity (%)	
	2019	2020	2019	2020	2019	2020
A (NTF)	$1.57 \pm 0.03a$	$1.49 \pm 0.07a$	$2.56 \pm 0.10a$	$2.59 \pm 0.02a$	$38.67 \pm 5.28b$	$42.47 \pm 2.55a$
B (TF)	$1.51 \pm 0.01b$	$1.55 \pm 0.06a$	$2.76 \pm 0.21a$	$2.59 \pm 0.14a$	$45.29 \pm 3.46a$	$40.15 \pm 3.95b$
C (TF)	$1.39 \pm 0.04c$	$1.47 \pm 0.05a$	$2.62 \pm 0.16a$	$2.66 \pm 0.10a$	$46.95 \pm 4.76a$	$44.74 \pm 3.32a$
D (TF)	$1.42 \pm 0.04c$	$1.49 \pm 0.09a$	$2.49 \pm 0.14a$	$2.49 \pm 0.07a$	$42.97 \pm 5.17a$	$40.16 \pm 2.91b$

¹Sites: A = Mithapukur, B = Badarganj, C = Gangachara, D = Rangpur Sadar (NTF = Non-Tobacco field, TF = Tobacco field)

but insignificant. Porosity was higher at site C (46.95%) in 2019 but declined in the following year (44.74%). Except for site A, the value of all other sites were reduced from 2019 to 2020. In 2020, significant differences were observed between the tobacco and non-tobacco field, and a significant improvement of porosity was observed in the non-tobacco field (38.67–42.47%). The reduction of porosity in the tobacco fields is a sign of the negative impact of tobacco cultivation which may reduce the soil's water-holding capacity [33]. A similar result was also observed by Moula et al. [34].

3.2 Analysis of chemical parameters

The values of different chemical properties are presented in Table 4. pH values were ranged from 6.34 to 6.54 in 2019 and 5.33 to 5.70 in 2020. In 2019, there were no significant differences between the tobacco and non-tobacco fields, but in 2020, tobacco fields showed significantly higher value than non-tobacco fields (Table 4). These decreasing pH values indicated medium soil acidic conditions thus can be restricted plant growth [33]. Kutub and Falgune [35] found extremely low pH under tobacco cultivation than other crops in their study. Still, the study represented a similar trend of pH change for both tobacco and non-tobacco fields.

Table 4 also depicted that EC values were raised for all four sites from 2019 to 2020 that were ranged between 0.98 dS/m and 1.51 dS/m. In 2019, a significantly higher value was observed in the non-tobacco field than tobacco fields but in 2020, the non-tobacco field presented insignificant results with the tobacco fields. Besides, the value of soil organic matter (SOM) was the best at site B (1.57%) in 2019 that was reduced to 0.82% in the following year. It was noted that the SOM value of site A was augmented from 2019 to 2020 (0.81–1.03%) whereas other sites' values were sharply decreased (average 1.54–0.98%). In 2020, except site D, no significant changes were seen among experimental sites though the non-tobacco field improved the SOM status in successive year data analysis. Moula et al. [34] found a similar SOM change in their study, and he reported that SOM decreased from 1.95 to 1.78% for

consecutive 2 years of tobacco cultivation that supports the study.

3.3 Major (N, P, K, S) and micro (Fe, Zn) nutrients

Yearly data of soil major and micronutrient values are presented in Table 5. The yearly data comparison stated that total N concentration was slightly upward (0.11–0.12%) in 2020 for the non-tobacco field, whereas N concentrations were dropped off all tobacco cultivated fields. In 2019, all sites showed statistically similar results but in 2020, non-tobacco fields showed significantly best results than tobacco cultivated fields. Table 5 also placed that the concentration of available P was the highest at site B in 2019 that was declined in the following year (10.5–7.63 mg/kg). Similar findings were also noticed in other sites although the tobacco field's depletion rate was higher. In 2020, the P concentration of the non-tobacco field significantly differed from the tobacco field. However, it was insignificant in 2019 except site D. Results of exchangeable K was placed that K concentration was the finest at site A in 2020 (0.44 cmolc/kg). A more noticeable fact was that except for site A, K values were lessened sharply from 2019 to 2020. Site A value was improved from 0.26 to 0.44 cmolc/kg which indicated the major K depletion in tobacco cultivated fields. In 2020, the exchangeable K values of site A was significantly differed from other sites and showed the best result. Available S concentration was also shown downward at all four sites in 2020 compared to 2019 although S concentration was significantly higher in non-tobacco fields (48.37 mg/kg). Overall, nutrients analysis declared that depletion of major nutrients in tobacco cultivated fields might be caused by the higher nutrient uptake nature of tobacco plants. Yanda [6] found a similar result in his study. He stated that the tobacco plant was a heavy feeder on soil nutrients than other crops and depleted soil nutrients very fast. Oloo [36] also found that tobacco cultivation led to the depletion of soil fertility that is a strong agreement of the research.

In successive year micronutrient data analysis, Fe concentration was higher at site B (2935 mg/kg) in 2020. Yearly data depicted that Fe concentration was improved

Table 4 Soil chemical parameters

Sites ¹	pH		EC (dS/m)		SOM (%)	
	2019	2020	2019	2020	2019	2020
A (NTF)	6.47 ± 0.38a	5.33 ± 0.06b	0.78 ± 0.07a	1.31 ± 0.18ab	0.81 ± 0.07b	1.03 ± 0.05ab
B (TF)	6.34 ± 0.08a	5.60 ± 0.10a	0.39 ± 0.00c	1.51 ± 0.12a	1.57 ± 0.25a	0.82 ± 0.05b
C (TF)	6.54 ± 0.13a	5.70 ± 0.10a	0.41 ± 0.03bc	0.98 ± 0.13b	1.53 ± 0.04a	0.83 ± 0.25b
D (TF)	6.40 ± 0.24a	5.70 ± 0.10a	0.47 ± 0.04b	1.07 ± 0.34b	1.53 ± 0.04a	1.28 ± 0.12a

¹Sites: A = Mithapukur, B = Badargonj, C = Gangachara, D = Rangpur Sadar (NTF = Non-Tobacco field, TF = Tobacco field)

Table 5 Major (N, P, K, S) and micro- (Fe, Zn) nutrients

Sites ¹	Total N (%)		Available P (mg/kg)		Exchangeable K (cmolc/kg soil)		Available S (mg/kg)		Fe (mg/kg)		Zn (mg/kg)	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
A(NTF)	0.11 ± 0.01ab	0.12 ± 0.02a	9.05 ± 0.61a	8.21 ± 0.22a	0.26 ± 0.01c	0.44 ± 0.03a	48.37 ± 7.16a	41.61 ± 7.90a	1690.18 ± 77.95c	2020.89 ± 586.18b	187.13 ± 11.97b	142.55 ± 34.62b
B(TF)	0.11 ± 0.01ab	0.08 ± 0.03b	9.97 ± 1.56a	6.86 ± 0.13c	0.33 ± 0.04b	0.21 ± 0.04b	31.06 ± 18.76ab	27.96 ± 9.88b	2425.88 ± 36.44a	2935.89 ± 153.36a	229.19 ± 15.51ab	337.08 ± 15.40a
C(TF)	0.13 ± 0.02a	0.09 ± 0.02b	10.5 ± 0.24a	7.63 ± 0.15b	0.32 ± 0.01b	0.22 ± 0.04b	36.50 ± 4.01ab	22.96 ± 5.51b	2213.25 ± 85.94b	2464.17 ± 124.15ab	242.13 ± 32.64ab	318.32 ± 25.45a
D(TF)	0.10 ± 0.01b	0.06 ± 0.01c	7.43 ± 1.20b	5.40 ± 0.78d	0.44 ± 0.02a	0.27 ± 0.05b	24.62 ± 6.00b	18.34 ± 9.12c	2126.08 ± 36.80b	2332.64 ± 326.73ab	273.03 ± 62.64a	347.13 ± 44.89a

¹Sites: A = Mithapukur, B = Badargonj, C = Gangachara, D = Rangpur Sadar (NTF = Non-Tobacco field, TF = Tobacco field)

in all sites for the following year, and the data were statistically insignificant between tobacco and non-tobacco field except site B. Sahrawat [37] stated that, in soil solution, nutrient imbalance might be occurred due to the high concentration of iron because of an antagonistic relationship with some nutrients like K and Zn. The concentration of Zn was declined in the non-tobacco field (187.13–142.55 mg/kg) but enhanced in all tobacco fields (248.12–334.24 mg/kg) along with significant differences with the non-tobacco field in 2020. According to Alloway [27], the regulatory limit of Zn is less than 300 mg/kg. In that sense, all tobacco fields exceeded the regulatory value in 2020. Zn is an essential micronutrient that is necessary for proper plant growth. Still, an excess amount of Zn negatively impacts soil microbial activities that inhibit plant growth. Alloway [27] reported that a high amount of Zn like > 500 mg/kg might hinder plant growth although crops can be grown in high Zn loading soils. Oloo [36] found that Zn concentration was higher in tobacco fields than virgin lands that support the study.

3.4 Parameters related to exchangeable bases

Results of successive year's cation exchange capacity (CEC), base saturation percentage (BSP), sodium adsorption ratio (SAR), exchangeable sodium percentage (ESP) are presented in Table 6. A yearly comparison of CEC results depicted that CEC of site A was sharply decreased in 2020 (from 9.70 to 5.21 cmolc/kg) whereas values of other sites were increased. In 2020, tobacco fields showed significantly lower CEC than all non-tobacco fields. The opposite results were found for base saturation (BSP) that indicated significant incremental growth in non-tobacco fields. Only site A improved the BSP (40.86–52.98% from 2019 to 2020) indicating the non-tobacco field might improve soil health. Results also stated that sodium adsorption ratio (SAR) and exchangeable sodium percentage (ESP) demonstrated a similar change and the values were increased in all four sites from 2019 to 2020. ESP was significantly higher in the non-tobacco field (3.51–9.92%) than in tobacco fields in 2020 (Table 6). Hossain and Salam [38] reported in their study that soils with 70% or more BSP limit agronomic growth and soils are more likely to have structural stability problems with more than 6% ESP. Though the BSP was less than the critical limit in this study, the ESP is more than 6% in two tobacco cultivated fields: site B and site C, and non-tobacco field site A which indicated the structural stability problems of soil-related to potential dispersion.

Table 6 Parameters related to exchangeable bases

Sites ¹	CEC (cmolc/kg)		BSP (%)		SAR		ESP (%)	
	2019	2020	2019	2020	2019	2020	2019	2020
A (NTF)	9.70 ± 1.96a	5.21 ± 2.11c	40.86 ± 6.53b	52.98 ± 9.78a	0.26 ± 0.02a	0.54 ± 0.12a	3.51 ± 0.47b	9.92 ± 3.02a
B (TF)	8.14 ± 0.33b	8.84 ± 1.22b	51.21 ± 1.90a	38.85 ± 4.40b	0.26 ± 0.01a	0.50 ± 0.02a	4.26 ± 0.25a	6.60 ± 0.62b
C (TF)	9.45 ± 2.49a	9.74 ± 0.75b	42.54 ± 6.52b	34.05 ± 3.13b	0.27 ± 0.02a	0.60 ± 0.22a	3.74 ± 0.54b	6.74 ± 2.76b
D (TF)	10.3 ± 0.62a	11.33 ± 1.75a	38.48 ± 1.27b	30.67 ± 1.06b	0.26 ± 0.02a	0.43 ± 0.06a	3.20 ± 0.12b	4.44 ± 2.17c

¹Sites: A = Mithapukur, B = Badargonj, C = Gangachara, D = Rangpur Sadar (NTF = Non-Tobacco field, TF = Tobacco field)

3.5 Analysis of heavy metals

Different values of successive year's heavy metals concentration are given in Table 7. Results illustrated that the concentration of Mn was the highest at site D (428.79 mg/kg) in 2019. However, all sites' Mn concentration was reduced from 2019 to 2020 and showed significant differences between tobacco and non-tobacco fields. According to Alloway [27] and WHO [28], Mn concentration of more than 80 mg/kg indicated a potential risk for soil. Thus all sites represented the Mn contamination in both years. Oloo [36] found that Mn concentration was higher in the tobacco field than that of the non-tobacco field that contradicts the research. Co concentration was found higher in the tobacco field as site D depicted the highest value in 2020 (48.60 mg/kg). More importantly, tobacco fields loaded more Co rather than non-tobacco fields, whereas value non-tobacco field decreased trend in successive year analysis (29.42–28.25 mg/kg). According to Alloway [27] and WHO [28], Co concentration ranged “between 1 and 40” mg/kg indicated safe for soil. Thus, sites C and D (tobacco field) crossed the critical limit in 2020 that is a matter of concern. Oloo [36] found in his study that Co concentration was higher in the tobacco field than that of the non-tobacco field that goes with the research. In terms of Cr, the tobacco field loaded more concentration than non-tobacco fields in successive year analysis where site D expressed the highest value (114.84 mg/kg). A good sign was observed in the non-tobacco field where Cr value was diminished from 2019 to 2020 (65.37–61.21 mg/kg). According to Alloway [27] and WHO [28], Cr concentration ranged “between 1 and 100” mg/kg designated safe for soil. From Table 7, it was seen that sites C and D (tobacco field) crossed the critical limit in 2020 that might be a potential cause for soil contamination. Oloo [36] found in his study that Cr concentration was higher in the tobacco field than that of the non-tobacco fields that sustained the research. In Ni analysis, significant loaded was observed in the tobacco field in successive

year analysis (average 75.51–138.77 mg/kg). Oppositely, the value of site A (non-tobacco field) was in a declining trend (32.19–26.58 mg/kg). A similar trend was also noticed in Pb analysis where site D was given the highest Pb loading data in 2020 (824.95 mg/kg). For both Pb and Ni, data were statistically insignificant among tobacco fields and significant with the non-tobacco fields for both years' analysis. According to Alloway [27] and WHO [28] Ni concentration < 35 mg/kg, Pd concentration < 85 mg/kg indicated safe for soil. Thus all sites of tobacco fields crossed the critical limit for both years that is a rising concern. Oloo [36] reported in his study that both Ni and Pb concentrations were higher in the tobacco field than that of the non-tobacco fields that support the study. This increased heavy metal contents in tobacco fields may be caused by the additional agro-chemical inputs like insecticides and pesticides required by the tobacco plants which may contain the heavy metals in their composition as reported in the study of Kibwage et al. [8]. Some metals were found in the plants sprayed with pesticides in the study of Maobe et al. [39]. Šmejkalová et al. [40] found in their study that soil microbial populations were suppressed by the increased heavy metal contents due to loss of microbial enzymatic activities. The poor microbial community leads to poor soil health thus increasing environmental pressure due to heavy metal contamination.

3.6 Pearson correlation coefficient micronutrients and heavy metals with soil pH and organic matter (SOM)

Pearson's correlation coefficient study for the investigated for soil pH and soil organic matter (SOM) with micronutrient and heavy metal concentrations in soil are presented in Table 8. Study of 2019 depicted that significant positive correlation was shown between SOM-Co (0.95*), SOM-Ni (0.96*), Fe-Mo (0.97*), Zn-Co (0.95*), Zn-Ni (0.96*), Zn-Pb (0.98*), Co-Ni (1.00**), Co-Pb (0.99**), Ni-Pb (0.99*). In

Table 7 Heavy metals analysis

Sites ¹	Mn (mg/kg)		Co (mg/kg)		Cr (mg/kg)		Ni (mg/kg)		Pb (mg/kg)	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
A(NTF)	371.9 ± 15.99b	247.58 ± 12.52c	29.42 ± 3.17a	28.25 ± 1.68c	65.37 ± 6.13a	61.21 ± 4.41b	32.19 ± 5.55b	26.58 ± 7.15b	87.83 ± 5.11c	84.51 ± 14.94b
B(TF)	295.36 ± 9.97c	280.80 ± 12.97b	33.90 ± 0.96a	38.03 ± 6.56ab	69.42 ± 5.84a	83.59 ± 25.38ab	70.23 ± 8.89a	126.62 ± 26.99a	406.24 ± 60.77b	682.14 ± 148.04a
C(TF)	214.05 ± 16.00d	171.39 ± 12.62d	34.93 ± 6.75a	40.43 ± 8.56ab	67.63 ± 5.93a	103.16 ± 15.67a	73.46 ± 6.91a	133.16 ± 33.28a	513.06 ± 45.41a	751.22 ± 102.77a
D(TF)	428.79 ± 17.58a	339.40 ± 9.44a	35.66 ± 5.81a	48.60 ± 15.27a	73.31 ± 11.60a	114.84 ± 23.51a	82.84 ± 5.69a	156.52 ± 32.99a	603.42 ± 78.09a	824.95 ± 116.92a

¹Sites: A = Mithapukur, B = Badargonj, C = Gangachara, D = Rangpur Sadar (NTF = Non-Tobacco field, TF = Tobacco field)

2020, significant positive correlation was seen between pH-Ni (0.98*), pH-Pb(0.99*), Fe-Mo (1.0**), Zn-Ni (0.98*), Zn-Pb (0.99*), Co-Cr (0.97*), Ni-Pb (1.00**). Other's correlations were found to be nonsignificant which means the concentration of one element may not influence other elements concentrations in the studied area.

Overall, correlation study of successive years recapitulated that in most of the cases; heavy metals were positively correlated with each other. So, heavy metals loading should be controlled otherwise increment of any heavy metal might be caused for other heavy metals load in the studied soil. Similar findings were observed by Khaledian et al. 2016 [41].

3.7 Heavy metal pollution and ecological risk assessment

The values of soil pollution indices (SPI) in the successive year are given in Table 9. The SPI value of Mn in the non-tobacco field was reduced from 4.65 to 3.09 in the successive year. The same scenario was also observed in the tobacco field. The highest SPI value of Mn was seen at site D in 2019 (5.36) which indicated high pollution. However, except site D in 2019, all studied soils were moderately Mn polluted, referred to by Zang et al. [29]. For Co, the SPI value in the non-tobacco field was minimized from 0.74 to 0.71 in the consecutive year. But the opposite scenario was noticed in all tobacco fields. Co's highest SPI value was found at site D in 2020 (1.21) which indicated slight pollution. However, except site D in 2020, all studied soils were Co unpolluted as referred by Zang et al. [29]. In addition, Cr's SPI value in the non-tobacco field was diminished from 0.65 to 0.61 in the following year. But the opposite scenario was identified in all tobacco fields. The highest SPI value of Cr was observed at site D in 2020 (1.15) which indicated slight pollution. However, except for sites C and D in 2020, all studied soils were Cr unpolluted as referred by Zang et al. [29]. Additionally, Ni's SPI value in the non-tobacco field was lessened from 0.92 to 0.76 in the subsequent year. But the reverse scenario was reported in all tobacco fields. The highest SPI value of Ni was detected at site D in 2020 (4.47) which indicated moderate pollution. However, except site A, all studied soils were moderately Ni polluted as referred by Zang et al. [29]. Moreover, the SPI value of Pb in the non-tobacco field was reduced from 1.03 to 0.99 in the succeeding year. But the opposite scenario was noted in all tobacco fields. The highest SPI value of Pb was detected at site D in 2020 (9.71), which indicated high pollution. However, sites A and B in 2019 expressed slight pollution and nonpolluting status in 2020 site A. All other studied soils were highly Pb polluted as referred by Zang et al. [29]. An overall analysis

Table 8 Pearson correlation coefficient of micronutrients and heavy metals with soil pH and organic matter (SOM)

Soil Properties in 2019										
	pH	SOM	Fe	Mn	Mo	Zn	Co	Cr	Ni	Pb
<i>Soil Properties in 2019</i>										
pH	1									
SOM	−0.29	1								
Fe	−0.43	0.93	1							
Mn	−0.45	−0.32	−0.45	1						
Mo	−0.24	0.88	0.97*	−0.65	1					
Zn	−0.18	0.84	0.60	0.11	0.48	1				
Co	−0.15	0.95*	0.78	−0.18	0.72	0.95*	1			
Cr	−0.53	0.70	0.51	0.44	0.32	0.91	0.79	1		
Ni	−0.24	0.96*	0.80	−0.12	0.72	0.96*	1.00**	0.83	1	
Pb	−0.12	0.92	0.71	−0.10	0.64	0.98*	0.99**	0.82	0.99*	1
<i>Soil Properties in 2020</i>										
pH	1									
SOM	0.02	1								
Fe	0.53	−0.55	1							
Mn	0.07	0.73	0.06	1						
Mo	0.60	−0.52	1.00**	0.06	1					
Zn	0.95	−0.03	0.72	0.24	0.78	1				
Co	0.91	0.42	0.32	0.43	0.39	0.88	1			
Cr	0.94	0.33	0.24	0.20	0.33	0.84	0.97*	1		
Ni	0.98*	0.10	0.59	0.25	0.66	0.98*	0.94	0.93	1	
Pb	0.99*	0.03	0.61	0.18	0.68	0.99*	0.92	0.92	1.00**	1

*Correlation is significant at the 0.05 level (2-tailed)

**Correlation is significant at the 0.01 level (2-tailed)

of SPI presented that all heavy metal pollution status was decreased in the non-tobacco field from 2019 to 2020 and the reverse has happened in all tobacco fields except Mn. In 2019, the value of each heavy metal was decreasing order Pb > Mn > Ni > Co > Cr, whereas in 2020, it was changed to Pb > Ni > Mn > Co > Cr.

The values of ecological risk (ER) for individual heavy metals in the successive year are also given in Table 9. Among the heavy metal, Mn values of side D (53.60 and 42.43 successively) illustrated the moderate risk of pollution which was a tobacco field. Though the Mn value of site A (46.49) in 2019 was presented at a moderate risk of pollution, the ER of Mn (30.95) in 2020 stated the low risk of pollution. However, all other metals were symbolized a low risk of pollution as referred by Hakanson [30]. The most vulnerable condition was seen in Pb ER values where all tobacco fields in 2020 denoted the moderate risk of pollution (> 40) although the values in 2019 were at low risk (< 40). For other metals, ER values of tobacco fields

were higher than the non-tobacco field though these were signified in low risk of pollution.

According to Table 10, the ecological risk index (RI) of tobacco fields was higher than the non-tobacco fields for both years. In 2019, the RI value of site A (non-tobacco field) was 62.16 that was diminished to 45.23. This is a good sign of soil quality improvement for the non-tobacco field. The RI value was the highest in site D (tobacco field) which was 109.22 in 2019, increased to 126.16 in 2020. Similar situations were also noticed for sites B and C which were also tobacco fields. According to Xia et al. [32], the RI value of more than 112.5 is characterized by moderate ecological risk. In that sense, site D (tobacco field) in 2020 (126.16) placed the moderate ecological risk of pollution along with all tobacco fields were got higher RI value in 2020 than that of 2019 which is a matter of great concern. These should be taken as top consideration as soon as possible. Otherwise, these tobacco fields can immerge in moderate to higher ecological risk soon. Good improvement was observed in the non-tobacco field (site A) where RI value was got lower

Table 9 Soil pollution and ecological risk status of sampling sites in the successive year

Sites ¹	Metals	SPI value in 2019	Soil pollution status in 2019	SPI value in 2020	Soil pollution status in 2020	ER value in 2019	Ecological risk status in 2019	ER value in 2020	Ecological risk status in 2020
A (NTF)	Mn	4.65	Moderate	3.09	Moderate	46.49	Moderate	30.95	Low
B (TF)		3.69	Moderate	3.51	Moderate	36.92	Low	35.10	Low
C (TF)		2.68	Mild	2.14	Mild	26.76	Low	21.42	Low
D (TF)		5.36	High	4.24	Moderate	53.60	Moderate	42.43	Moderate
A (NTF)	Co	0.74	Low	0.71	Unpolluted	3.68	Low	3.53	Low
B (TF)		0.85	Low	0.95	Unpolluted	4.24	Low	4.75	Low
C (TF)		0.87	Low	1.01	Slight	4.37	Low	5.05	Low
D (TF)		0.89	Low	1.21	Slight	4.46	Low	6.07	Low
A (NTF)	Cr	0.65	Low	0.61	Unpolluted	1.31	Low	1.22	Low
B (TF)		0.69	Low	0.84	Unpolluted	1.39	Low	1.67	Low
C (TF)		0.68	Low	1.03	Slight	1.35	Low	2.06	Low
D (TF)		0.73	Low	1.15	Slight	1.47	Low	2.30	Low
A (NTF)	Ni	0.92	Low	0.76	Unpolluted	5.52	Low	4.56	Low
B (TF)		2.01	Mild	3.62	Moderate	12.04	Low	21.71	Low
C (TF)		2.10	Mild	3.80	Moderate	12.59	Low	22.83	Low
D (TF)		2.37	Mild	4.47	Moderate	14.20	Low	26.83	Low
A (NTF)	Pb	1.03	Slight	0.99	Unpolluted	5.17	Low	4.97	Low
B (TF)		4.78	Moderate	8.03	High	23.90	Low	40.13	Moderate
C (TF)		6.04	High	8.84	High	30.18	Low	44.19	Moderate
D (TF)		7.10	High	9.71	High	35.50	Low	48.53	Moderate

¹ Sites: A = Mithapukur, B = Badargonj C = Gangachara, D = Rangpur Sadar (NTF = Non-Tobacco field, TF = Tobacco field)

in 2020 (45.23) than that in 2019 (62.16). The overall progression of SPI, ER, and RI is shown in Figs. 2, 3. The ER and RI is the potential indicator for the assessing ecological risk of soil heavy metals [42]. The overall results predicted a moderate risk of soil heavy metal pollution in tobacco fields especially Pb and Mn. Pb also represented a high pollution index (PI). This is potentially harmful because Pb is easily absorbed by crops and damages human health when ingested [43]. So,

Pb pollution should be controlled and tobacco farming is needed to discourage farmers due to higher RI value.

4 Conclusion

Tobacco cultivation is a common practice in the study area that is increasing day by day and the fertile lands of this area are affected by the negative impact of frequent tobacco cultivation. The physicochemical study revealed that soil porosity was affected by tobacco cultivation and organic matter contents were reduced in the tobacco cultivated soils that are hazardous for soil health. Tobacco is a nutrient hunger plant which in turn caused nutrient depletion of the cultivated land. This study found the depletion of the major soil nutrients like N, P, K, S in tobacco cultivated lands compared to the non-tobacco cultivated fields. The major alarming part is that tobacco cultivation caused heavy metal (Mn, Mo, Co, Cr, Ni, Pb) accumulation in the study area due to its additional fertilizer, pesticide, and insecticide requirements. Overall correlation studies

Table 10 Risk status of sampling sites in the successive year

Sites ¹	Risk index value in 2019	Risk status in 2020	Risk index value in 2020	Risk status in 2019
A (NTF)	62.16	Low	45.23	Low
B (TF)	78.48	Low	103.36	Low
C (TF)	75.25	Low	95.56	Low
D (TF)	109.22	Low	126.16	Moderate

¹ Sites: A = Mithapukur, B = Badargonj C = Gangachara, D = Rangpur Sadar (NTF = Non-Tobacco field, TF = Tobacco field)

Fig. 2 Pollution index and ecological risk index of Mn (a), Co (b), Cr (c), Ni (d), Pb (e) in the tobacco and non-tobacco fields

also stated that there was a significant positive relationship between heavy metals and soil properties. Mn and Pb concentration were elaborated the moderate risk of heavy metal pollution. The RI value illustrated that the tobacco field in Rangpur Sadar is at moderate risk of pollution as well as all other tobacco fields are at the potential risk of pollution. Therefore, tobacco cultivation leads to soil fertility depletion and heavy metal contamination in the study area. However, tobacco's alternative profitable crops are to be suggested in this area to prevent soil quality degradation caused by tobacco cultivation.

Fig. 3 Ecological risk index assessment of the tobacco and non-tobacco fields in the successive years

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Compliance with ethical standards

Conflict of interests The authors declare that they have no conflict of interest.

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