

Table of Contents

Chapter	Title	Page No.
1	Introduction	1-3
2	Methodology	4-8
	2.1. Data Used	4
	2.2. Methodology	6
	2.3. Study area	8
3	Results	9-106
	3.1. District-wise Daily Fire Events in Punjab	9-83
	3.2. Estimation of area under residue burning 2015	84-95
	3.3. Date-wise fire events in districts of Punjab	96-103
	3.4. Impact of biomass power plants over residue burning	104-106
4	Comparison of active fire events between 2014 and 2015	107-124
	4.1. District-wise Daily Fire Events Comparison between 2014 and 2015 for the period from 15 October to 15 November	107-124
5	Discussion	125-134
	5.1. Paddy Stubble Burning: Why Farmers do it?	125
	5.2. Implications of stubble burning	125-127
	5.3. Technologies available to handle paddy stubble	128-129
	5.4. Alternative uses of straw	129-133
	5.5. Role and policies of Government	133-134
6	Conclusion	135-138
	References	139-140

LIST OF FIGURES

Fig. No.	Description	Page No.
2.1	Methodology flowchart	7
3.1	Active fire points overlaid on MODIS satellite imagery of 15-Oct-2015	9
3.2	District-wise fire events captured in Punjab on 15-Oct-2015	10
3.3	Active fire points overlaid on MODIS satellite imagery of 16-Oct-2015	11
3.4	District-wise fire events captured in Punjab on 16-Oct-2015	12
3.5	Active fire points overlaid on MODIS satellite imagery of 17-Oct-2015	13
3.6	District-wise fire events captured in Punjab on 17-Oct-2015	14
3.7	Active fire points overlaid on MODIS satellite imagery of 18-Oct-2015	15
3.8	District-wise fire events captured in Punjab on 18-Oct-2015	16
3.9	Active fire points overlaid on MODIS satellite imagery of 19-Oct-2015	17
3.10	District-wise fire events captured in Punjab on 19-Oct-2015	18
3.11	Active fire points overlaid on MODIS satellite imagery of 20-Oct-2015	19
3.12	District-wise fire events captured in Punjab on 20-Oct-2015	20
3.13	Active fire points overlaid on MODIS satellite imagery of 21-Oct-2015	21
3.14	District-wise fire events captured in Punjab on 21-Oct-2015	22
3.15	Active fire points overlaid on MODIS satellite imagery of 22-Oct-2015	23
3.16	District-wise fire events captured in Punjab on 22-Oct-2015	24
3.17	Active fire points overlaid on MODIS satellite imagery of 23-Oct-2015	25
3.18	District-wise fire events captured in Punjab on 23-Oct-2015	26
3.19	Active fire points overlaid on MODIS satellite imagery of 24-Oct-2015	27
3.20	District-wise fire events captured in Punjab on 24-Oct-2015	28
3.21	Active fire points overlaid on MODIS satellite imagery of 25-Oct-2015	29
3.22	District-wise fire events captured in Punjab on 25-Oct-2015	30
3.23	Active fire points overlaid on MODIS satellite imagery of 26-Oct-2015	31
3.24	District-wise fire events captured in Punjab on 26-Oct-2015	32
3.25	Active fire points overlaid on MODIS satellite imagery of 27-Oct-2015	33
3.26	District-wise fire events captured in Punjab on 27-Oct-2015	34
3.27	Active fire points overlaid on MODIS satellite imagery of 28-Oct-2015	35
3.28	District-wise fire events captured in Punjab on 28-Oct-2015	36
3.29	Active fire points overlaid on MODIS satellite imagery of 29-Oct-2015	37
3.30	District-wise fire events captured in Punjab on 29-Oct-2015	38
3.31	Active fire points overlaid on MODIS satellite imagery of 30-Oct-2015	39
3.32	District-wise fire events captured in Punjab on 30-Oct-2015	40
3.33	Active fire points overlaid on MODIS satellite imagery of 31-Oct-2015	41
3.34	District-wise fire events captured in Punjab on 31-Oct-2015	42
3.35	Active fire points overlaid on MODIS satellite imagery of 01-Nov-2015	43
3.36	District-wise fire events captured in Punjab on 01-Nov-2015	44
3.37	Active fire points overlaid on MODIS satellite imagery of 02-Nov-2015	45
3.38	District-wise fire events captured in Punjab on 02-Nov-2015	46
3.39	Active fire points overlaid on MODIS satellite imagery of 03-Nov-2015	47
3.40	District-wise fire events captured in Punjab on 03-Nov-2015	48

3.41	Active fire points overlaid on MODIS satellite imagery of 04-Nov-2015	49
3.42	District-wise fire events captured in Punjab on 04-Nov-2015	50
3.43	Active fire points overlaid on MODIS satellite imagery of 05-Nov-2015	51
3.44	District-wise fire events captured in Punjab on 05-Nov-2015	52
3.45	Active fire points overlaid on MODIS satellite imagery of 06-Nov-2015	53
3.46	District-wise fire events captured in Punjab on 06-Nov-2015	54
3.47	Active fire points overlaid on MODIS satellite imagery of 07-Nov-2015	55
3.48	District-wise fire events captured in Punjab on 07-Nov-2015	56
3.49	Active fire points overlaid on MODIS satellite imagery of 08-Nov-2015	57
3.50	District-wise fire events captured in Punjab on 08-Nov-2015	58
3.51	Active fire points overlaid on MODIS satellite imagery of 09-Nov-2015	59
3.52	District-wise fire events captured in Punjab on 09-Nov-2015	60
3.53	Active fire points overlaid on MODIS satellite imagery of 10-Nov-2015	61
3.54	District-wise fire events captured in Punjab on 10-Nov-2015	62
3.55	Active fire points overlaid on MODIS satellite imagery of 11-Nov-2015	63
3.56	District-wise fire events captured in Punjab on 11-Nov-2015	64
3.57	Active fire points overlaid on MODIS satellite imagery of 12-Nov-2015	65
3.58	District-wise fire events captured in Punjab on 12-Nov-2015	66
3.59	Active fire points overlaid on MODIS satellite imagery of 13-Nov-2015	67
3.60	District-wise fire events captured in Punjab on 13-Nov-2015	68
3.61	Active fire points overlaid on MODIS satellite imagery of 14-Nov-2015	69
3.62	District-wise fire events captured in Punjab on 14-Nov-2015	70
3.63	Active fire points overlaid on MODIS satellite imagery of 15-Nov-2015	71
3.64	District-wise fire events captured in Punjab on 15-Nov-2015.	72
3.65	Active fire points overlaid on MODIS satellite imagery of 16-Nov-2015	73
3.66	District-wise fire events captured in Punjab on 16-Nov-2015	74
3.67	Active fire points overlaid on MODIS satellite imagery of 17-Nov-2015	75
3.68	District-wise fire events captured in Punjab on 17-Nov-2015.	76
3.69	Active fire points overlaid on MODIS satellite imagery of 18-Nov-2015	77
3.70	District-wise fire events captured in Punjab on 18-Nov-2015.	78
3.71	District-wise fire events captured in Punjab from 15-Oct-2015 to 15-Nov-2015.	79
3.72	Five weeks comparison of fire events captured in Punjab from 15-Oct-2015 to 18-Nov-2015.	81
3.73	Pie chart depicting percentage of fire counts in different regions of Punjab	82
3.74	Number of fire events in Pathankot 15-Oct to 15 Nov-2015	96
3.75	Number of fire events in Gurdaspur 15-Oct to 15 Nov-2015	96
3.76	Number of fire events in Amritsar 15-Oct to 15 Nov-2015	96
3.77	Number of fire events in Tarn Taran 15-Oct to 15 Nov-2015	97
3.78	Number of fire events in Hoshiarpur 15-Oct to 15 Nov-2015	97
3.79	Number of fire events in Jalandhar 15-Oct to 15 Nov-2015	97
3.80	Number of fire events in Kapurthala 15-Oct to 15 Nov-2015	98
3.81	Number of fire events in SBS Nagar 15-Oct to 15 Nov-2015	98
3.82	Number of fire events in Rupnagar 15-Oct to 15 Nov-2015	98
3.83	Number of fire events in SAS Nagar 15-Oct to 15 Nov-2015	99
3.84	Number of fire events in Patiala 15-Oct to 15 Nov-2015	99

3.85	Number of fire events in Fatehgarh Sahib 15-Oct to 15 Nov-2015	99
3.86	Number of fire events in Ludhiana 15-Oct to 15 Nov-2015	100
3.87	Number of fire events in Sangrur 15-Oct to 15 Nov-2015	100
3.88	Number of fire events in Barnala 15-Oct to 15 Nov-2015	100
3.89	Number of fire events in Moga 15-Oct to 15 Nov-2015	101
3.90	Number of fire events in Fridkot 15-Oct to 15 Nov-2015	101
3.91	Number of fire events in Firozpur 15-Oct to 15 Nov-2015	101
3.92	Number of fire events in Fazilka 15-Oct to 15 Nov-2015	102
3.93	Number of fire events in Muktsar 15-Oct to 15 Nov-2015	102
3.94	Number of fire events in Bathinda 15-Oct to 15 Nov-2015	102
3.95	Number of fire events in Mansa 15-Oct to 15 Nov-2015	103
3.96	Number of fire events in Punjab 15-Oct to 15 Nov-2015	103
4.1	District-wise comparison of fire events captured in Punjab on 15-Oct-2014 & 15	107
4.2	District-wise comparison of fire events captured in Punjab on 16-Oct-2014 & 15	107
4.3	District-wise comparison of fire events captured in Punjab on 17-Oct-2014 & 15	108
4.4	District-wise comparison of fire events captured in Punjab on 18-Oct-2014 & 15	108
4.5	District-wise comparison of fire events captured in Punjab on 19-Oct-2014 & 15	109
4.6	District-wise comparison of fire events captured in Punjab on 20-Oct-2014 & 15	109
4.7	District-wise comparison of fire events captured in Punjab on 21-Oct-2014 & 15	110
4.8	District-wise comparison of fire events captured in Punjab on 22-Oct-2014 & 15	110
4.9	District-wise comparison of fire events captured in Punjab on 23-Oct-2014 & 15	111
4.10	District-wise comparison of fire events captured in Punjab on 24-Oct-2014 & 15	111
4.11	District-wise comparison of fire events captured in Punjab on 25-Oct-2014 & 15	112
4.12	District-wise comparison of fire events captured in Punjab on 26-Oct-2014 & 15	112
4.13	District-wise comparison of fire events captured in Punjab on 27-Oct-2014 & 15	113
4.14	District-wise comparison of fire events captured in Punjab on 28-Oct-2014 & 15	113
4.15	District-wise comparison of fire events captured in Punjab on 29-Oct-2014 & 15	114
4.16	District-wise comparison of fire events captured in Punjab on 30-Oct-2014 & 15	114
4.17	District-wise comparison of fire events captured in Punjab on 31-Oct-2014 & 15	115
4.18	District-wise comparison of fire events captured in Punjab on 01-Nov-2014 & 15	115
4.19	District-wise comparison of fire events captured in Punjab on 02-Nov-2014 & 15	116
4.20	District-wise comparison of fire events captured in Punjab on 03-Nov-2014 & 15	116
4.21	District-wise comparison of fire events captured in Punjab on 04-Nov-2014 & 15	117
4.22	District-wise comparison of fire events captured in Punjab on 05-Nov-2014 & 15	117
4.23	District-wise comparison of fire events captured in Punjab on 06-Nov-2014 & 15	118
4.24	District-wise comparison of fire events captured in Punjab on 07-Nov-2014 & 15	118
4.25	District-wise comparison of fire events captured in Punjab on 08-Nov-2014 & 15	119
4.26	District-wise comparison of fire events captured in Punjab on 09-Nov-2014 & 15	119
4.27	District-wise comparison of fire events captured in Punjab on 10-Nov-2014 & 15	120
4.28	District-wise comparison of fire events captured in Punjab on 11-Nov-2014 & 15	120
4.29	District-wise comparison of fire events captured in Punjab on 12-Nov-2014 & 15	121
4.30	District-wise comparison of fire events captured in Punjab on 13-Nov-2014 & 15	121
4.31	District-wise comparison of fire events captured in Punjab on 14-Nov-2014 & 15	122
4.32	District-wise comparison of fire events captured in Punjab on 15-Nov-2014 & 15	122
4.33	District-wise comparison of fire events captured in Punjab from 15-Oct to 15-	123

	Nov 2014 & 2015	
4.34	Weekly comparison of fire events captured in Punjab from 15-Oct to 15-Nov 2014 & 2015	123
4.35	Overall comparison of fire events captured in Punjab from 15-Oct to 15-Nov 2014 & 2015	124
4.36	Interactive (additive) effects of Crop Residue burning in relation to Greenhouse gases (GHG) loading in the atmosphere (Source: Teodoro & Roger 1999).	126

LIST OF MAPS

Map No.	Description	Page No.
2.1	Study area – Punjab State	8
3.1	Active fire locations detected by MODIS in Punjab from 15-Oct-2015 to 15-Nov-2015.	80
3.2	Fire event density map of Punjab for the period from 15-Oct-2015 to 15-Nov-2015.	83
3.3	Classified burnt area in Punjab from satellite data during the period of 15-Oct to 15-Nov-2015.	84
3.4	Identified burnt area in Punjab using IRS R2 AWiFS data, 18 October 2015.	86
3.5	Identified burnt area in Punjab using IRS R2 AWiFS data, 22 October 2015.	86
3.6	Identified burnt area in Punjab using IRS R2 AWiFS data, 27 October 2015.	87
3.7	Identified burnt area in Punjab using IRS R2 AWiFS data, 1 November 2015.	87
3.8	Identified burnt area in Punjab using IRS R2 AWiFS data, 6 November 2015.	88
3.9	Identified burnt area in Punjab using IRS R2 LISS-III data, 18 October 2015, Path/Row-095/049 and 095/050	88
3.10	Identified burnt area in Punjab using IRS R2 LISS-III data, 27 October 2015, Path/Row-092/049.	89
3.11	Identified burnt area in Punjab using IRS R2 LISS-III data, 1 November 2015, Path/Row-095/049 and 095/050.	89
3.12	Identified burnt area in Punjab using IRS R2 LISS-III data, 20 November 2015, Path/Row-092/049.	89
3.13	Location of active fire and burnt area patches as seen on 6 th November 2015 through LISS-IV	90
3.14	Classified burnt area in Punjab from satellite data during the period of 15-Oct to 15-Nov-2015 with overlaid ground truth points.	91
3.15	Validation of classified burnt area through ground truth points in (a) Fatehgarh Sahib, (b) Sangrur, (c) Moga, (d) Patiala, (e) Kapurthala, (f) Firozpur, (g) Bathinda and (h) Ludhiana.	92-95
3.16	Impacts of Biomass Power Plants over residue burning	104
3.17	Impacts of Biomass Power Plants over residue burning- Muktsar and Fazilka	105
3.18	Impacts of Biomass Power Plants over residue burning- Mnasa	105
3.19	Impacts of Biomass Power Plants over residue burning- Patiala	106
3.20	Impacts of Biomass Power Plants over residue burning- Hoshiarpur and Jalandhar	106

LIST OF TABLES

Table No.	Description	Page No.
2.1	Data used for burnt area estimation in Punjab	4-5
3.1	Districtwise area under residue burning 2014 & 2015	85