Effect of fly ash on Crop Production around coal-fired thermal power plant in rural India

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Abstract— *The fly ash emitting from Kolaghat thermal power plant (KTPP), India, is affecting the crop production in the vicinity of power plant. Use of NPK fertilizers for cereal crops has increased by 0-50% in the surrounding area (<4km) during last four years (2011-2015) whereas it is 14.29% - 33.33% for the rest of Kolaghat block. Increase in use of nitrogen and phosphorus bearing fertilizers have been observed but potassium requirement (0-25%) has become lower within area 4km radius from KTPP. For the remaining area of the block, it is quite higher than that of adjacent area. Pest incidence has increased (66.67%) throughout the study area. But a considerable increase in pest attack has been observed in the nearer circles of KTPP. Doses of pesticides are higher (25% - 100%) in the adjacent area (<4km) than the rest of the block (12.5%-46.67%). Yields of different cultivated crops also have decreased by 1.08% - 24.7% in the area close to KTPP. On the other hand, the rest of the block has experienced little yield deviation (-0.2% to -9.34%) for all crops expect wheat (+6.48%), maize (+0.41%), mustard (+10.08%), and moong (*Vigna radiata*) that have gained more yields (+10.25%). Consequently, the cost of cultivation (<4km) is higher (12.5%-76.47%) than the rest (6.58%-62.5%) of the block. The results clearly show that the adverse impact of fly ash on crop production in the proximity (<4km) of KTPP. Site-specific crop adaptation, resources management, organic farming and good agricultural practices can nourish the agricultural sustainability and improve the socio-economic status in the affected area of coal-fired thermal power plant in rural India.*

***Keywords*— crop production, cultivation cost, fertilizer application, fly ash, pest incidence.**

I. INTRODUCTION

Agriculture is the livelihood of 58 % population of India (www.ibef.org/industry/agriculture-presentation). Agriculture sustains the rural economy of agrarian communities. Farming communities grow many crops for their own consumption and earning money by selling the agricultural produces in the local markets. Production of crops depends on soil, water, weather &climate, available inputs etc. Conducive environment supports the crop cultivation through sustainable uses of natural resources to maximize the potential yield of cultivated crops. Intensive cultivation and injudicious uses of agricultural inputs intensify the poor health of soil and congenial condition of pest infestation in the rural areas. In addition, natural calamities, hazards and pollution also instigate the poor productivity of soil and proneness of infestation. Coal burned thermal power plant encourages fly ash pollution in the adjacent area (Adak, et al., 2016). Fly ash is affecting the soil properties and micro-climate around the power plant (Arun,et al., 2009). Kolaghat block in the district of Purba Medinipur , West Bengal is experiencing the impact of fly ash coming out from the Kolaghat thermal power plant(KTPP) situated in the Kolaghat block at $22^0$28'16"N and $87^0$52'12"E on the right bank of the Rupnarayan river in the district of Purba Medinipur, West Bengal . The KTPP was installed in the year 1984. Now it has six units amounting total capacity of 1260MW. The power plant consumes 18000 ton of coal and generates 75000-8000 ton ash per day. The considerable amount of fly ash subsides in the surrounding area within 4km from KTPP (Adak, *et.al*, 2016; Dasgupta, A. and Paul, S., 2011). The fly ash influences the soil properties and modifies soil pH to alkaline due to alkaline nature of fly ash (pH 8.4).Addition of fly ash increased the pH of amendments from 6.15 to 7.05 (Gond, et al., 2013). It reflected that soil reaction of adjacent area (<4 km) of thermal power plant was alkaline (> 7.5) which reduced the production potential of crops needed for subsistence & economy in the locality (Adak, et al., 2016). Soils become more alkaline due to alkaline nature of fly ash around coal based thermal power plant (Adak, et al., 2016;Pokale, W. K., 2012;; Basu, et al., 2009; Singh, et al., 1995). The climate and soil within the distance of 4 km from KTPP are influenced by emission of fly ash (Adak, et al., 2016). Due to it the crop acreage of kolaghat block is reducing with the passage of time from the year of installment (Adak, et al., 2016). The pressure on productivity per unit area is mounting to meet the required demand of the agricultural products. Therefore, intensive cultivation with high cropping intensity is being practiced in the impact region of flay ash. Doses of fertilizers increase to yield the optimum produces. Depression in yields was reported due to toxicity of boron and deficiency of phosphorus and zinc in fly ash used for agriculture (Chatterjee, R.K. and Ratan R.K., 1987). Pest incidence occurs frequently and pest population begets more and due to crop to crop sequence and no fallow or no crop time is allowed. The crops consequently are losing their yield capacity. Average grain & biomass yields of wheat have been affected by the application of different levels of fly ash (Aggarwal, et al., 2009). In the surrounding area of coal burned thermal power plant, agriculture is affected (Adak,et al., 2016). Agrawal & Agrawal (1989) showed that plants in the vicinity are affected by coal-fired thermal power plant during the study of assessing the impact of air pollutants on vegetation around Obra thermal power plant (1550 MW) in the Mirzapur district of Uttar Pradesh. Warhate (2009) studied the impact of coal mining on Air, Water & Soil on the surrounding area of coal mining at Wani dist. Yavatmal. Environmental segments namely air, water & soil in this area are affected within 10-15 km from the source. Human beings, animal kingdom, plants & soil are extensively affected within 5 km of the source.The increase in quantity of fertilizer application, frequency and quantity of pest controlling agents and cost of cultivation hinders the agricultural sustainability. The decrease in yield of crops affects the socio-economic status of the concerned area. In this regard, Kolaghat block has been considered as the victim of losing crop production and increasing cost of cultivation due to fly ash coming out from the Kolaghat thermal power plant. The objectives of the study:

- To assess the change in doses of fertilizers for providing major plant nutrients (NPK).
- To show the types of pest incidence, nature and doses of pesticides used in the concerned area.
- To examine the temporal and spatial impact of fly ash on crop production.
- To illustrate the increase in cost of cultivation due to Coal fired thermal power plant.
- To suggest and recommend some mitigating measures to improve the socio-economic status of the region.

II. MATERIAL AND METHOD

The data were collected from field survey. The 4 km distance from Kolaghat was delineated through the survey by using soil survey method (Soil Survey Staff, 1999). Mouza map and block map were used to demark the different area (Fig.1). During the study period (2011-2015), fertilizer application, pesticides spraying, yield information and cost of cultivation were observed and data were collected directly from the field. Major plant nutrients (NPK) bearing fertilizers had been applied in the field and their doses were calculated for one hectare of land. Common pesticides available in the local market had been used for crop protection. Yield data were collected and recorded in ton per hectare. Cost of produces was assessed on the basis of price in their local market and converted to rupees per ton.

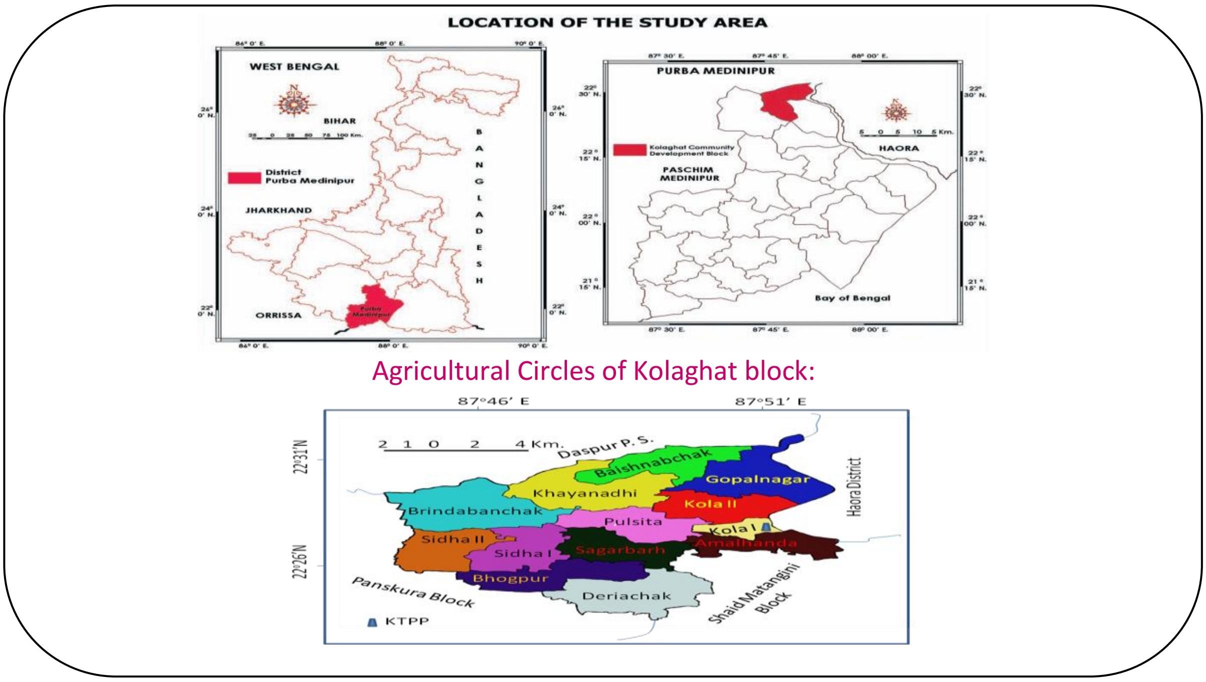

FIGURE 1. LOCATION MAP OF KOLAGHAT BLOCK IN THE DISTRICT PURBA MEDINIPUR OF WEST BENGAL, INDIA

III. RESULTS AND DISCUSSION

3.1 Increase in use of Fertilizers for crop cultivation

Nutrition is the biochemical process of every living body. Plants enjoy seventeen essential nutrients for their growth and development. Among the nutrients nitrogen, phosphorus and potassium are major elements which are consumed in large quantity by the plants. Soil supports these elements initially to the plants. Failing it additional nutrients are provided from outside to the soil as well as plants. Different crops are being cultivated to mitigate the daily requirement of agricultural food stuffs in the locality (Table-1). Therefore, nitrogen-phosphorus-potassium bearing fertilizers are being applied for crop cultivation. In the area (<4km) doses of NPK have been increased by with the passage of time (2011-2015). In case of cereals crops (rice, wheat & maize) it varies from 0% to 50% within 4km whereas it is roving from14.29% to 33.33%. Rate of fertilizer application (<4km) for oil seed crops (mustard, sesame & ground nut) has become higher than that of preceding year for nitrogen(0% -50%), phosphorus(50%) and potassium (0% to 11.11%) while nitrogen and phosphorus doses are lower than that of adjacent areas of KTPP but potassium requirement is higher in the outside area of impact zone(>4km). Jute requires more nitrogen and phosphorus than previous year, but in the surrounding area it is higher and potassium application is more (16.67%) for the rest areas. Many vegetables grow in the Kolaghat block. It has been observed that the all vegetables crops required more major nutrients than that of preceding years (Table 2). Within the 4km from KTPP the increasing trends have been experienced in the doses of nitrogen (33.33%-66.67%), phosphorus (20%-66.67%) and potassium (0%-25%). In the rest areas (>4km) the doses are low for nitrogen (25%-60%), phosphorus (16.67%- 66.67%) and potassium (16.67%- 66.67%).Moong (*Vigna radiata*) and urad beams (*Vigna mungo*) absorbs more nutrients than earlier years. The fertilizer requirement is gradually increasing from 2011-2015 for spices crops (turmeric, ginger and onion). It implies that potassium is rich in the adjacent area but nitrogen and phosphorus are not in adequate form of availability. According to Lal, et al., (2014) fly ash contains 0.084%nitrogen, 0.043% Phosphorus (P) and 0.33%potassium (K). Phosphorus availability reduces due to higher pH of soil which is induced by the alkaline nature (7.5-8.42) of fly ash. It is ascertained that fly ash is affecting the nutrient contents in the surrounding area (<4km) and improving the potassium availability.

TABLE 1
PERCENTAGE OF TEMPORAL AND SPATILAL CHANGES IN DOSES OF FERTILIZERS OVER 2011 FOR CEREAL, OIL SEEDS & JUTE CROPS

Name of crops	Type of fertilizers	2011		2013				2015			
		Dose (<4km) Kg. ha^{-1}	Dose (>4km) Kg. ha^{-1}	Dose (<4km) Kg. ha^{-1}	Dose (>4km) Kg. ha^{-1}	% change (<4km)	% change (>4km)	Dose (<4km) Kg. ha^{-1}	Dose (>4km) Kg. ha^{-1}	% change (<4km)	% change (>4km)
Rice	Nitrogen (N)	160	150	180	160	12.5	6.667	200	180	25	20
	Phosphorus (P_2O_5)	125	120	140	130	12	8.333	150	140	20	16.67
	Potassium (K_2O)	125	130	130	140	4	7.692	140	150	12	15.38
Wheat	Nitrogen (N)	80	60	100	70	25	16.67	120	80	50	33.33
	Phosphorus (P_2O_5)	40	35	50	40	25	14.29	60	45	50	28.57
	Potassium (K_2O)	35	40	40	45	14.29	12.5	40	50	14.29	25
Maize	Nitrogen (N)	75	60	80	75	6.67	25	100	80	33.33	33.33
	Phosphorus (P_2O_5)	35	30	40	35	14.29	16.67	50	40	42.86	33.33
	Potassium (K_2O)	30	35	30	35	0	0	30	40	0	14.29
Mustard	Nitrogen (N)	50	40	60	45	20	12.5	70	50	40	25
	Phosphorus (P_2O_5)	40	30	50	35	25	16.67	60	40	50	33.33
	Potassium (K_2O)	30	40	35	45	16.67	12.5	30	45	0	12.5
Sesame	Nitrogen (N)	60	40	75	45	25	12.5	90	50	50	25
	Phosphorus (P_2O_5)	40	30	55	40	37.5	33.33	60	40	50	33.33
	Potassium (K_2O)	30	30	30	35	0	16.67	32	40	6. 67	33.33
Ground nut	Nitrogen (N)	20	18	25	20	25	11.11	30	25	50	38.89
	Phosphorus (P_2O_5)	40	35	50	40	25	14.29	60	45	50	28.57
	Potassium (K_2O)	18	20	20	22	11.11	10	20	25	11.11	25
Jute	Nitrogen (N)	60	50	80	60	33.33	20	100	70	66.67	40
	Phosphorus (P_2O_5)	30	25	40	30	33.33	20	50	35	66. 67	40
	Potassium (K_2O)	25	30	25	30	0	0	25	35	0	16.67

TABLE 2
PERCENTAGE OF TEMPORAL AND SPATILAL CHANGES IN DOSES OF FERTILIZERS OVER 2011 FOR VEGETABLES, PULSES & SPIECES

Name of crops	Type of fertilizers	2011		2013				2015			
		Dose (<4km) Kg. ha^{-1}	Dose (>4km) Kg. ha^{-1}	Dose (<4km) Kg. ha^{-1}	Dose (>4km) Kg. ha^{-1}	% change (<4km)	% change (>4km)	Dose (<4km) Kg. ha^{-1}	Dose (>4km) Kg. ha^{-1}	% change (<4km)	% change (>4km)
Brinjal	Nitrogen (N)	100	80	120	100	20	25	150	100	50	25
	Phosphorus (P_2O_5)	50	40	60	50	20	25	80	60	60	50
	Potassium (K_2O)	40	50	45	50	12.5	0	45	60	12.5	20
Chili	Nitrogen (N)	80	70	100	80	25	14.29	120	100	50	42.86
	Phosphorus (P_2O_5)	40	35	50	40	25	14.29	60	50	50	42.86
	Potassium (K_2O)	35	40	40	50	14.29	25	40	50	14.29	25
Ladies Finger	Nitrogen (N)	80	70	100	80	25	14.29	120	100	50	42.86
	Phosphorus (P_2O_5)	40	35	50	40	25	14.29	60	50	50	42.86
	Potassium (K_2O)	35	40	35	40	0	0	40	50	14.29	25
Tomato	Nitrogen (N)	100	80	120	90	20	12.5	150	100	50	25
	Phosphorus (P_2O_5)	50	40	60	45	20	12.5	80	50	60	25
	Potassium (K_2O)	40	50	40	50	0	0	40	60	0	20
Cucumber	Nitrogen (N)	30	25	40	30	33.33	20	50	40	66.67	60
	Phosphorus (P_2O_5)	15	12	20	15	33.33	25	25	20	66.67	66.67
	Potassium (K_2O)	12	15	12	20	0	33.33	15	25	25	66.67
Pumpkin	Nitrogen (N)	25	20	30	25	20	25	40	30	60	50
	Phosphorus (P_2O_5)	12	10	15	12	25	20	20	15	66.67	50
	Potassium (K_2O)	12	15	15	18	25	20	15	22	25	46.67
Potato	Nitrogen (N)	150	130	175	150	16.67	15.38	200	175	33.33	34.62
	Phosphorus (P_2O_5)	125	120	140	125	12	4.167	150	140	20	16.67
	Potassium (K_2O)	115	120	115	125	0	4.167	120	140	4.35	16.67
Radish	Nitrogen (N)	50	40	60	50	20	25	80	60	60	50
	Phosphorus (P_2O_5)	25	20	30	25	20	25	40	30	60	50
	Potassium (K_2O)	20	25	18	30	-10	20	22	30	10	20
Spinach	Nitrogen (N)	50	40	60	50	20	25	80	60	60	50
	Phosphorus (P_2O_5)	25	20	30	25	20	25	40	30	60	50
	Potassium (K_2O)	20	25	22	30	10	20	20	35	0	40
Amaranths	Nitrogen (N)	50	40	60	50	20	25	80	60	60	50
	Phosphorus (P_2O_5)	25	20	30	25	20	25	40	30	60	50
	Potassium (K_2O)	20	25	22	30	10	20	22	35	10	40
Moong	Nitrogen (N)	18	15	20	18	11.11	20	25	20	38.89	33.33
	Phosphorus (P_2O_5)	35	30	40	35	14.29	16.67	50	40	42.86	33.33
	Potassium (K_2O)	15	18	18	18	20	0	18	25	20	38.89
Urad beans	Nitrogen (N)	17	15	20	17	17.65	13.33	25	20	47.06	33.33
	Phosphorus (P_2O_5)	32	30	40	32	25	6.667	50	40	56.25	33.33
	Potassium (K_2O)	15	18	17	20	13.33	11.11	16	22	6.67	22.22
Turmeric	Nitrogen (N)	60	50	80	60	33.33	20	90	80	50	60
	Phosphorus (P_2O_5)	30	25	40	30	33.33	20	60	40	100	60
	Potassium (K_2O)	25	30	25	35	0	16.67	28	40	12	33.33
Ginger	Nitrogen (N)	60	60	80	70	33.33	16.67	90	80	50	33.33
	Phosphorus (P_2O_5)	40	30	50	35	25	16.67	60	40	50	33.33
	Potassium (K_2O)	25	30	25	35	0	16.67	28	40	12	33.33
Onion	Nitrogen (N)	100	80	120	100	20	25	150	120	50	50
	Phosphorus (P_2O_5)	70	60	80	70	14.29	16.67	100	80	42.86	33.33
	Potassium (K_2O)	60	70	65	70	8.33	0	60	80	0	14.29

3.2 Increase in use of pesticides for crop protection

The growing crops in the Kolaghat block have been infested by several pests. Insects are the major pests in the block. Different crops have been attacked by different insects and record has been taken on doses of chemical pesticides (Table 3 &4). Within the 4 km from KTPP the pesticide application is higher than that of the rest of block for all crops. The doses of applied chemicals are increasing with passage of time throughout the block. It is ranging from 25% to 100% over last four years (2011-2015) whereas it is roving 12.5 % to 46.67% in the rest portion of land (>4km). In case of vegetables doses of pesticides recorded are higher than other crops irrespectible of distance though nearer land has been infected more than the rest of the block showing the increase in percentage of doses of pesticides used for controlling the pests. The adjacent area (<4km) has been attacked mostly by higher number of borer, caterpillar, flies, aphid etc. which have been protected by spraying of the higher dose of pest controlling agents. Pest menace in the surrounding areas of Dahanu thermal power plant in Maharashtra was greatly escalated (Arun, et al., 2009). This reflects that apart from intensive cultivation and pest resistance, the fly ash shedding in the surrounding area (<4km) is creating conducive and congenial environment for more infestation and multiplication of pests. The rest block area is showing the medium changes of pesticide dose basically due to intensive cultivation and pest resistance. Trizophos, quinalphos , cypermethrin, spinosad and fipronil have been applied against borer caterpillar, semilooper etc. Acephate, propergite, ethion, acetamiprid, thiamethoxam have been used to control aphid, jassid, mite, fly, thrip etc. The common diseases are rot, blight, dumping off etc. These are caused by fungi. It has been observed that in the surrounding area (<4km) doses of applied pest controlling agents are higher than rest of the block. It implies that fly ash coming out from the thermal power plant is causing high pest infestation.

TABLE 3
PERCENTAGE OF TEMPORAL AND SPATILAL CHANGES IN DOSES OF PESTICIDES OVER 2011 FOR CEREAL, OIL SEEDS & JUTE CROPS

Name of crops	Type of Pesticide	Name of major pest	2011		2013				2015			
			Dose (<4km) ml. L^{-1}	Dose (>4km) ml. L^{-1}	Dose (<4km) ml. L^{-1}	Dose (>4km) ml. L^{-1}	% change (<4km)	% change (>4km)	Dose (<4km) ml. L^{-1}	Dose (>4km) ml. L^{-1}	% change (<4km)	% change (>4km)
Rice	Trizophos40%EC	stem borer	1.5	1.5	1.8	1.6	20	6.67	2	1.75	33.33	16.67
	Cypermethrin 20%EC	brown plant hopper	1	0.9	1.25	1	25	11.1	1.5	1.2	50	33.33
	Hexaconazole 5%EC	root rot	1.5	1.5	1.75	1.6	16.67	6.67	2	1.8	33.33	20
Wheat	Quinalphos 25%EC	caterpillar	1.25	1.25	1.75	1.5	40	20	2	1.75	60	40
	Acephate	mite, jassid	2	1.7	2.25	1.85	12.5	8.82	2.5	2	25	17.65
	Mencozeb 75% WP	rust	2	1.5	2.25	1.7	12.5	13.3	2.5	2	25	33.33
Maize	Chloropyriphos	Stem borer	1.5	1.5	1.8	1.75	20	16.7	2	1.9	33.33	26.67
	Cypermethrin	Leaf roller	1	1	1.25	1.25	25	25	1.5	1.3	50	30
	Carbandazim 50%WP	Seedling blight	1	0.75	1.2	0.8	20	6.67	1.25	1	25	33.33
Mustard	Dimethoate	aphid	1.5	1.5	1.75	1.75	16.67	16.7	2	1.8	33.33	20
	Trizophos	sawfly	1.4	1.5	1.75	1.5	25	0	2	1.75	42.86	16.67
	Carbandazim 50%WP	alternaria blight	1.2	1.2	1.25	1.25	4.17	4.17	1.5	1.5	25	25
Sesame	Ethion 50 %EC	jassid	1.5	1.5	1.75	1.6	16.67	6.67	2	1.75	33.33	16.67
	Trizophos40%EC	hairy caterpillar	1.5	1.5	1.8	1.75	20	16.7	2	1.8	33.33	20
	Carbendazim50%WP	blight	1	0.75	1.25	0.85	25	13.3	1.5	1	50	33.33
Ground nut	Trizophos40%EC	hairy caterpillar	1.5	1.25	1.75	1.3	16.67	4	2	1.5	33.33	20
	Cypermethrin 20%EC	aphid	1.5	1	1.75	1.1	16.67	10	2	1.2	33.33	20
	Benomyl 50%WP	tikka disease	0.8	0.75	1	0.85	25	13.3	1.2	1	50	33.33
Jute	Ethion 50 %EC	mite	1.5	1.25	1.8	1.4	20	12	2	1.5	33.33	20
	Trizophos40%EC	Semi-looper	1.5	1.4	1.8	1.5	20	7.14	2	1.75	33.33	25
	Carbendazim50%WP	Stem rot	1	0.75	1.25	0.8	25	6.67	1.5	1	50	33.33

TABLE 4
PERCENTAGE OF TEMPORAL AND SPATILAL CHANGES IN DOSES OF PESTICIDES OVER 2011 FOR VEGETABLES, PULSES & SPIECES

Name of crops	Type of Pesticide	Name of major pest	2011		2013				2015			
			Dose (<4km) ml. L^{-1}	Dose (>4km) ml. L^{-1}	Dose (<4km) ml. L^{-1}	Dose (>4km) ml. L^{-1}	% change (<4km)	% change (>4km)	Dose (<4km) ml. L^{-1}	Dose (>4km) ml. L^{-1}	% change (<4km)	% change (>4km)
Brinjal	Spinosad 2.5 %EC	fruit &shoot borer	0.85	0.75	1	0.8	17.65	6.67	1.25	1	47.06	33.33
	acetamiprid 20 % SP	white fly	1	0.75	1.25	0.8	25	6.67	1.5	1	50	33.33
	Profenophos50%	mite	1.5	1.2	1.8	1.3	20	8.33	2	1.5	33.33	25
Chili	Propergite 57%EC	Thrip, mite	0.5	0.5	0.8	0.6	60	20	1	0.75	100	50
	Fripronil 5%EC	Pod borer	1	0.76	1.25	0.8	25	5.26	1.5	1	50	31.58
	Metalaxyl 35%WS	Damping off	1	0.75	1.25	1	25	33.3	1.5	1.1	50	46.67
Ladies Finger	Acetamiprid 20%SP	White fly	1.5	1.25	1.8	1.3	20	4	2	1.5	33.33	20
	Propergite 57%EC	mites	1	0.78	1.3	0.8	30	2.56	1.5	1	50	28.21
	Quinalphos 25%EC	Fruit borer	1.5	1.25	1.75	1.5	16.67	20	2	1.75	33.33	40
Tomato	Fripronil 5%EC	caterpillar	1	0.75	1.25	0.8	25	6.67	1.5	1	50	33.33
	Acetamiprid 20%SP	White fly	1.2	1	1.5	1.3	25	30	2	1.5	66.67	50
	Metalaxyl 35%WS	Fruit rot	1	0.72	1.2	0.8	20	11.1	1.5	1	50	38.89
Cucumber	Thiamethoxam 25%WDG	White fly	0.75	0.7	1	0.8	33.33	14.3	1.2	1	60	42.86
	Quinalphos 25%EC	Semi-looper	1.45	1.3	1.7	1.5	17.24	15.4	2	1.75	37.93	34.62
	Carbendazim50%WP	Rot fungus	1	1	1.25	1.1	25	10	1.5	1.25	50	25
Pumpkin	Thiamethoxam 25%WDG	Fruit fly	1	0.74	1.2	0.75	20	1.35	1.5	1	50	35.14
	Quinalphos 25%EC	caterpillar	1.5	1.6	1.75	1.75	16.67	9.37	2	1.8	33.33	12.5
	Carbendazim50%WP	Fruit rot	1.5	1.2	1.6	1.25	6.667	4.17	2	1.5	33.33	25
Potato	Propergite 57%EC	White fly	1	0.8	1.2	1	20	25	1.5	1.2	50	50
	Fripronil 5%EC	caterpillar	1	0.72	1.25	0.8	25	11.1	1.5	1	50	38.89
	Metalaxyl 35%WS	Late blight	1.5	1.2	1.75	1.3	16.67	8.33	2	1.5	33.33	25
Radish	Fripronil 5%EC	Caterpillar	1	0.76	1.25	0.8	25	5.26	1.5	1	50	31.58
	Acetamiprid 20%SP	White fly	1.5	1.25	1.8	1.5	20	20	2	1.75	33.33	40
	Metalaxyl 35%WS	Root rot	1.6	1.2	1.75	1.25	9.375	4.17	2	1.5	25	25
Spinach	Quinalphos 25%EC	Caterpillar	1.5	1.25	1.75	1.5	16.67	20	2	1.8	33.33	44
	Acephate	White fly	1.75	1.5	2.2	1.8	25.71	20	2.5	2	42.86	33.33
	Mencozeb 75% WP	Leaf rot	1.5	1.25	1.8	1.5	20	20	2	1.75	33.33	40
Amaranths	Quinalphos 25%EC	caterpillar	1.5	1.25	1.75	1.5	16.67	20	2	1.8	33.33	44
	Acephate	White fly	2	1.6	2.2	1.8	10	12.5	2.5	2	25	25
	Mencozeb 75% WP	Root rot	1.75	1.5	1.9	1.5	8.571	0	2	1.75	14.29	16.67
Moong	Trizophos40%EC	Pod borer	1.48	1.25	1.75	1.5	18.24	20	2	1.75	35.14	40
	Cypermethrin 20%EC	Leaf hopper	1	0.9	1.2	1	20	11.1	1.5	1.3	50	44.44
	carbendazim50%WP	Rut fungus	1	0.75	1.3	1	30	33.3	1.5	1.2	50	60
Urad beams	Trizophos40%EC	Pod borer	1.55	1.4	1.8	1.5	16.13	7.14	2	1.75	29.03	25
	Cypermethrin 20%EC	jassid	1	1	1.25	1.1	25	10	1.5	1.3	50	30
	carbendazim 50%WP	Fruit rot	1	0.74	1.25	0.8	25	8.11	1.5	1	50	35.14
Turmeric	Cypermethrin 20%EC	Scale insect	1	1	1.2	1.1	20	10	1.5	1.3	50	30
	Quinalphos 25%EC	Shoot borer	1.5	1.4	1.75	1.5	16.67	7.14	2	1.75	33.33	25
	Carbendazim50%WP	Rhizome rot	1.2	0.75	1.3	1	8.333	33.3	1.5	1.25	25	66.67
Ginger	Cypermethrin 20%EC	White grub	1	0.75	1.2	1	20	33.3	1.5	1.3	50	73.33
	Quinalphos 25%EC	Shoot borer	1.5	1.25	1.8	1.5	20	20	2	1.75	33.33	40
	Carbendazim50%WP	Leaf blight	0.8	0.72	1.2	1	50	38.9	1.5	1.25	87.5	73.61
Onion	Cypermethrin 20%EC	thrip	1	0.9	1.25	1.1	25	22.2	1.5	1.3	50	44.44
	Quinalphos 25%EC	Leaf eating caterpillar	1.5	1.35	1.75	1.5	16.67	11.1	2	1.75	33.33	29.63
	Carbendazim50%WP	Leaf blight	1	1	1.2	1.2	20	20	1.5	1.25	50	25

3.3 Spatial and Temporal Yield Decrease of cultivated crops

In Kolghat block several agricultural crops have been being cultivated to fulfill the subsistentive demand of the locality. Irrespective of the soil properties in the two areas inside and outside of line of impact of fly ash, average yield (per ha) of different crops cultivated in different seasons with common cultural practices have been recorded for the years 2011, 2013 and 2015(Table 5). Rice is the staple food of the region. Within <4km, productivity of rice has been reduced by 1.08% from the year 2011 to 2015 whereas its change is very negligible (-0.2%) beyond 4km from KTPP.

TABLE 5
PERCENTAGE OF TEMPORAL AND SPATILAL CHANGES IN CROP YIELDS OVER 2011

Name of crops	Variety	Season	2011		2013				2015			
			Yield (<4km) ton (ha)	Yield (>4km) ton (ha)	Yield (<4km) ton (ha)	Yield (>4km) ton (ha)	% Yield change (<4km)	% Yield change(>4km)	Yield (<4km) ton (ha)	Yield (>4km) ton (ha)	% Yield change (<4km)	% Yield change (>4km)
Rice	IR-36	Post monsoon	5.825	5.916	5.624	5.912	-3.45	-0.07	5.762	5.904	-1.08	-0.2
Wheat	UP-262	Post monsoon	3.737	4.247	3.613	4.223	-3.32	-0.57	3.515	4.522	-5.94	6.48
Maize	Kisan	Post monsoon	3.8124	4.211	3.701	4.213	-2.92	0.05	3.754	4.228	-1.53	0.41
Mustard	B-54	Post monsoon	0.834	1.101	0.825	1.135	-1.08	3.09	0.725	1.212	-13.1	10.08
Sesame	B-9	Pre-monsoon	1.375	1.434	1.242	1.402	-9.67	-2.23	1.128	1.385	-18	-3.42
Ground nut	JL-24	Post monsoon	1.342	1.552	1.238	1.512	-7.75	-2.58	1.011	1.407	-24.7	-9.34
Jute	Nabin	monsoon	2.231	2.324	2.221	2.412	-0.45	3.79	2.021	2.203	-9.41	-5.21
Brinjal	Mukto-kosi	Post monsoon	14.452	16.125	12.85	15.998	-11.1	-0.79	11.532	15.512	-20.2	-3.8
Chili (green)	Surjamu-khi	Post monsoon	1.721	2.131	1.527	2.015	-11.3	-5.44	1.317	1.986	-23.5	-6.8
Ladies Finger	Pusa Swani	monsoon	5.527	7.225	5.241	7.155	-5.17	-0.97	5.005	7.21	-9.44	-0.21
Tomato	Pusa Rubi	Post monsoon	16.129	19.015	15.525	18.586	-3.74	-2.26	13.511	18.213	-16.2	-4.22
Cucumber	Pusa Sanjok	Post monsoon	7.427	9.105	7.245	9.013	-2.45	-1.01	7.005	8.985	-5.68	-1.32
Pumpkin	Chitai	Post monsoon	11.524	15.254	11.122	14.782	-3.49	-3.09	10.142	15.027	-12	-1.49
Potato	Jyoti	Post monsoon	18.218	22.512	17.231	22.108	-5.42	-1.79	16.248	20.894	-10.8	-7.19
Radish	Red bombai	Post. monsoon	13.124	14.73	12.525	14.586	-4.56	-0.98	12.143	13.698	-7.47	-7.01
Spinach (leaf)	Pusa Jyoti	Post monsoon	12.822	15.512	12.061	15.324	-5.94	-1.21	12.431	15.204	-3.05	-1.99
Amaranths	Chanpanote	Post monsoon	4.324	5.905	4.102	6.001	-5.13	1.63	4.003	5.802	-7.42	-1.74
Moong	Panna	Pre-monsoon	0.741	0.829	0.655	0.873	-11.6	5.31	0.721	0.914	-2.7	10.25
Urad beams	B-76	Pre-monsoon	0.823	0.942	0.785	0.951	-4.62	0.96	0.734	0.886	-10.8	-5.94
Turmeric	Prava	monsoon	4.432	7.125	4.246	7.031	-4.2	-1.32	4.105	6.872	-7.38	-3.55
Ginger	China	monsoon	3.425	6.508	3.312	6.324	-3.3	-2.83	3.218	6.312	-6.04	-3.01
Onion	Pusa Red	Post monsoon	9.241	12.45	8.524	11.595	-7.76	-6.87	8.042	11.62	-13	-6.67

This suggests that fly ash has been affecting the rice production in the surrounding areas of thermal power plant (Fig. 2). In the post monsoon period, wheat and maize that are other cereals grow in the areas. Both the crops gradually are losing their producing capacity in the adjacent areas. In case of wheat and maize decreasing trends (-5.94% and -1.53%) have been observed in the nearer circles (<4km) while the rest areas of the block show the improvement in production (6.475% and 0.404%) during last four years (2011-2015). Usually cultivated oil seeds crops are mustard (*Brassica campestris*), sesame (*Sesamum indicum*) and ground nut (*Arachis hypogaea*). These three crops have been losing their production capability by 13.1%, 18% and 24.7% respectively in the areas within 4 km from KTPP. In the rest areas, sesame (-3.42%) and ground nut (-9.34%) have lost yield potentiality due to intensive cultivation but mustard production (10.08%) has increased. This facts reflect that fly ash considerably is affecting the crop production in the adjacent area (<4km).The decline in yields had been reported around the Dahanu thermal power plant in Maharashtra (Arun, et al., 2009). Only one fibre crop jute has been cultivated in the block. Throughout the block jute (*Corchorus olitorius*) has been yielding regressively (-9.415% in <4km and -5.21% in >4km). The vegetables grown in the locality have been losing productivity in all the areas. The notably changes (2011-2015) have occurred in chili (-23.5%), brinjal (-20.2%), tomato (-16.2%), potato (-10.8%), ladies finger (-9.44%), radish (-7.47%) and amaranths (-7.42%) with in 4km radius of KTPP. The rest areas have reflected less than 5% reduction in production except potato (-7.19%). Though pulses are having high demand, only moong and uard beams are being cultivated in the block. Both are losing production gradually. Production of some spices crops turmeric (-7.38%), ginger (-6.312%), onion (-13%) etc. have been also found decreasing trends (<4km) whereas in the rest areas it is nearly half. It has been observed that the loss of crop productivity is higher in the surrounding areas (<4km) of KTPP. This supportively has implied that fly ash coming out from thermal power plant considerably is affecting the crop production around KTPP.

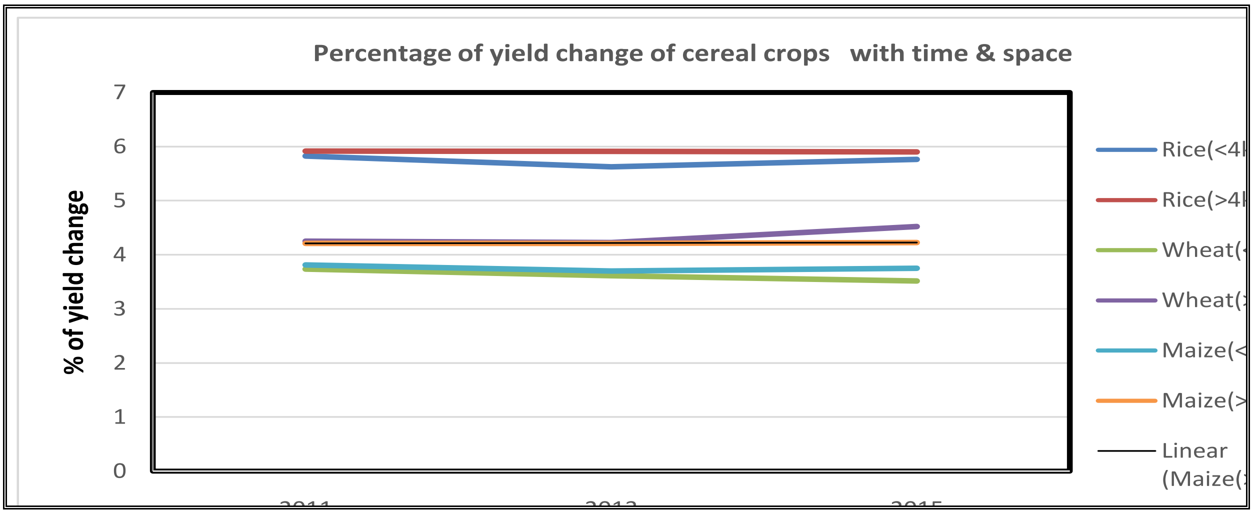

FIGURE 2. PERCENTAGE OF YIELD CHANGE OF CEREAL CROPS WITH TIME AND SPACE

3.4 Increase in cost of cultivation for crop production

Many material inputs are required for the agricultural crops cultivation which leads better production. The inputs include seed, nutrients bearing fertilizers, pesticide, water etc. Fertilizers and pesticides are the costly inputs of agricultural sector. These two inputs mainly influence the price of agricultural produces. The cost of cultivation has been incurred for rice (27.5%), wheat (24%) and maize (25%) in the radius of 4km from KTPP during last four years (2011-2015) whereas these are 15.79%, 13.04% and 22.22% respectively for the rest of area of the block (Table 6). The expenditure (<4km) involved in crop production has increased for mustard (15.91%), sesame(17.07%) and ground nut (12.5%) while these are 10%, 11.9% and 6.67% respectively beyond 4km. There is a clear cost difference for the oil seed crops inside and outside of the impact zone of fly ash. It has been observed that vegetable crops grown in the block have involved expenses more than the previous years. For brinjal (44%), chili (16.88%), ladies finger (55.56%) and tomato (57.89%) cost of cultivation has increased in surrounding area (<4km) of KTPP whereas these are 25%, 6.58%, 52.94% and 55.56 respectively for the rest area of block. The cucurbitaceous crops (cucumber and pumpkin) have been cultivated with more inputs in which suggested costs are higher than the previous year. The expenses for cultivation of potato , radish, spinach, amaranths also have increased with passing time and is higher than the area outside of affected zone (>4km). Moong, urad beams, turmeric, ginger and onion are cultivated in the block. Their cost of crop production has become higher with passage of time but percentage of change in crop cultivation has been found lower with increase in distance from KTPP. This facts reflect that the fly ash considerably is affecting the soils and micro-climate of the adjacent area (<4km) which incurs more expenses of crop production.

TABLE 6
PERCENTAGE OF TEMPORAL AND SPATILAL CHANGES IN COST OF CULTIVATION OVER 2011

Name of crops	2011		2013				2015			
	Cost (<4km) Rs. ton^{1}	Cost (>4km) Rs. ton^{1}	Cost (<4km) Rs. ton^{1}	Cost (>4km) Rs. ton^{1}	% change (<4km)	% change (>4km)	Cost (<4km) Rs. ton^{1}	Cost (>4km) Rs. ton^{1}	% change (<4km)	% change (>4km)
Rice	10000	9500	11500	10500	15	10.53	12750	11000	27.5	15.79
Wheat	12500	11500	14500	12000	16	4.35	15500	13000	24	13.04
Maize	10000	9000	11000	10000	10	11.11	12500	11000	25	22.22
Mustard	22000	20000	25000	21500	13.64	7.5	25500	22000	15.91	10
Sesame	20500	21000	23000	22500	12.2	7.14	24000	23500	17.07	11.9
Ground Nut	40000	37500	43500	39000	8.75	4	45000	40000	12.5	6.67
Jute	10500	12500	12000	14000	14.29	12	14000	15000	33.33	20
Brinjal	12500	12000	15500	14500	24	20.83	18000	15000	44	25
Chili	38500	38000	43200	39000	12.21	2.63	45000	40500	16.88	6.58
Ladies Finger	9000	8500	11750	10500	30.56	23.53	14000	13000	55.56	52.94
Tomato	9500	9000	11500	12000	21.05	33.33	15000	14000	57.89	55.56
Cucumber	9500	9000	12000	11500	26.32	27.78	15000	13000	57.89	44.44
Pumpkin	7500	7000	9500	8500	26.67	21.43	12000	9000	60	28.57
Potato	7500	7000	10000	8000	33.33	14.29	11000	9000	46.67	28.57
Radish	5500	5000	8000	6500	45.45	30	9000	7000	63.64	40
Spinach	10500	10000	13500	11500	28.57	15	16000	13000	52.38	30
Amaranths	8500	8000	12000	12000	41.18	50	15000	13000	76.47	62.5
Moong	34500	33000	37500	37000	8.696	12.12	42000	40000	21.74	21.21
Urad beams	24500	24000	28500	27500	16.33	14.58	32000	30000	30.61	25
Turmeric	18000	17500	21000	20000	16.67	14.29	25000	22500	38.89	28.57
Ginger	24500	23000	28000	30000	14.29	30.43	35000	32000	42.86	39.13
Onion	11500	11000	14000	12500	21.74	13.64	16000	14000	39.13	27.27

3.5 Recommendation

The agriculture is the prime livelihood of the locality around the Kolaghat thermal power plant. The cost of cultivation is being increased day by day. This leads the farming community to stop growing crops. Therefore, the socio-economic condition is becoming more unbearable for their subsistence. For sustainability of agriculture around the thermal power plant, proper evaluation of land, micro-climate, water, vegetation etc. should be conducted to illustrate the present requirement of crop cultivation. Land-use planning, i.e. what crops should be cultivated on what tracts of land by what methods and in which seasons of the year, has become more important today than it has ever been for suitable cropping taken into the account of farmer's priorities and policy objectives with respect to sustainable agricultural development (Lal and Pierce, 1991) Natural resource analysis should be done to predict the impact of fly ash on them which may suggest the suitable crops to be grown. Site specific crop adoption, problem identification and eradication, crop management should be followed (Adak, et al., 2016). Different crop models may be adopted to sustain the agriculture in the areas. Organic farming and precision agriculture may reduce the impact of fly ash in the region. Authority of KTPP should exercise new technology to minimize the emission of fly ash. They must ensure the scientific disposal of bottom ash and hot water used in power plant. The plant authority should encourage the plantation of trees and should efficiently and technically utilize the ash in form of brick; low land filling for legal building construction, binding in flood hit areas etc.

IV. CONCLUSION

Kolaght thermal power plant is affecting the agricultural sustainability in the locality within 4km distance. The farming community is losing their interest in crop cultivation because the cost of production increases with the time. Use of fertilizers and pesticides become more in the surrounding area of KTPP where land is losing its fertility and pest infestation is increasing. These lead the high cost of production. The incurred cost for farming is higher in the adjacent area (<4km) though it is increasing throughout the block with passage of time due to increase in cost of fertilizers , pesticides, electricity, fossil fuel, seeds, labour etc. Proper utilization and management of bottom ash and fly ash may improve the persistent condition of the locality. Site specific resources evaluation and management should be adopted to abate the impact of fly ash. Organic farming and precision agriculture will lead the agricultural sustainability. These will incur less input for cultivation and their organic sources with the specification of requirement will involve less cost of cultivation. Scientific awareness will highlight the problems and find ways to overcome. All the constructive attempts should nourish the agricultural sustainability to boost the socio-economic condition of the affected area of fly ash.

ACKNOWLEDGEMENT

We are very grateful to the Office of Assistant Director of Agriculture, Kolaghat, Government of West Bengal; Bidhan Chandra Krishi Viswavidyalaya, Mohonpur, West Bengal; National Institute of Technology, Durgapur; Agricultural Training Centre, Ramakrishna Mission Asharama, Narendrapur, Kolkata-700103 for providing valuable different assistances for conducting our research work.

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