http://dx.doi.org/10.22161/ijeab/1.3.34 *ISSN: 2456-1878*

Effect of Fly Ash on Crop Coverage around coal-fired Thermal Power Plant in Rural India

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Abstract— *Fly ash coming out from Kolaghat thermal power plant, West Bengal, India affects the crop coverage in the surrounding area (<4km). The arable areas under different crops, rice (-4.87%) , wheat (-67.6%), maize (-10%), mustard (-29.1%), sesame (-8.33%), jute (-10%), vegetables (-14.8%), flowers (-8.06%) and pulses (-32.4%) have been gradually losing due to fly ash (<4km) except spices (4.76%) during last four years (2011-2015) whereas the area beyond 4km has gained the space for more cultivation (overall 1.7%) except rice(-0.09%) and jute(-1.41%) due to low price and demand. The nearer circles, Kola-I ,Kola-II, Gopalnagar, Pulsita, Sagarbarh and Amalhanda has lost cultivable land by 0.95% to 2.86% recording overall change 67.64% to 65.52% while the rest circles shows the change from 76.27% to 75.12%. The average cropping system (<4km) has dropped down from 181.3% to 166.8% whereas it has shifted from 195.1% to 183.6% in the outer side (>4km). As the consequence of fly ash, agricultural land (<4km) has been converted to non-agricultural one by 1.096% (Sagarbarh) to 5.184% (Kola-II) contrasting the transformation to non-arable in the area (>4km) from 0.537 % (Siddha-I) to 2.383% (Baishnabchak). Site-specific evaluation and recommendation as well as organic farming and precision agriculture should be adopted to abate the impact of coal-burned thermal power plant for agricultural sustainability in rural India.*

Keywords—Fly ash, Crop Coverage, Cropping Intensity, Land use Pattern.

I. INTRODUCTION

Throughout the world, the most demanded from of energy is electricity. Electricity is the driving force of the modern civilization. Out of total produced electricity, Coal fired thermal power plant contributes 41% of electricity in the world (www.worldcoal.org/coal/uses-coal/coal-electricity) and 61.32 % in India ("All India Installed Capacity of Utility Power Stations" (PDF) Retrieved 9 September 2016). At present (2016) 132 number of coal fired thermal power plants have been installed in different states all over India. In West Bengal 13 coal burned thermal power plants have been established sharing83.67% out of 10068.40MW ("All India Installed Capacity of Utility Power Stations" *(PDF)* Retrieved 9 September 2016). Kolaghat thermal power plant (KTPP) is one of them. It was installed in the year 1984 with initial capacity of 210MW. Gradually its electricity generating capability had been raised to 1260MW with six units in the year 1994. The Kolaghat Thermal Power Plant is situated 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 present electricity generating capacity of KTPP is 1260 MW. The plant produces 7500-8000 metric ton of ash every day by consuming a total of 18000 ton of coal. The Power Plant emits considerable amount of fly ash. For usual disposal of ash one acre of land is required for one megawatt electricity produced in the whole life of the plant that is about 30 years (Adak, *et al*., 2016; Dasgupta, A. and Paul, S., 2011). So the KTPP requires 1260 acre of land for the disposal of ash generated in its life time. At present the plant has only 325 acre of land located 4-5 km away from it. The fly ash which is coming out of the chimneys generally subsides in the surrounding areas generally 3 – 4 km away (Adak, *et al*., 2016; Dasgupta, A. and Paul, S., 2011). In order to cope up with the pressure of population, every bit of available land has been brought under various types of uses, which put high pressure on the land (Joshi and Nagare, 2009). Kolaghat Block is the most affected area of coal-fired thermal plant (Adak, *et al*,, 2016; Dasgupta, A. and Paul, S., 2011). It is covering geographical area of 15480.51. It is divided into thirteen gram- panchayats or circles namely Kola-I ,Kola-II, Gopalnagar, Baishnavchak, Khanyadihi , Pulsita ,Sagarbarh , Amalhanda , Deriachak , Bhogpur , Siddha-I , Siddha-II and Brindabanchak. Some circles Kola-I, Kola-II, Gopalnagar, Pulsita, Sagarbarh, Amalhanda are situated within radius (4km) of danger zones of thermal power plant. Agriculture is the prime source of livelihood of the block. Socio-economic conditions of the region mainly depend on agriculture. The agricultural areas are decreasing with the passage of time after the installment of thermal power plant at Kolaghat (Adak, *et al*,, 2016; Dasgupta, A. and Paul, S., 2011). According to the

http://dx.doi.org/10.22161/ijeab/1.3.34 *ISSN: 2456-1878*

Summary report of the study on "Post-Clearance Environmental Impacts and Cost-benefit Analysis of Power Generation in India" Conducted by National Environmental Engineering Research Institute in February, 2006, it was stated that land was losing due to change in natural soil properties affected by coal based plants at Ramagundam in Telangana, Chandrapur in Maharashtra and Gandhinagar in the state of Gujarat, India. According to Garg, J.K. (1990) deposition of fly ash and coal dust has affected about 844.90 sq. km area as per December 1988 imagery in Talcher in the state of Odisha. Due to mining activities and thermal power generation, forest area was decreased by 34 % during the period 1975 to 1989. The area under fly ash deposition increased from 25 sq. km in 1979 to 117 sq. km in 1987 due to Talcher Thermal Power Station (TTPS) in the state of Odisha. Avirneni, S. and Bandlamudi, D. (2013) reported that fly ash affected the land use, soil and water. Kumar, *et al.,* (2013) also reported that the thermal power plant had serious impacts on land, soil and air. Y Y Dudhapachare (2012) observed during investigation of upcoming thermal power plant in Chandrapur district of Maharashtra that the basic requirement for establishing the thermal power plant was huge land for plant area, ash Dump Lake, residential colony and water reservoir. This was direct impact on the land, but beyond this there was much invisible impact and land use in associate with the thermal power. According to Chitade, *et al.,* (2010) from the analysis of land use land cover classification of multitemporal satellite data it had been observed that there are enormous changes especially in vegetation and agricultural area. Almost dense vegetation had been converted either into mine land or artificially created mountains of mine overburden in Chandrapur thermal power plant of Maharashtra. Shamshad, *et al.,* (2012) also observed that fly ash affected the general aesthetics of environment in terms of land use, air, soil and water. According to Salesh Kalkal and Parmod Bhardwaj (2014) the industrialization through establishment of thermal power plant had significantly changed the land use/land cover pattern in rural areas, particularly in nearby areas (Jharli and its surroundings) of National Capital Region (NCR) of Delhi. They also observed that in 2004-05, the agricultural land in the study area was 45604110 m² contributing 93.66 per cent of total area. In the year 2011-12, the agricultural land in the study area was 31838980 m² and occupied 65.40 percent of total area. So, agricultural land had decreased by 13765130 m² areas recording a decline of 28.27 percent. The decrease of crop land results less production in agricultural sector which affects the socio-economic condition of the concerned area. Information about land use change is necessary to update land cover maps and for effective management and planning of the resources for sustainable development (Alphan, 2003). In this regard, Kolaghat block has been considered as the victim of losing crop lands due to fly ash emitting from Kolaghat thermal power plant.

The objectives of the study:

- To examine the temporal and spatial impact of coal –burned thermal power plant on crop coverage.
- To identify the effect of fly ash on land use pattern of Kolaghat block.
- To assess the change in arable land, net cultivated land, gross cultivated land, cropping intensity, net irrigated area and gross irrigated area of Kolaghat block where thermal power plant is situated.
- To suggest and recommend some improving measures in order to minimize the impact of fly ash coming out from the thermal power plant.
- To generate awareness on agricultural sustainability in the affected area of coal fired thermal power plant.

II. MATERIALS AND METHODS

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 estimate the different area (Fig. 1). The cultivated areas under different crops were collected from field survey in 2011, 2013 and 2015. Information of total geographical area and agricultural land were collected from the office of Assistant Director of Agriculture, Kolaghat, Government of West Bengal, India. Net cultivated area indicates the actual area used for raising crops. Gross cultivated area was estimated by collecting the field data of cropped area throughout year.Net irrigated area was measured by the field data collected where irrigation facility was availed. Cropping intensity was estimated by the formula (total cultivated area throughout year / net cultivable area multiplied by 100).

III. RESULTS AND DISCUSSION

In the Kolaghat block where thermal power plant (KTPP) is situated, different crops are being cultivated throughout the year. Several crops have been losing their areas during (2011- 2015) the study has been carried out. The crop coverage concerned with geographical area, arable land, net cultivable land, gross cultivated area, cropping intensity (CI), net and gross irrigated areas, non-agricultural land, crop wise area distribution etc. has been described for depicting the influence of fly ash coming

http://dx.doi.org/10.22161/ijeab/1.3.34 *ISSN: 2456-1878*

out from KTPP in the adjacent areas (4km) and the distant areas (> 4km) from KTPP.

3.1. Effect of Fly ash on Spatial and temporal changes of Crop Coverage:

Crop area of Kolaghat block is influenced by the Kolaghat thermal power plant. Different crops like rice, wheat, maize, mustard, sesame, jute, vegetables, flowers, pulses spices etc grow in the block. These crops are losing their area within the radius of 4km from the centre of KTPP (Table -1). In 2011 within 4km radius rice was cultivated in 1890 ha area whereas in 2013 that area was 1837ha and in 2015 it is 1798 ha. Rice is the staple food of the area. The land under rice cultivation has been significantly decreasing (-4.87% in 2015 from 2011) in the adjacent area of KTPP due to the fly ash emitting from the power plant which is affecting the vegetative and reproductive growth of paddy. Fly ash also is changing the soil properties which hinder the nutrient availability of the plant (Singh, *et al.*, 1995; Basu, *et al.*, 2009). On the other hand, rice is gaining area (0.22% in 2013) beyond the 4km radius from KTPP because of local demand and supporting price.

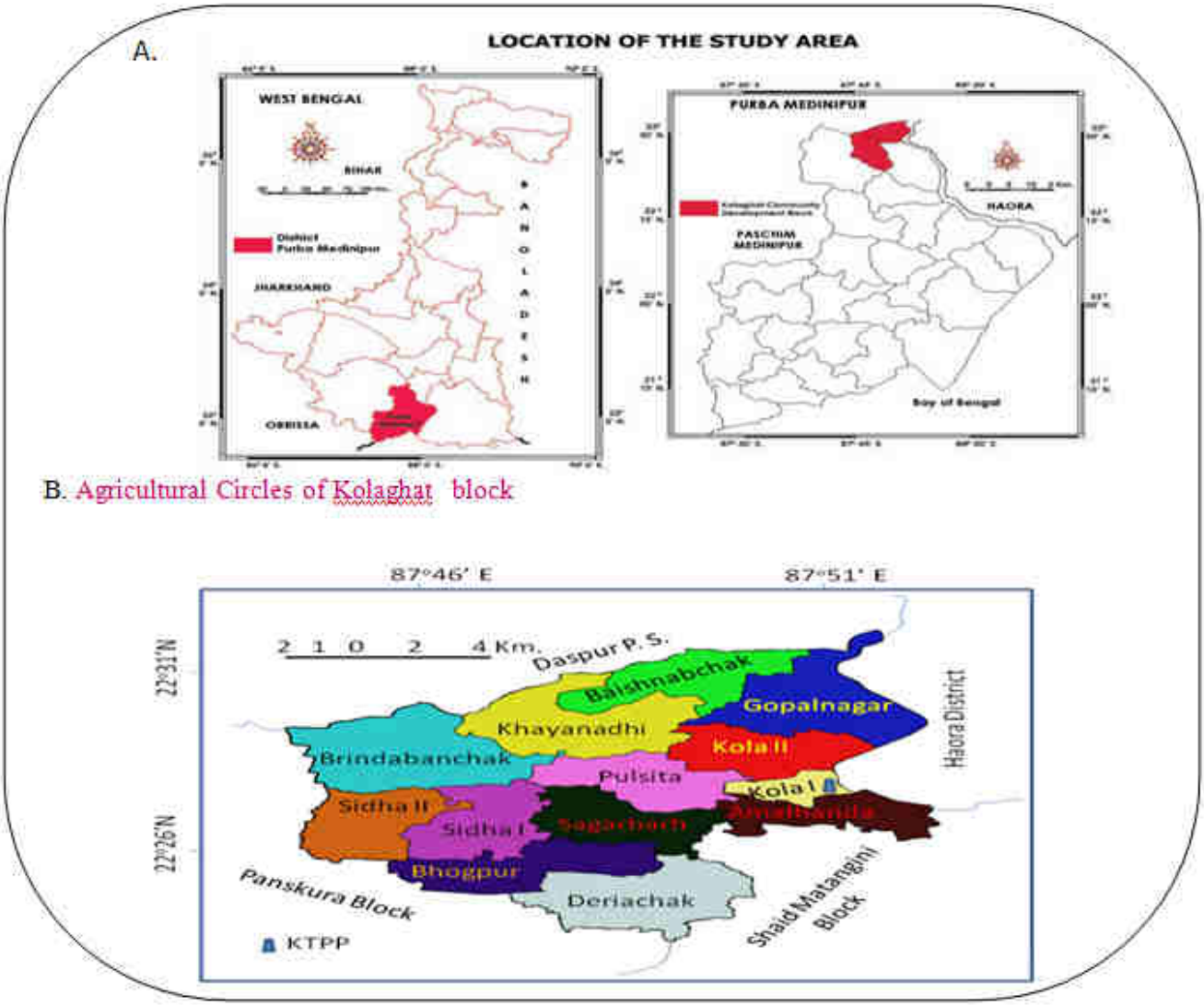

Fig.1: Location map of Kolaghat block in the district Purba Medinipur of West Bengal, India

Wheat and maize have been cultivated in lesser area (-67.6% and -10% in 2015 from 2011) and are losing importance in the area within 4km whereas their cultivation acreage outside the 4km is increasing to some extent (6.25% and 16.67% in 2015 over 2011). Major oil seed crops of the block are mustard and sesame. The two crops are facing the decreasing trend in area coverage (-29.1% and -8.33% respectively from 2011 to 2015) though both are having good demand in the locality affected by fly ash (Adak, *et al.*, 2016). The areas outside 4km are supporting the growing of these two crops resulting in increase (1.54% and 25% respectively from 2011 to 2015) of cultivated land. Vegetables, flowers, pulses and spices crops are losing the land area yearly. The arable areas under these crops in 2011 are vividly depicting the decreasing trend in 2015 whereas the

http://dx.doi.org/10.22161/ijeab/1.3.34 *ISSN: 2456-1878*

situation is increasing trend beyond the 4km from the power plant due to lesser impact of fly ash and cost of cultivation. Vegetables, flowers, pulses and spices crops have gained area 1.83 %, 3.93%, 6.37% & 46.53% respectively over the area in 2011. It has been observed that total crop area in the surrounding land (<4km) of KTPP is affected by the power plant which reflects the decrease in crop land(-8.26% in 2015 from 2011) whereas in the rest areas(>4km from KTPP) of Kolaghat block, the total crop coverage has increased by 1.7% over last four years (2011-2015) .

3.2. Impact of fly ash on cultivable land and cropping intensity:

In the Kolaghat block, cultivable area is losing gradually over passage of time (Table 2, 3 & 4). Fly ashes usually have been shedding in considerable amount within the 4 km from the power plant (Adak, *et al.*, 2016; Dasgupta, A. and Paul, S., 2011). At Kola-I,Kola-II, Gopalnagar. Pulsita, Amulhanda which are situated within the radius of 4 km from the Kolaghat thermal power plant, the percentage of cultivable land to the total geographical area have been found more decreasing trend than the circles i.e., Baishnabchak , Sagarbarh, Deriachak, Bhogpur, Siddha-I, Siddha-II and Brindabanchak which are beyond 4 km of power plant. Kola-I has experienced the 79.53 %, 77.86% and 76.86 % arable land over total geographical area respectively in 2011, 2013 and 2015. At Kola-II the losing trend has become little bit higher (55.18% in 2011, 53.72% in 2013 & 52.32% in 2015) due to proximity of the location of dumping of the bottom ash of the thermal power plant. The area of Gopalnagar encompasses within 3-4 km of power plant. The farming land of Gopalnagar is also considerably losing by 2-3 % over the period of two years. The cultivable area of Khayanadhi (4-6Km) has no significant change due to location of outside of impact zone of flay ash. The circle Amulhanda is also suffering from losing arable land (2-3% by two years). The rest circles of Kolaghat block have not been influenced by the fly ash generated by the coal-burned power plant. But the changes in farming land of these circles are results of low demand, high prices of farming inputs, less market prices of crops' produces etc. The gap of cultivable land between inside and outside of impact zone of fly ash is becoming wider (9.63% in 2011 and 10.40% in 2015) with passage of time.

Table.1: Crop-wise land coverage within 4km and beyond it in the year 2011, 2013& 2015 of Kolaghat block

Name of crops	2011		2013				2015			
	<4km Area(ha)	>4km Area(ha)	<4km Area(ha)	% Change	>4km Area(ha)	% Change	<4km Area(ha)	% Change	>4km Area(ha)	% Change
Rice	1890	5391	1837	-2.804	5403	0.22	1798	-4.87	5386	-0.09
Wheat	3.7	8	2.1	-43.24	7	-12.5	1.2	-67.6	8.5	6.25
Maize	7	12	5.4	-22.86	11	-8.33	6.3	-10	14	16.67
Mustard	55	130	45	-18.18	125	-3.85	39	-29.1	132	1.54
Sesame	6	28	4.8	-20	30	7.14	5.5	-8.33	35	25
Jute	5	71	4.2	-16	73	2.82	4.5	-10	70	-1.41
Vegetables	445	1312	392	-11.91	1350	2.9	379	-14.8	1336	1.83
Flowers	806	1171	764	-5.21	1204	2.82	741	-8.06	1217	3.93
Pulses	105	377	92	-12.38	339	-10.1	71	-32.4	401	6.37
Spices	21	101	17	-19.1	123	21.8	22	4.76	148	46.53
Total	3343.7	8601	3163.5	-5.389	8665	0.74	3067.5	-8.26	8747.5	1.7

Cropping intensity (CI) is estimated from gross cultivated area throughout the year to net cultivated area multiplied by 100. The overall CIs of the block are 190.2 %, 185.3% and 177.9% in the years 2011, 2013 & 2015 respectively. The notable fall (181.3% to 166.8%) in CI has been observed during last four years (2011-2015) in the circles within 4 km from the KTPP whereas it has shifted from 195.15% to 183.6% beyond 4 km. This is due to adverse impact of fly ash coming out of power plant (Adak, *et al.*, 2016; Dasgupta, A. and Paul, S., 2011). The rest circles are losing the very little CI due to lesser margin in profit and high cost of cultivation. Maximum CI has been found in Siddha-II (222.69% in 2011, 210.7% in 2013 & 200.22% in 2015) in consequence of the fertile land, irrigation facility, community farming etc.

http://dx.doi.org/10.22161/ijeab/1.3.34 *ISSN: 2456-1878*

Table.2: Circle-wise Geographical Area, Cultivable Area, Cultivated Area & Irrigated Area- 2011

Circle's names	Total geographical area	Cultivable area	% of cultivable area to Total geographical area	Net cultivated area	Gross cultivated area	Cropping Intensity (%)	% of net area sown to cultivable area	Net irrigated area	Gross irrigated area	% of net irrigated area to net cultivated
Kola-I	405.428	322.457	79.53	287.165	517.542	180.2	89.06	251.43	498.251	87.55
Kola-II	1151.541	635.463	55.18	543.241	1012.341	186.4	85.49	516.13	927.582	95.01
Gopalnagar	1492.578	938.046	62.85	798.735	1427.478	178.7	85.15	759.47	1254.354	95.08
Sagarbarh	1040.979	908.055	87.23	813.916	1478.925	181.7	89.63	784.32	1264.254	96.36
Amulhanda	759.752	378.45	49.81	327.825	685.942	209.2	86.62	310.27	547.523	94.64
Pulsita	1118.15	854.69	76.44	687.498	1147.143	166.9	80.44	640.78	1075.951	93.21
Sub-total (<4km)	**5968.428**	**4037.161**	**67.64**	**3458.4**	**6269.371**	**181.3**	**85.66**	**3262**	**5567.915**	**94.33**
Baishnabchak	1245.124	829.854	66.65	726.463	1398.415	192.5	87.54	708.15	1191.589	97.48
Khayanadhi	1719.377	1333.858	77.58	1109.18	1991.957	179.6	83.16	1091.3	1737.892	98.39
Deriachak	1411.474	1150.684	81.52	1017.82	1896.358	186.3	88.45	923.45	1686.584	90.73
Bhogpur	1122.369	764.243	68.09	658.925	1109.546	168.4	86.22	511.93	1004.317	77.69
Siddha-I	1052.795	915.264	86.94	843.162	1782.421	211.4	92.12	819.31	1597.369	97.17
Siddha-II	1057.41	882.679	83.48	735.289	1637.427	222.7	83.3	721.98	1478.147	98.19
Brindabanchak	1903.533	1378.625	72.42	1231.27	2518.664	204.6	89.31	1176.4	2299.358	95.55
Sub-total (>4km)	**9512.082**	**7255.207**	**76.27**	**6322.1**	**12334.79**	**195.1**	**87.14**	**5953**	**10995.256**	**94.15**
Grand Total	15480.51	11292.368	72.95	9780.49	18604.159	190.2	86.61	9214.9	16563.171	94.22

Table.3. Circle-wise Geographical Area, Cultivable Area, Cultivated Area & Irrigated Area- 2013

Circle's names	*Total geographical area*	*Cultivable area*	*% of cultivable*	*Net cultivated area*	*Gross cultivated area*	*Cropping Intensity*	*% of net area sown*	*Net irrigated*	*Gross irrigated area*	*% of net irrigated area to net cultivated area*
Kola-I	*405.428*	*315.669*	*77.86*	*271.236*	*484.322*	*178.6*	*85.92*	*245.14*	*472.142*	*90.38*
Kola-II	*1151.541*	*618.6*	*53.72*	*534.715*	*982.234*	*183.7*	*86.44*	*509.43*	*929.854*	*95.27*
Gopalnagar	*1492.578*	*913.076*	*61.17*	*782.269*	*1357.425*	*173.5*	*85.67*	*751.29*	*1304.853*	*96.04*
Sagarbarh	*1040.979*	*903.076*	*86.75*	*801.624*	*1387.435*	*173.1*	*88.77*	*800.72*	*1301.365*	*99.89*
Amulhanda	*759.752*	*369.384*	*48.62*	*312.176*	*612.364*	*196.2*	*84.51*	*311.14*	*587.234*	*99.67*
Pulsita	*1118.15*	*850.027*	*76.02*	*675.925*	*1098.741*	*162.6*	*79.52*	*670.26*	*1098.327*	*99.16*
Sub-total (<4km)	***5968.428***	***3969.832***	***66.51***	***3377.9***	***5922.521***	***175.3***	***85.09***	***3288***	***5693.775***	***97.34***
Baishnabchak	*1245.124*	*825.899*	*66.33*	*710.724*	*1348.407*	*189.7*	*86.05*	*701.4*	*1295.357*	*98.69*
Khayanadhi	*1719.377*	*1319.31*	*76.73*	*1093.2*	*1897.246*	*173.6*	*82.86*	*1087.7*	*1773.852*	*99.5*
Deriachak	*1411.474*	*1141.024*	*80.84*	*1023.9*	*1874.921*	*183.1*	*89.73*	*948.76*	*1711.457*	*92.66*
Bhogpur	*1122.369*	*754.476*	*67.22*	*742.198*	*1214.216*	*163.6*	*98.37*	*541.3*	*1035.841*	*72.93*
Siddha-I	*1052.795*	*916.109*	*87.02*	*845.734*	*1767.357*	*209*	*92.32*	*832.63*	*1623.732*	*98.45*
Siddha-II	*1057.41*	*879.351*	*83.16*	*852.298*	*1795.784*	*210.7*	*96.92*	*728.13*	*1534.876*	*85.43*
Brindabanchak	*1903.533*	*1363.389*	*71.62*	*1213.14*	*2451.957*	*202.1*	*88.98*	*1184.8*	*2332.258*	*97.66*
Sub-total (>4km)	***9512.082***	***7199.558***	***75.69***	***6481.2***	***12349.89***	***190.5***	***90.02***	***6025***	***11307.373***	***92.96***
Grand Total	*15480.51*	*11169.39*	*72.15*	*9859.13*	*18272.409*	*185.3*	*88.27*	*9312.7*	*17001.148*	*94.46*

http://dx.doi.org/10.22161/ijeab/1.3.34 *ISSN: 2456-1878*

The decrease in gross cultivated land has been experienced in the areas within the distance of 4 km from KTPP. Fly ash is affecting the agriculture of these circles. Gross irrigated area has increased to some extent. Percentage of irrigated area has got enhanced due to uses of water lifting pumps, water carrying pipes procured from government scheme of farm mechanization or personally purchased. All the circles of the Kolaghat block are having the irrigation facility in more than 90% of the cultivated land except Bhogpur (76.6% in 2015) and Siddha-II (87.88% in2015) which are situated in >4km.

Table.4. Circle-wise Geographical Area, Cultivable Area, Cultivated Area & Irrigated Area- 2015

Circle's names	Total geographical area	Cultivable area	% of cultivable area to Total geographical area	Net cultivated area	Gross cultivated area	Cropping Intensity (%)	% of net area sown to cultivable area	Net irrigated area	Gross irrigated area	% of net irrigated area to net cultivated area
Kola-I	405.428	311.617	76.86	253.745	413.254	162.9	81.43	238.44	395.214	93.97
Kola-II	1151.541	602.522	52.32	521.263	907.365	174.1	86.51	501.29	885.367	96.17
Gopalnagar	1492.578	900.105	60.31	770.149	1280.341	166.2	85.56	756.13	1207.451	98.18
Sagarbarh	1040.979	898.105	86.28	785.764	1347.475	171.5	87.49	706.74	1285.214	89.94
Amulhanda	759.752	359.674	47.34	321.536	558.347	173.6	89.4	316.63	513.564	98.47
Pulsita	1118.15	838.37	74.98	671.239	1037.367	154.5	80.06	665.24	1002.372	99.11
Sub-total(<4km)	**5968.428**	**3910.393**	**65.52**	**3323.7**	**5544.149**	**166.8**	**85**	**3184**	**5289.182**	**95.81**
Baishnabchak	1245.124	810.079	65.06	705.625	1291.478	183	87.11	700.21	1217.258	99.23
Khayanadhi	1719.377	1312.036	76.31	1132.43	1897.189	167.5	86.31	1083.9	1726.964	95.72
Deriachak	1411.474	1136.194	80.5	1053.46	1783.152	169.3	92.72	962.78	1702.861	91.39
Bhogpur	1122.369	747.965	66.64	726.235	1287.068	177.2	97.09	556.3	1128.345	76.6
Siddha-I	1052.795	910.353	86.47	851.924	1684.254	197.7	93.58	840.73	1614.863	98.69
Siddha-II	1057.41	874.359	82.69	855.839	1713.546	200.2	97.88	752.13	1587.139	87.88
Brindabanchak	1903.533	1354.295	71.15	1224.2	2368.412	193.5	90.39	1196.3	2346.275	97.72
Sub-total(>4km)	**9512.082**	**7145.281**	**75.12**	**6549.7**	**12025.1**	**183.6**	**91.66**	**6092**	**11323.705**	**93.02**
Grand Total	15480.51	11055.674	71.42	9873.4	17569.248	177.9	89.31	9276.8	16612.887	93.96

3.3. Effect of fly ash on Land use pattern change:

The surrounding areas (<4km) of Kolaghat thermal power plant significantly and gradually have been turning to non-agricultural land after installation of Kolaghat thermal power plant (Table 5). Kola-I had the arable land of 82.971 hectare in 2011 and in 2015 it has been observed that 3.36% has lost. The farming area of Kola-II also has been reduced by 5.18% in four years (2011-2015). But the nature of change is fluctuating. The farming community turns the no crops' lands to cultivated land when they perceive the profitable return from cultivation and also are being encouraged by the several schemes of agricultural department or NGOs with funds support or inputs supply free of cost. Usually the trends depict that the agricultural land has been left more unseeded in the adjacent areas of Kolaghat thermal power plant. The circles within 4 km from power plant i.e. Kola-I, Kola-II, Gopalnagar Pulsita, Amulhanda have been changing the pattern of land use by -1.096% to -5.18 % in 2015 from 2011. Land-cover modification is frequently caused by changes in the management of agricultural land use (Lambin, *et al.*, 2000). Agricultural land in the alarming zones of fly ash is being turned to fallow area, habitation & transport of increasing population or converted to water bodies in the Kolaghat block.

http://dx.doi.org/10.22161/ijeab/1.3.34 *ISSN: 2456-1878*

Table.5: Circle –wise conversion agricultural land to non- agricultural land & change percentage year –wise

Circle's name (hectare)	Land area	2011	2013		2015	
		Area(ha)		%change	Area(ha)	%change
Kola-I (405.428)	Non- agricultural	82.971	89.759	8.181	93.811	13.065
	Agricultural	322.457	315.669	-2.105	311.617	-3.362
Kola-II (1151.541)	Non-agricultural	516.078	532.941	3.268	549.019	6.3829
	Agricultural	635.463	618.6	-2.654	602.522	-5.184
Gopalnagar (1492.578)	Non-agricultural	554.532	579.502	4.503	592.473	6.842
	Agricultural	938.046	913.076	-2.662	900.105	-4.045
Pulsita (1118.15)	Non-agricultural	263.46	268.123	1.77	279.78	6.1945
	Agricultural	854.69	850.027	-0.546	838.37	-1.909
Sagarbarh (1040.979)	Non-agricultural	132.924	137.903	3.746	142.874	7.4855
	Agricultural	908.055	903.076	-0.548	898.105	-1.096
Amalhanda (759.752)	Non-agricultural	381.302	390.368	2.378	400.078	4.9242
	Agricultural	378.45	369.384	-2.396	359.674	-4.961
Sub Total(<4km) (5968.428)	**Non-agricultural**	**2217.83**	**2289.617**	**3.237**	**2357.469**	**6.2962**
	Agricultural	**4037.161**	**3969.832**	**-1.668**	**3910.393**	**-3.14**
Baishnabchak (1245.124)	Non-agricultural	415.27	419.225	0.952	435.045	4.762
	Agricultural	829.854	825.899	-0.477	810.079	-2.383
Khanyadihi (1719.377)	Non-agricultural	385.519	400.067	3.774	407.341	5.6604
	Agricultural	1333.858	1319.31	-1.091	1312.036	-1.636
Deriachak (1411.474)	Non-agricultural	260.79	270.45	3.704	275.28	5.5562
	Agricultural	1150.684	1141.024	-0.84	1136.194	-1.259
Bhogpur (1122.369)	Non-agricultural	358.126	367.893	2.727	374.404	4.5453
	Agricultural	764.243	754.476	-1.278	747.965	-2.13
Siddha-I (1052.795)	Non-agricultural	137.531	136.686	-0.614	142.442	3.5708
	Agricultural	915.264	916.109	0.092	910.353	-0.537
Siddha-II (1057.41)	Non-agricultural	174.731	178.059	1.905	183.051	4.7616
	Agricultural	882.679	879.351	-0.377	874.359	-0.943
Brindabanchak (1903.533)	Non-agricultural	524.908	540.144	2.903	549.238	4.6351
	Agricultural	1378.625	1363.389	-1.105	1354.295	-1.765
Sub Total(>4km) (9512.082)	**Non-agricultural**	**2256.875**	**2312.524**	**2.466**	**1117.666**	**-50.48**
	Agricultural	**7255.207**	**7199.558**	**-0.767**	**7145.281**	**-1.515**
Total area (15480.51)	Non-agricultural	4188.142	4311.12	2.936	4424.836	5.6515
	Agricultural	11292.368	11169.39	-1.089	11055.674	-2.141

. The land use types have got little bit of decrease (0.943% to 2.383% over last four years) in the circles which are outside of 4 km distant from KTPP due to habitation, road construction, non profitable agriculture etc (Fig.2). It leads to potential threat to agricultural production due to the constant loss of arable land (Masek *et al.*, 2000 and Ji, *et al.*, 2001). Maximum decrease (5.18%) of land use type has been observed in Kola-II. It is ascertained that fly ash is affecting the land use pattern of the surrounding areas of Kolaghat thermal power plant. As a result the agricultural land has lost 3.14% (<4km) and 1.515% (>4km) reflecting nearly double drip. Rate of

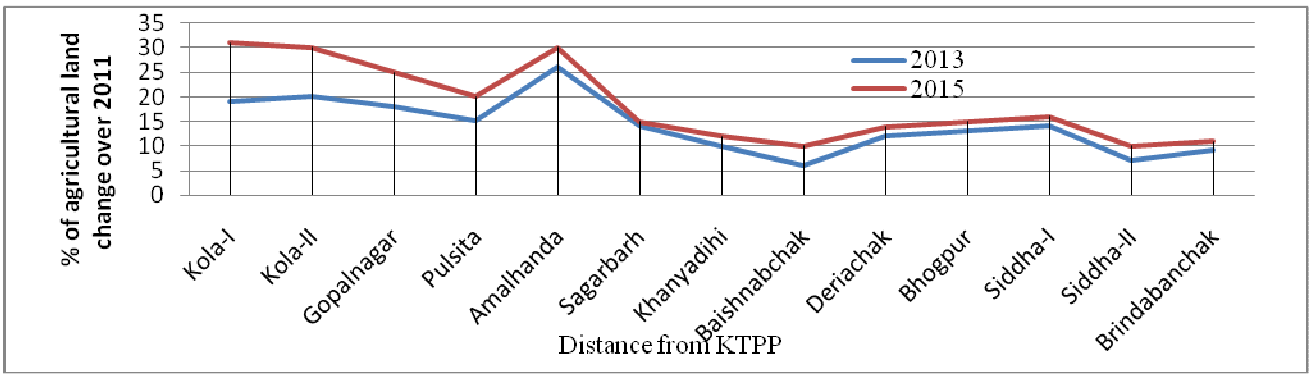

Fig.2: Decrease in agricultural land with passage of time (2011-2015) and distance (km) from KTPP

http://dx.doi.org/10.22161/ijeab/1.3.34 *ISSN: 2456-1878*

transformation (13.06% over last four years) to Non-arable land has been found highest in Kola-I which is very closer to the power plant and ash ponds are situated in this circle. During transportation to the ponds, ashes start spreading around the area of travelling of vehicles. Overall land use pattern of Kolaghat block has changed from arable to non-agricultural land by 2.141% in four years (2011-2015).

4. Recommendation:

The Kolaghat Thermal power plant authority should adopt the emerging technology to minimize the emission of fly ash from the chimneys. During disposal and transportation of bottom ash, care should be taken in order to reduce the spreading of ash on the ways. The KTPP authority should arrange the plantation of suitable trees in the surroundings and encourage the planting programme on regular basis. They may conduct impact assessment of fly ash at the adjacent areas in reasonable interval. On the basis of evaluated impact of fly ash, site specific cropping pattern, crop suitability, alternative land use pattern, potential crop selectivity etc should be adopted. The proper and sustainable agricultural practices would be exercised as per localized need based approaches. Organic farming system and precision agriculture can be run to abate the effect of the alkaline nature of fly ash. Detailed evaluation of land capability, site –specific suitability, land irrigability and crop selectivity may be conducted to find out the best possible uses of land in the affected area of KTPP. The evaluation of crop suitability around the KTPP (conducted by Adak *et al.*, 2016*)* can be followed to utilize the land properly in order to sustain the agriculture in the rural areas around the KTPP.

IV. CONCLUSION

Fly ash emitting from Kolaghat thermal power plant considerably has been affecting the surrounding area (<4km) under different crops. Conversion of agricultural land to non – arable is alarming for sustainable agriculture. Cropping intensity which indicates the yearly repetition of crop farming upon net cultivable land has been dropping gradually. The present study reveals that the fly ash has been reducing the crop growing potentiality of the adjacent areas. The rest circles (>4km) of Kolaghat block have no or very little bit of impact of fly ash or gradually effect has been deceasing with increase of distance from KTPP. Site- specific resources and problem management as well as precision farming should be adopted for agricultural sustainability and improvement of socio-economic condition of the fly ash affected area.

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 assistance for conducting our research work.

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