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Research Article

IMPACT OF COAL-FIRED THERMAL POWER PLANT ON AGRICULTURAL PRODUCTION

ADAK SUBHAS*[1], ADHIKARI KALYAN[2] AND BRAHMACHARI KOUSHIK[3]

[1,2]Department of Earth and Environmental Studies, National Institute of Technology, Durgapur, India
[3]Department of Agronomy, Bidhan Chandra Krishi Viswavidyalay, Mohanpur, West Bengal, India
*Corresponding Author: Email-subhas.adak@rediffmail.com

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Abstract- Kolaghat thermal power plant (KTPP), India, is affecting Agricultural production in the adjacent areas. Uses 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. Increases in use of nitrogen and phosphorus bearing fertilizers have been observed but change in potassium requirement (0-25%) has become lower within area 4km radius from KTPP. For the remaining area of the block, the change is quite higher (12.5-66.67%) than that of adjacent area. 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 black gram (+10.25%) that have gained more yields. 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 agricultural production in the proximity (<4km) of KTPP. Site-specific crop adaptation and resources management can nourish environmental and agricultural sustainability.

Keywords- Thermal Power Plant, Fly ash, Agricultural production, Fertilizer application, Cultivation cost

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Introduction

Agriculture 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. Fly ash is affecting the soil properties and micro-climate around the power plant [4]. 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 for six units. The considerable amount of fly ash subsides in the surrounding area within 4km from KTPP [1, 7]. Addition of fly ash increased the pH of amendments from 6.15 to 7.05[8]. Soils become more alkaline due to alkaline nature of fly ash around coal based thermal power plant [1,5,11,12]. It reflected that soil reaction of adjacent area (<4 km) to thermal power plant was alkaline (> 7.5) which reduced the production potential of crops needed for subsistence & economy in the locality [1]. The climate and soil within the distance of 4 km from KTPP were influenced by emission of fly ash [1]. Depression in yields was reported due to toxicity of boron and deficiency of phosphorus and zinc in fly ash used for agriculture[6].Average grain & biomass yields of wheat have been affected by the application of different levels offly ash[3]. Agrawal & Agrawal [2] 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 [15] studied the impact of coal mining on Air, Water & Soil on the surrounding area of coal mining at Wani dist. Yavatmal. The increase in quantity of fertilizer application 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 agricultural production and increasing cost of cultivation due to fly ash coming out from KTPP.

The objectives of the study:

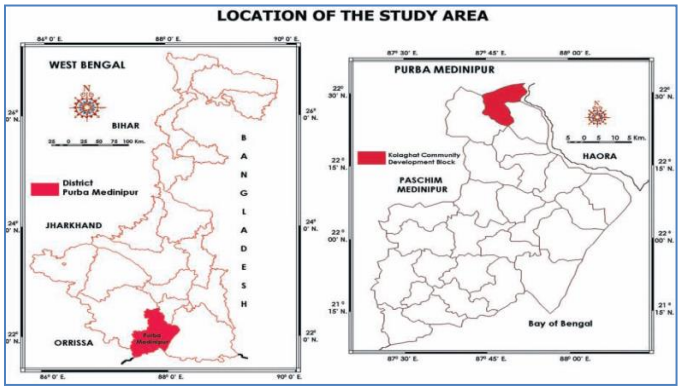
- To evaluate the temporal and spatial impact of fly ash on Agricultural production
- To determine the change in doses of fertilizers for providing major plant nutrients (NPK)
- To assess the increase in cost of cultivation due to Coal fired thermal power plant
- To suggest and recommend some mitigating measures around KTPP
- To develop awareness on environmental and agricultural sustainability in the affected area of coal burned thermal power plant.

Materials and Methods

Mouza map and block map were used to demark the different area. The 4 km distance from Kolaghat was delineated through the survey by using soil survey method [14].The data were collected from field survey [Fig-1]. During the study period (2011-2015), fertilizer application, 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. Yield data were collected and recorded in ton per hectare. Cost of production was assessed on the basis of price in their local market and converted rupees per ton.

A.



B. Agricultural Circles of Kolaghat block:

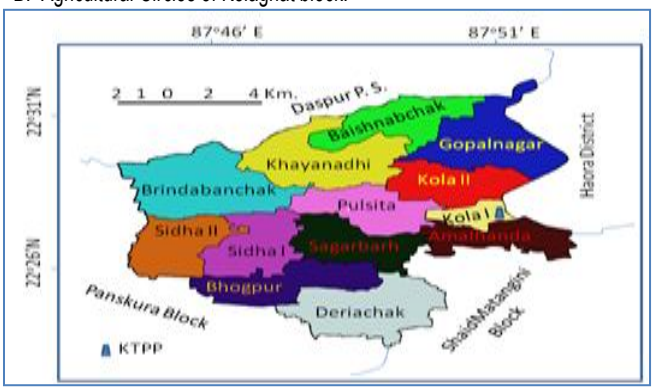


Fig-1 Location map of Kolaghat block in the district Purba Medinipur of West Bengal, India

Results and Discussion

Increase in use of Fertilizers for Agricultural cultivation

Different crops are being cultivated to mitigate the daily requirement of agricultural food stuffs in the locality [Table-1-3]. 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. 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*) absorb 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. [9]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 [Fig-2-4].

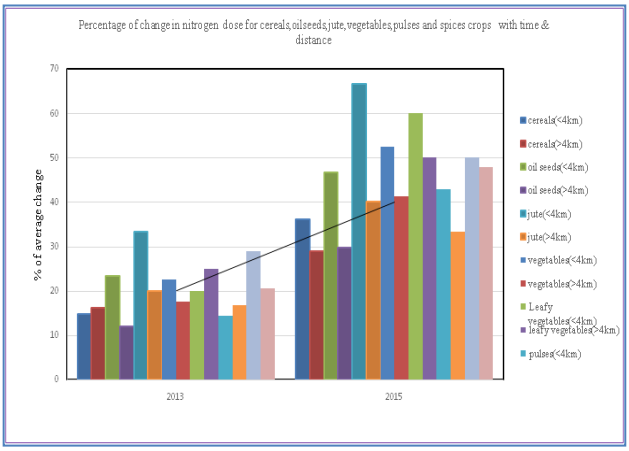


Fig-2 % of change in nitrogenous fertilizer dose for crops over 2011.

Doses of nitrogen and phosphorus fertilizer increased more in 2015 than 2013 within 4km radius from KTPP whereas these were less in the areas beyond 4km from the thermal power plant. Through the passage of time nitrogen and phosphorus requirement is increasing [Fig-2-3]. Availability of phosphorus is also fluctuating because of soil reaction affected by alkaline fly ash.

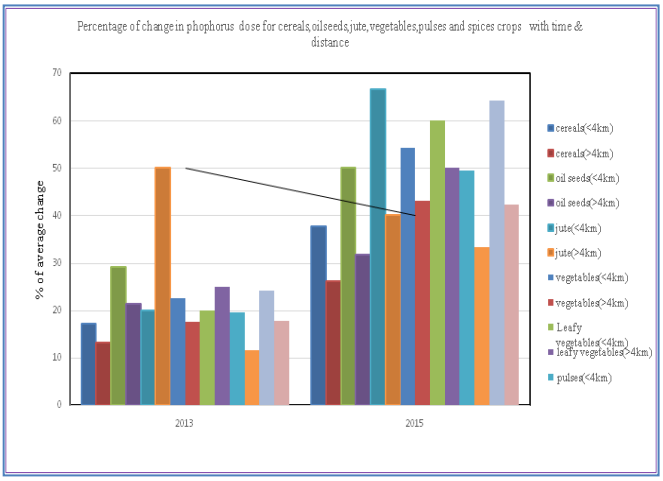


Fig-3 % of change in phosphorus fertilizer dose for crops over 2011

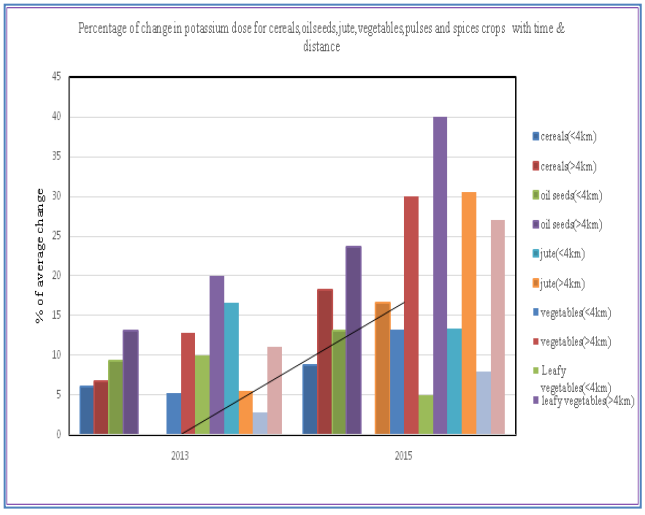


Fig-4 % of change in potassium fertilizer dose for crops over 2011

Potassium requirement is less in the adjacent areas whereas it is more for the rest of the block. It implies that fly ash is influencing the availability of potassium. The fly ash contains higher K_2O (0.15 -3.5%) whereas soil is having less (0.04-3.1%) [12].

Table-1 *Percentage of temporal and spatial 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
Average change in percentage for cereals	Nitrogen (N)					14.72	16.11			36.11	28.89
	Phosphorus (P_2O_5)					17.10	13.10			37.62	26.19
	Potassium (K_2O)					6.10	6.73			8.76	18.22
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
Average change in percentage for oil seeds	Nitrogen (N)					23.33	12.04			46.67	29.63
	Phosphorus (P_2O_5)					29.17	21.43			50.00	31.74
	Potassium (K_2O)					9.26	13.06			13.06	23.61
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 spatial changes in doses of fertilizers over 2011 for vegetables*

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
Average change in percentage for vegetables	Nitrogen (N)					22.5	18.93			52.5	41.29
	Phosphorus (P_2O_5)					22.54	17.53			54.17	43.0
	Potassium (K_2O)					5.23	12.81			13.18	30.0

Table-3 *Percentage of temporal and spatial changes in doses of fertilizers over 2011 for leafy vegetables, pulses & spices*

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)
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
Average change in percentage for leafy vegetables	Nitrogen (N)					20	25			60	50
	Phosphorus (P_2O_5)					20	25			60	50
	Potassium (K_2O)					10	20			5	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
Average change in percentage for pulses	Nitrogen (N)					14.38	16.66			42.97	33.3
	Phosphorus (P_2O_5)					19.64	11.66			49.55	33.33
	Potassium (K_2O)					16.66	5.55			13.33	30.55
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
Average change in percentage for spices	Nitrogen (N)					28.89	20.55			50.0	47.77
	Phosphorus (P_2O_5)					24.21	17.78			64.28	42.22
	Potassium (K_2O)					2.78	11.11			8.0	26.98

Spatial and temporal yield decrease of cultivated crops

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-4-5]. This suggests that fly ash has been affecting the rice production in the surrounding areas of thermal power plant [Fig-5]. 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 areas (<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 fact 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 [4]. 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.

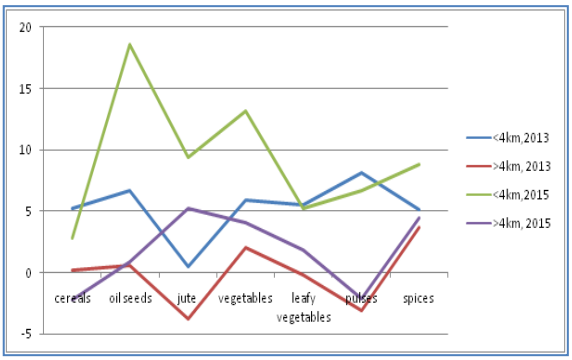


Fig-5 Percentage of yield change of different crops with time and space

Decrease in yields of cereals, oilseeds, jute and vegetables within 4kmis more whereas this is comparatively less in the area beyond 4km during the period (2011-2015). Production of pulses, leafy vegetables and spices has been found more stable in the adjacent area than the rest area.

Increase in cost of production for crop production

Fertilizers inputs mainly influence the price of agricultural produces. The costs of cultivation incurred are 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) in crop production has increased for mustard (15.91%), sesame (17.07%) and ground nut (12.5%) while it is 10%, 11.9% and 6.67% respectively beyond 4km of KTPP. There is a clear cost difference for the oil seed crops inside and outside of the impact zone of fly ash. It was observed that vegetable crops grown in the block involved expenses more than the previous years.

Table-4 *Percentage of temporal and spatial 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 MS	5.825	5.916	5.624	5.912	-3.45	-0.07	5.762	5.904	-1.08	-0.2
Wheat	UP-262	Post MS	3.737	4.247	3.613	4.223	-3.32	-0.57	3.515	4.522	-5.94	6.48
Maize	Kisan	Post MS	3.8124	4.211	3.701	4.213	-2.92	0.05	3.754	4.228	-1.53	0.41
Average change for cereals							-5.23	-0.20			-2.85	2.25
Mustard	B-54	Post MS	0.834	1.101	0.825	1.135	-1.08	3.09	0.725	1.212	-13.1	10.08
Sesame	B-9	Pre- MS	1.375	1.434	1.242	1.402	-9.67	-2.23	1.128	1.385	-18	-3.42
Ground nut	JL-24	Post MS	1.342	1.552	1.238	1.512	-7.75	-2.58	1.011	1.407	-24.7	-9.34
Average change for oil seeds							-6.67	-0.57			-18.6	-0.89
Jute	Nabin	MS	2.231	2.324	2.221	2.412	-0.45	3.79	2.021	2.203	-9.41	-5.21
Brinjal	Muktokosi	Post MS	14.452	16.125	12.85	15.998	-11.1	-0.79	11.532	15.512	-20.2	-3.8
Chili (green)	Surjamukhi	Post MS	1.721	2.131	1.527	2.015	-11.3	-5.44	1.317	1.986	-23.5	-6.8
Ladies Finger	Pusa Swani	MS	5.527	7.225	5.241	7.155	-5.17	-0.97	5.005	7.21	-9.44	-0.21
Tomato	Pusa Rubi	Post MS	16.129	19.015	15.525	18.586	-3.74	-2.26	13.511	18.213	-16.2	-4.22
Cucumber	Pusa Sanjok	Post MS	7.427	9.105	7.245	9.013	-2.45	-1.01	7.005	8.985	-5.68	-1.32
Pumpkin	Chitai	Post MS	11.524	15.254	11.122	14.782	-3.49	-3.09	10.142	15.027	-12	-1.49
Potato	Jyoti	Post MS	18.218	22.512	17.231	22.108	-5.42	-1.79	16.248	20.894	-10.8	-7.19
Radish	Red bombai	Post. MS	13.124	14.73	12.525	14.586	-4.56	-0.98	12.143	13.698	-7.47	-7.01
Average change for vegetables							-5.90	-2.04			-13.16	-4.01

MS: Monsoon

Table-5 *Percentage of temporal and spatial 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)
Spinach (leaf)	Pusa Jyoti	Post MS	12.822	15.512	12.061	15.324	-5.94	-1.21	12.431	15.204	-3.05	-1.99
Amaranths	Chanpanote	Post MS	4.324	5.905	4.102	6.001	-5.13	1.63	4.003	5.802	-7.42	-1.74
Average change for leafy vegetables								-5.53	0.21		-5.53	-1.86
Moong	Panna	Pre- MS	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- MS	0.823	0.942	0.785	0.951	-4.62	0.96	0.734	0.886	-10.8	-5.94
Average change for pulses							-8.11	3.13			-6.75	2.15
Turmeric	Prava	MS	4.432	7.125	4.246	7.031	-4.2	-1.32	4.105	6.872	-7.38	-3.55
Ginger	China	MS	3.425	6.508	3.312	6.324	-3.3	-2.83	3.218	6.312	-6.04	-3.01
Onion	Pusa Red	Post MS	9.241	12.45	8.524	11.595	-7.76	-6.87	8.042	11.62	-13	-6.67
Average change for spices							-5.09	-3.67			-8.81	-4.41

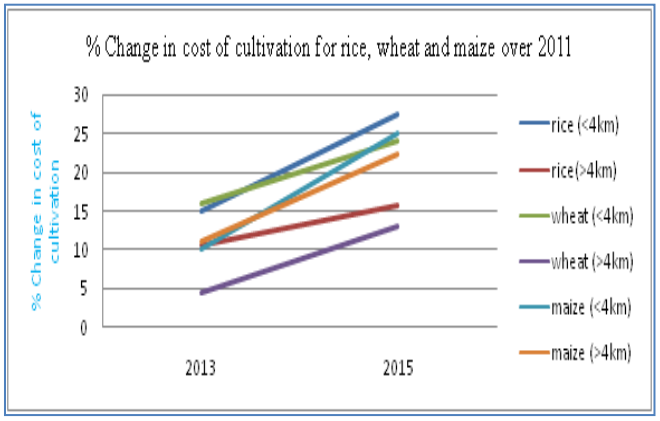


Fig-6 % Change in cost of cultivation for cereal crops over 2011

Cost of cultivation for brinjal (44%), chili (16.88%), ladies finger (55.56%) and tomato (57.89%)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 [Fig-6-11]. The cucurbitaceous crops involve higher cultivation cost than the previous year. The expenses for cultivation of potato, radish, spinach, amaranths also are increasing with passing time and are higher than the area outside of affected zone (>4km). For black gram, urad beams, turmeric, ginger and onion the 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 fact reflect that the fly ash considerably is affecting the soils and micro-climate of the adjacent area (<4km) which incurs more expenses of Agricultural production.

Table-6 *Percentage of temporal and spatial changes in production cost 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
Pumkin	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
Black Gram	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

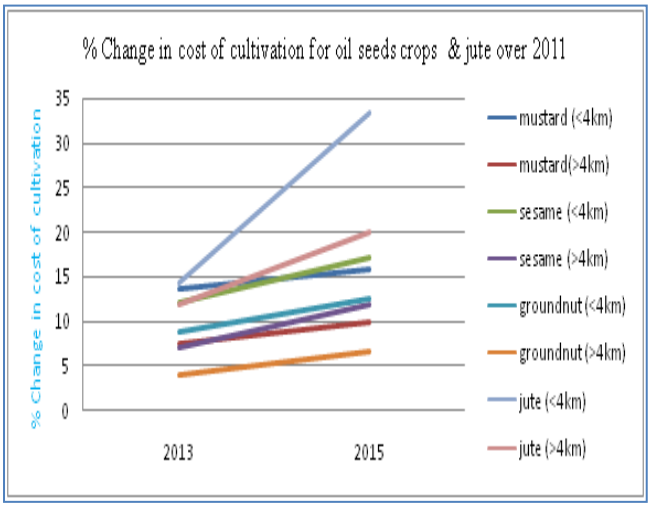


Fig- 7 % Change in cost of cultivation for oil seeds crops and jute over 2011

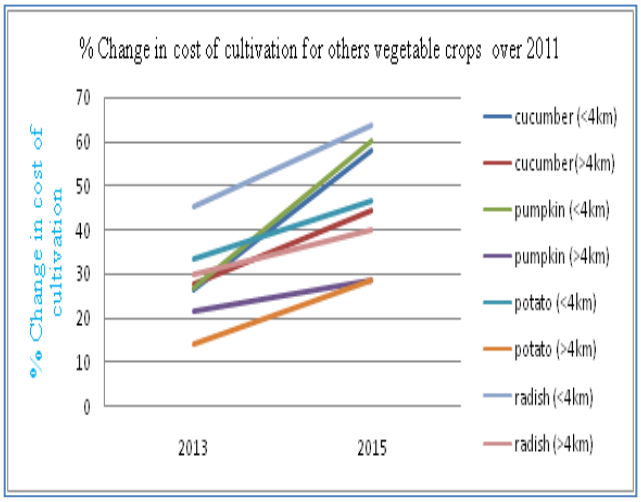


Fig-9 % Change in cost of cultivation for other vegetable crops over 2011

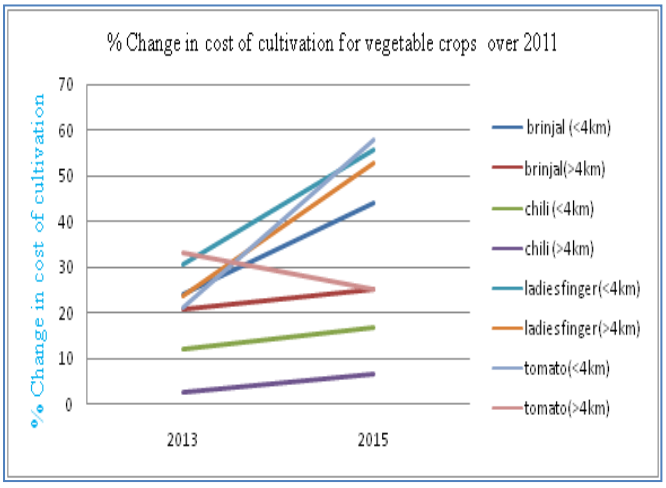


Fig-8 % Change in cost of cultivation for vegetable crops over 2011

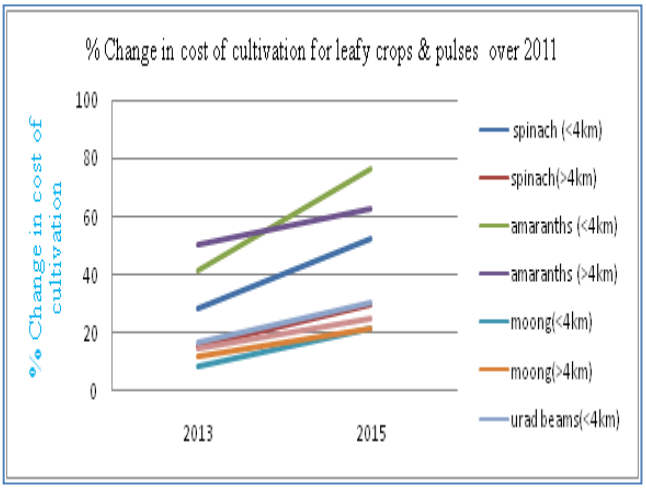


Fig-10 % Change in cost of cultivation for leafy crops and pulses over 2011

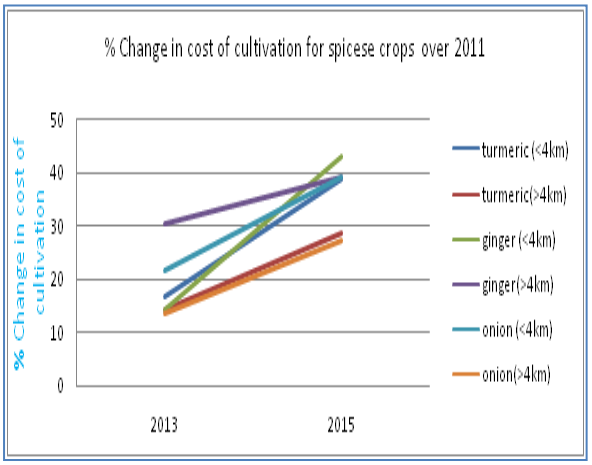


Fig-11 % Change in cost of cultivation for spices crops over 2011

Recommendation

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 bricks, low land filling for legal building construction, binding in flood hit areas etc. For sustainability of environment and agriculture around the thermal power plant, doses of nitrogen and phosphorus should be increases as per soil testing results. Dose of potassium should be less and acidic fertilizers are suitable for adjacent area (<4km). Site specific crop suitability developed by Adak et al. [4] should be adopted to sustain the agriculture in the areas.

Conclusion

The farming community is losing their interest in crop cultivation because the cost of production increases with the time around the thermal power plant. Uses of fertilizers become more in the surrounding area of KTPP where land is losing its fertility. Proper utilization and management of bottom ash and fly ash may improve the persistent condition of the locality. These will incur less inputs for cultivation and will involve less cost of production. Land use planning will address the problems and find ways to nourish environmental and agricultural sustainability.

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