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Regional characteristics of stubble burning in Punjab, India and the effect of the COVID-19 lockdown

by

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About the Aakash Working Papers

These working papers are based on the work of the Aakash Project at the Research Institute for Humanity and Nature (RIHN), Kyoto, Japan.

This study addresses air pollution caused by the large-scale post-harvest burning of rice straw in October and November in the Indian states of Punjab and Haryana. The burning results in severe air pollution in the areas around it, affecting public health and the well-being of hundreds of millions of people. Therefore, the Aakash project aims to encourage the social change needed to keep air clean, improve public health, and develop sustainable agriculture in northwestern India.

The aim of this series is to share the initial findings and lessons learned from the research studies conducted by the Aakash project. By sharing new knowledge in a prompt manner, we will be able to identify complexities and develop solutions faster than if this was not done. In addition, reporting detailed information and data that cannot be presented in a general paper will create new areas of knowledge. We hope that the publication of this series will stimulate discussion among project members and facilitate communication with academic and general stakeholders outside the project.

Preface

The Aakash Project, which started in 2017 as an incubation study of the Research Institute for Humanity and Nature, was adopted after a 2-year feasibility study period, and completed its pre-research activities in 2019. In April 2020, the project commenced full research activities. At that time, the coronavirus disease 2019 (COVID-19) pandemic emerged and the international movement of people was restricted to prevent the spread of the coronavirus. As such, travel between India and Japan was halted. Many of the project members from Japan were planning to visit India for research activities, but all of these visits were cancelled. This was a major set-back for our project.

However, a strong bond developed between the Indian and Japanese members of the team throughout the period leading up to full research activities. In 2020, when the Japanese members of the team were unable to travel to India, the Centers for International Projects Trust, a Punjab-based nongovernmental organization, took on the responsibility of conducting a questionnaire survey. Some of the results of this survey are reported in this first issue of the Aakash working paper.

In this report, we present the results of an analysis of the differences in rice straw burning between 2019 and 2020 from various perspectives. This is a rare study that captured the effect of the COVID-19 pandemic. The pandemic was an unexpected event for us, but it is noteworthy that we were able to obtain valuable data at a time of great social change.

I would like to express my sincere thanks to our colleagues in India for making this research possible. I am also pleased to publish this first issue of the Aakash Working Paper Series as a testament to the bonds that bind us all. We hope that this working paper series will continue to stimulate debate among members of the Aakash Project and among external academics and stakeholders.

March 2022

Sachiko Hayashida, Professor, Dr. Sci.
Aakash project leader
Research Institute for Humanity and Nature

Regional characteristics of stubble burning in Punjab, India and the effect of the COVID-19 lockdown

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Abstract

Air pollution caused by stubble burning has become an increasing problem in Northern India during the past decade, with no effective solution yet to be found. In this study, to understand the current situation in Punjab, a village-level questionnaire survey was conducted in 129 villages across 12 districts from January to February 2021. The stubble burning area estimated from the survey was compared with fire detection counts and fire radiative power data obtained from satellite observations. The regional characteristics of stubble burning and the effect of the COVID-19 lockdown were also examined in terms of transplanting and harvesting dates, shift to direct-seeded rice and the machine transplantation of rice. The findings revealed north–south differences in agricultural practices as well as stubble burning within the state. The interval between the kharif and rabi crops remained the same or was shorter in 2020, resulting in an increase in stubble burning in some villages. The impact of the COVID-19 lockdown on stubble burning was negligible, except in villages near large cities where labour shortages were particularly apparent.

Keywords: stubble burning, air pollution, satellite observation, labour shortage, COVID-19

Introduction

In Northern India, air pollution caused by stubble burning was first observed during the 1980s following the establishment of rice and wheat double cropping systems. Since then, air pollution has become increasingly apparent, especially with the implementation of The Punjab Preservation of Subsoil Water Act in 2009 (Balwinder-Singh et al. 2019). To address the problem, the state and the central governments introduced both in-situ and ex-situ management practices, such as the provision of new and subsidized machinery for crop residue management and alternative use of straw as bio-fuel energy (Shyamsundar et al. 2019). However, despite these measures, no effective solution has yet been achieved. According to a recent report by the Punjab Pollution Control Board (PPCB), cases of stubble burning in Punjab from satellite observations were higher in autumn of 2020 than in the previous three years (51,703 in 2018, 52,790 in 2019, and 76,590 in 2020; The Tribune 2020, November 28).

Meanwhile, the outbreak of the coronavirus disease 2019 (COVID-19) and the subsequent nationwide lockdown (March 25-May 31, 2020) had various effects on agricultural practices, notably rice transplanting during the kharif season (rainy season during June to September). More than 95% of rice-growing regions in India are dependent on manual labour for crop establishment, and therefore, the serious labour shortages caused by the COVID-19 lockdown, which triggered mass reverse migration from the northwestern states of Haryana and Punjab (Balwinder-Singh et al. 2020), had a significant effect across much of Northern India (The Tribune 2020, May 5; Vatta et al. 2021). In addition, new farming laws implemented in September 2020 resulted in further tensions and subsequent protests. These laws, the Farmers' Produce Trade and Commerce (Promotion and Facilitation) Bill (2020), the Farmers (Empowerment and Protection) Agreement on Price Assurance and Farm Services Bill (2020), and the Essential Commodities (Amendment) Bill (2020), allowed private firms to direct trade with local farmers, potentially undermining the existing Minimum Support Price (MSP) regime in Punjab (The Tribune 2020, September 22). The resulting protests against the central government continued for more than a year, ending in November 2021.There was considerable reluctance to cooperate with the stubble burning initiatives during that time.

Many previous studies and the PPCB have used satellite observations to identify regions of stubble burning; however, the limitations of satellite data have been previously reported (Liu et al 2020). For example, in Punjab, these observations are carried out for only a few hours per day (twice daily), and local farmers tend to carry out their burning practices by avoiding the time of satellite observations. In this region, satellite data is limited, and the lack of accurate information on the location and degree of burning hinder the implementation of effective control measures.

Another limitation is that despite understanding the adverse effects of stubble burning, individual farmers are often reluctant to reveal their own practices due to a fear of government penalties. Local governments implement fines of Rs 2,500 for offending farmers with up to two acres, Rs 5,000 for those with between two and five acres, and Rs 15,000 for those with more than five acres (The Tribune 2019, October 29). As a result, obtaining reliable information from individual farmers is difficult, further hindering any detailed understanding of the geographical locations and extent of stubble burning.

In this study, we conducted a village-level questionnaire survey of crop residue management in 129 villages across the state of Punjab to examine the current status of stubble burning. Regional characteristics of stubble burning across the state were determined, as well as the effect of the COVID-19 lockdown on the resulting agricultural practices in 2020.

Methodology and the Study area

The questionnaire survey was completed from January to February of 2021, by the Centers for International Projects Trust (CIPT), a New Delhi-based NPO. The survey data was obtained from village representatives conversant in local agricultural practices, agricultural extension officials, and the Primary Agricultural Cooperative Societies (PACSs). The questionnaire explored village-level information on rice cultivation during the kharif season, and wheat and potato cultivation during the rabi season of 2019/20 and 2020/21.

The survey covered a total of 129 study villages across 12 districts in Punjab (48 in Amritsar; 47 in Ludhiana; 19 in Moga; 3 in Gurdaspur; 2 each in Bathinda, Fazilka, Hoshiarpur, and Muktsar; and 1 each in Barnala, Faridkot, Mansa, and SBS Nagar). However, as the survey was conducted within a limited period of only two months, we could not ensure even distribution of the study villages and these were mainly concentrated in the districts of Amritsar, Ludhiana, and Moga, with a few in the north- and south-western districts.

The characteristics of the 129 villages were compared with the 2011 Census data as shown in Table 1. The average geographical area of the study villages was 1,682 acres (state average: 981 acres), with an average of 431 households (state average: 267 households), and an average population of 2,248 individuals (state average: 1,379 individuals). The average cultivation area per farming household was 7.0 acres (state average: 8.9 acres), and the average ratio of cultivator to total worker was 36.1% (state average 32.4%), and that of agricultural labourers to total workers was 21.3% (state average: 21.2%). In summary, the study villages were larger in size, with more population and number of households compared with the state average, although the average farm size was smaller.

Table 1. Characteristics of the study villages

Geographical area	No. of villages
below 500 acres	21
500–1000 acres	30
1000–2000 acres	30
2000–3000 acres	11
3000 acres or above	21
Average: 1682 acres	

Village population	No. of villages
below 1000	34
1000–2000	39
2000–3000	18
3000–4000	19
4000–5000	9
5000 or above	10
Average: 2248 individuals	

No. of Households (HH)	No. of villages
below 100	16
100–200	22
200–300	22
300–400	15
400–500	12
500–750	22
750–1000	10
1000 or above	10
Average: 431 HH	

Cultivation area per Farm HH	No. of villages
below 2.0 acres	4
2.0–4.0 acres	25
4.0–6.0 acres	35
6.0–8.0 acres	25
8.0–10.0 acres	14
10.0 acres or above	26
Average: 7.0 acres/ HH	

Cultivator/Total worker	No. of villages
below 20 %	16
20–40 %	64
40–60 %	41
60 % or above	8
Average: 36.1 %	

Agricultural Labour/Total worker	No. of villages
below 20 %	72
20–40 %	43
40–60 %	13
60 % or above	1
Average: 21.3 %	

Results and Discussion

Area under rice cultivation

The cultivation area of rice is not uniform across the state. In general, two types of rice are grown in Punjab: basmati and non-basmati varieties (paddy varieties). Basmati varieties, which have superior cooking and eating characteristics, are produced in areas with a relatively cooler temperature, even though rice crops tend to be better suited to regions with a high temperature and high humidity (Mahal and Kaur 2021). Within Punjab, basmati is generally grown in more northern regions (Majha), while non-basmati varieties are grown in central and southern regions (Malwa) (Figure 1). However, basmati is also grown in some villages in the southwest. In line with this, the extent and geographical pattern of stubble burning across the state may be related to differences in growth characteristics between basmati and non-basmati rice, such as growth duration and plant height.

Changes in agricultural practices from 2019 to 2020

The details of changes in agricultural practices that took place in the 129 study villages from 2019 to 2020 as a result of the COVID-19 lockdown are shown in Table 2. These changes were especially notable during the kharif season. The area under paddy cultivation increased in 53% villages, with an average increase of 40.9 acres. Meanwhile, the area under basmati cultivation increased only in 15% villages, which might be due to assured procurement of paddy by the government and farmers tended to reduce their marketing risk during the pandemic period. Due to the sudden lockdown during the first wave of COVID-19 in India, many migrant workers returned to their homes, resulting in significant labour shortages in farming villages across Punjab (The Tribune 2020, May 5). As a result, farmers were

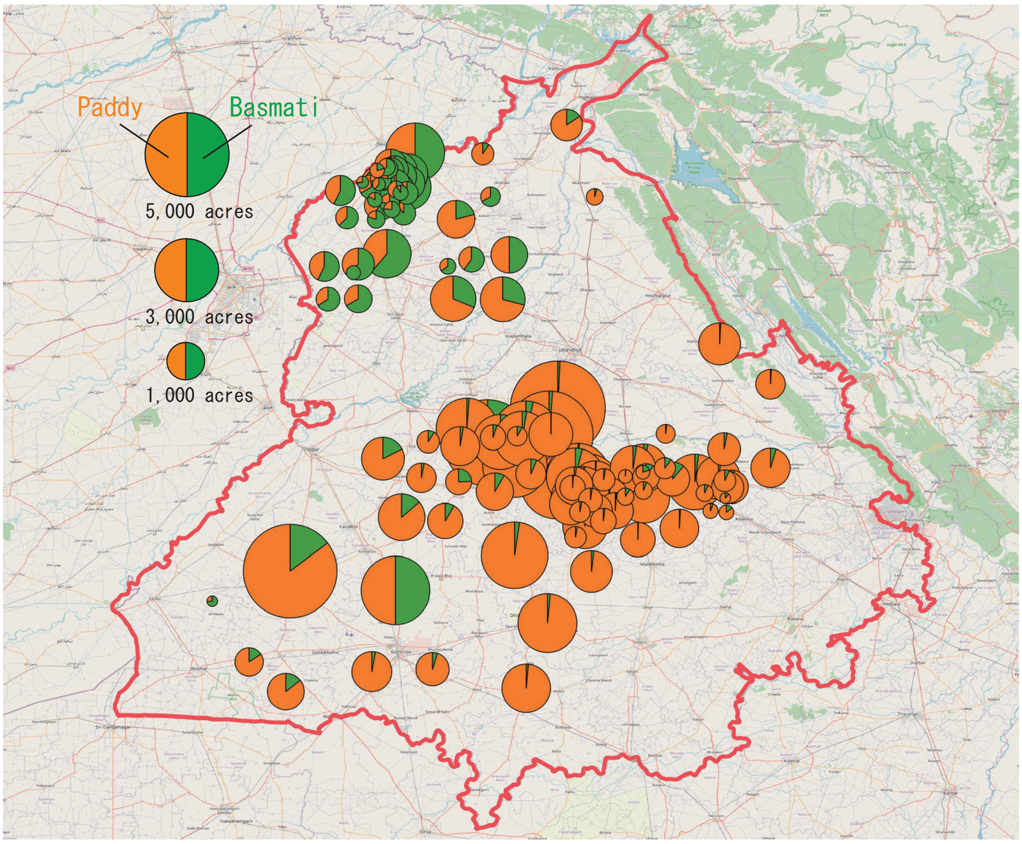

Figure 1. Location and acreage of paddy (non-basmati) and basmati rice cultivation in 2019

Table 2. Changes in agricultural practices from 2019 to 2020

Change	% of villages	Average
Increase in paddy cultivation	53.1	+40.9 acres
Increase in basmati cultivation	14.8	−48.5 acres
Increase in transplanting	47.7	−25.3 acres
Increase in direct seeding	55.5	+33.2 acres
Increase in use of rice planter	25.0	+41.9 acres
Earlier transplanting of paddy rice	76.6	−2.8 days
Earlier completion of paddy transplanting	30.5	+0.4 days
Earlier harvest of paddy rice	35.2	−0.3 days
Earlier end of paddy harvest	15.6	+0.7 days
Increase in the interval between kharif and rabi crops	49.1	+0.4 days

forced to consider alternative methods of rice planting. They had two main options: direct seeding of rice (DSR) or adoption of mechanical transplantation of paddy. Based on the findings of the survey, the area with transplanted rice declined in 52% villages, while that of DSR increased in 56% villages, suggesting that some farmers chose to give up transplanting in favour of DSR. This was particularly apparent in the villages near Moga and Ludhiana (Figure 2), reflecting the extreme labour shortages in areas close to large cities. Meanwhile, the use of rice planters increased in 25% villages in 2020, which is noteworthy because their use in the study villages was very limited prior to the COVID-19 pandemic. Again, those villages near Moga and Ludhiana showed a notable increase in mechanical transplantation of rice

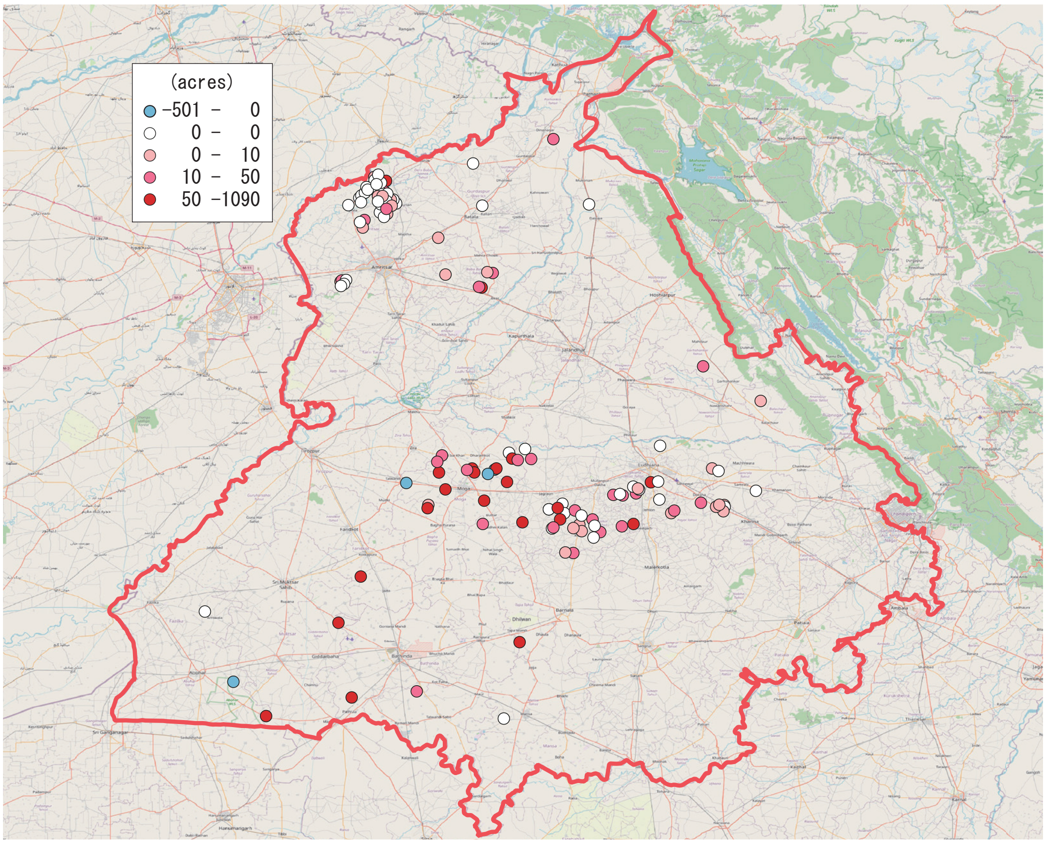

Figure 2. Changes in the acreage of direct seeding from 2019 to 2020

(Figure 3).

The labour shortages resulting from the COVID-19 lockdown also affected the transplanting date of paddy rice in 2020. In order to prevent a further decline in groundwater levels, as the Punjab Preservation of Subsoil Water Act was enacted in 2009, banning transplantation of paddy rice before June 15 (this was later revised to June 20 in 2018). However, in 2020, the lack of labour meant that the farmers would be unable to complete transplantation within this short time-frame. The state government therefore advanced the transplanting date by 10 days, to June 10 (The Tribune 2020, May 10).

In Punjab, the transplanting of paddy rice generally occurs earlier in the north than the south. In 2019, transplanting started on June 23 in the villages around Amritsar and on July 4 in the villages around Ludhiana, a difference of around 10 days. In contrast, transplanting occurred earlier in 2020 in 77% villages, except those near Ludhiana, where transplanting occurred later (Figure 4). Again, these findings reflect the labour shortages caused by the COVID-19 lockdown.

Meanwhile, the date of harvest also tends to be earlier in northern Punjab than in southern Punjab. In 2019, harvest started on October 16 in the villages around Amritsar and on November 6 in those around Ludhiana, a difference of around 20 days. However, compared with transplanting, in 2020 the date of harvest occurred earlier in only 35% of the villages, and in many villages, it remained unchanged. These findings suggest that in many villages, the cultivation period was therefore longer in 2020. Meanwhile, in the villages near Moga, the harvest date was later than in the previous year (Figure 5).

The interval between the harvest of kharif crops and sowing of rabi crops has an important effect on stubble burning. If the interval is short, farmers tend to carry out burning because there is insufficient time for straw management, whereas if the interval is longer, other methods of straw management would be possible. In 2019, the interval was longer in the north than in the central regions, at 38 days in the

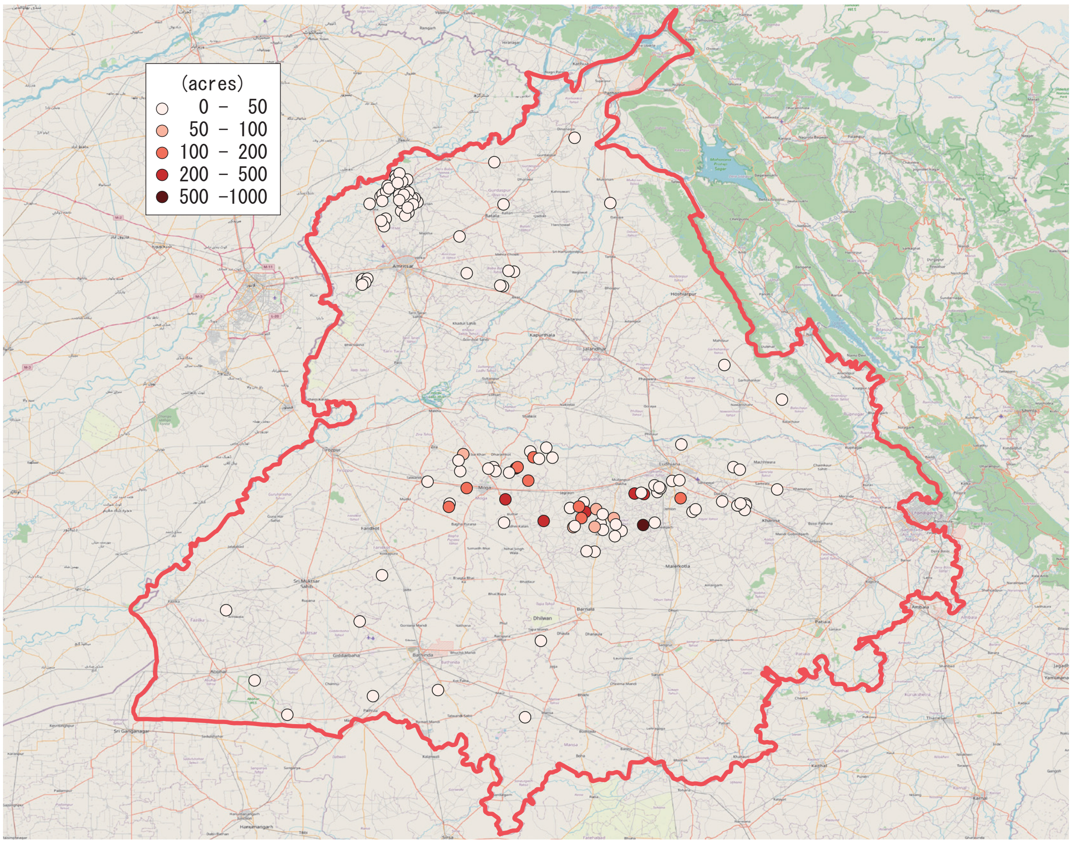

Figure 3. Changes in the acreage of rice planted with rice planters from 2019 to 2020

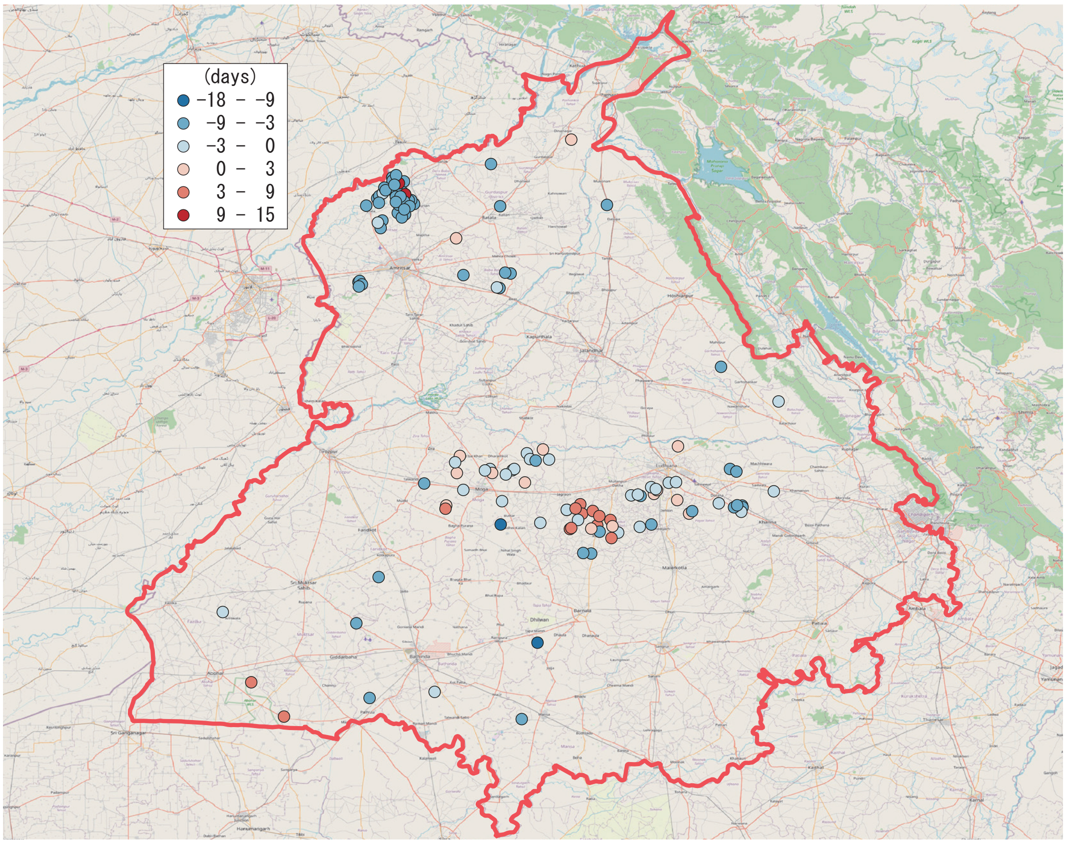

Figure 4. Changes in the transplanting date of paddy rice from 2019 to 2020

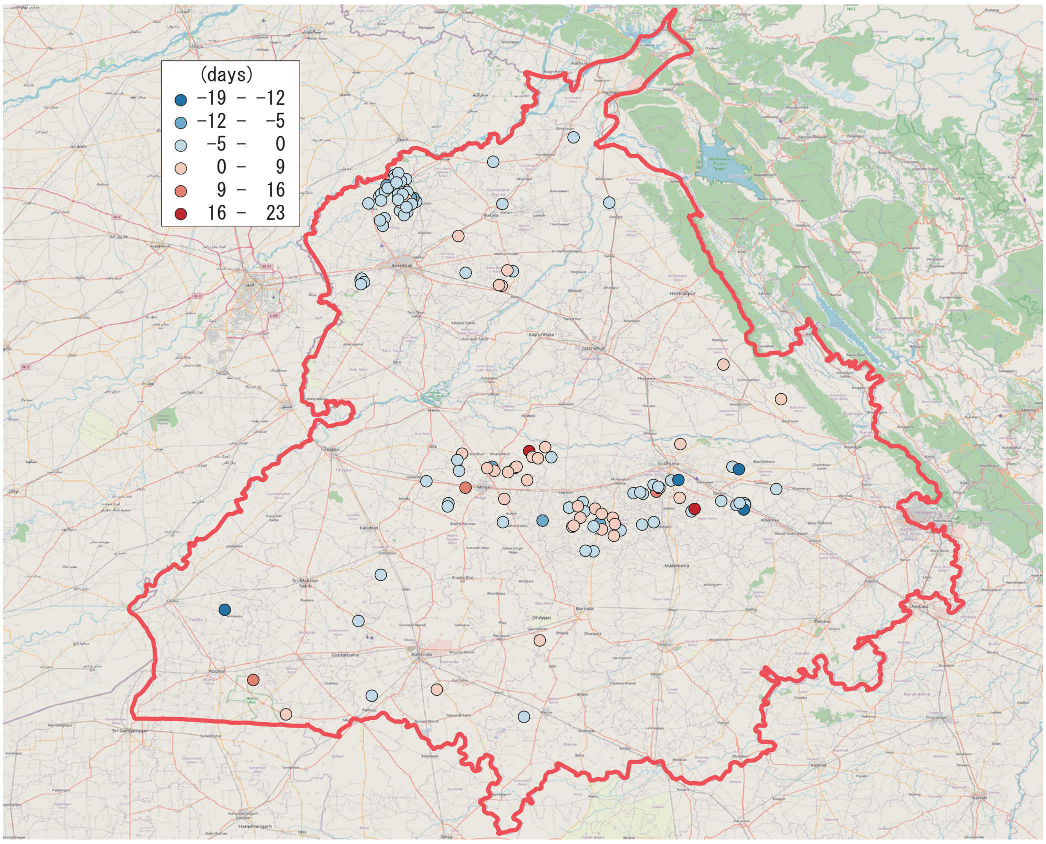

Figure 5. Changes in the harvest date of paddy rice from 2019 to 2020

villages around Amritsar and 3 days in those near Ludhiana. Meanwhile, in 2020, no clear trends were observed compared with the previous year (Figure 6); however, the interval was very short in the villages near Ludhiana.

Changes in burning area and agricultural practices

Figure 7 shows the area of burning, partial burning, and no burning after the kharif harvest in 2019 and 2020, calculated from the results of the questionnaire survey. The area of burning and partial burning was larger in the villages in the southern and central regions in both 2019 and 2020, while the area of no burning was relatively large in villages in the north. These regional differences in burning area are thought to be due to differences in the choice of rice varieties. In the north, where more basmati rice is grown, the harvest season is earlier and is often carried out manually, so long stubbles are not left in the fields after cutting close to the ground, resulting in less burning. Meanwhile, in more central and southern regions where non-basmati rice is favoured, the harvest season is later and tends to involve a combine harvester, so there is less time for crop residue management, and burning is often the only option.

A comparison between 2019 and 2020 revealed an increase in burning in villages near Moga, and an increase in partial burning in villages near Ludhiana and Amritsar. These findings are thought to be related to the labour shortages resulting from the COVID-19 lockdown.

The details of the relationship between burning area and changes in agricultural practices in 2020 are shown in Table 3. The 119 study villages were classified into three groups according to the changes in burning and partial burning from 2019 to 2020. A total of 31 villages showed an increase in burning area in 2020, 26 showed no change, and 62 showed a decrease. The area of stubble burning in the study villages decreased in 2020, in contrast with the overall increase across the entire state estimated from

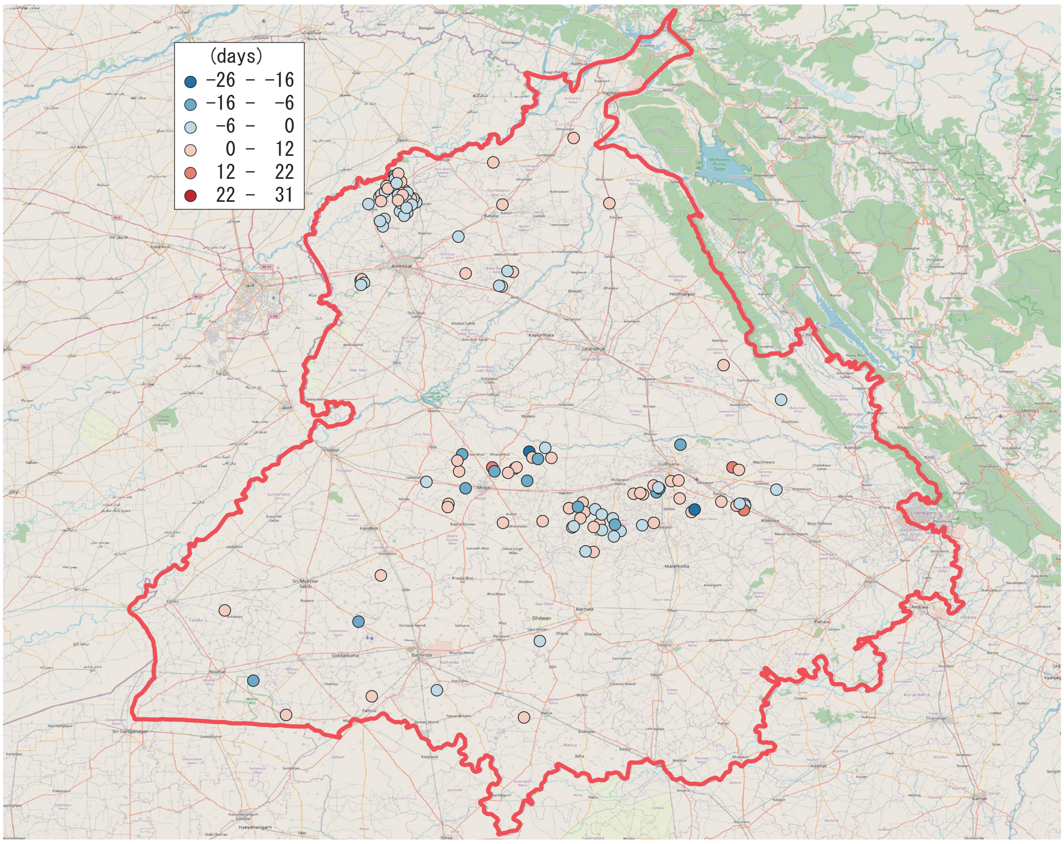

Figure 6. Changes in the interval between the kharif and rabi seasons from 2019 to 2020

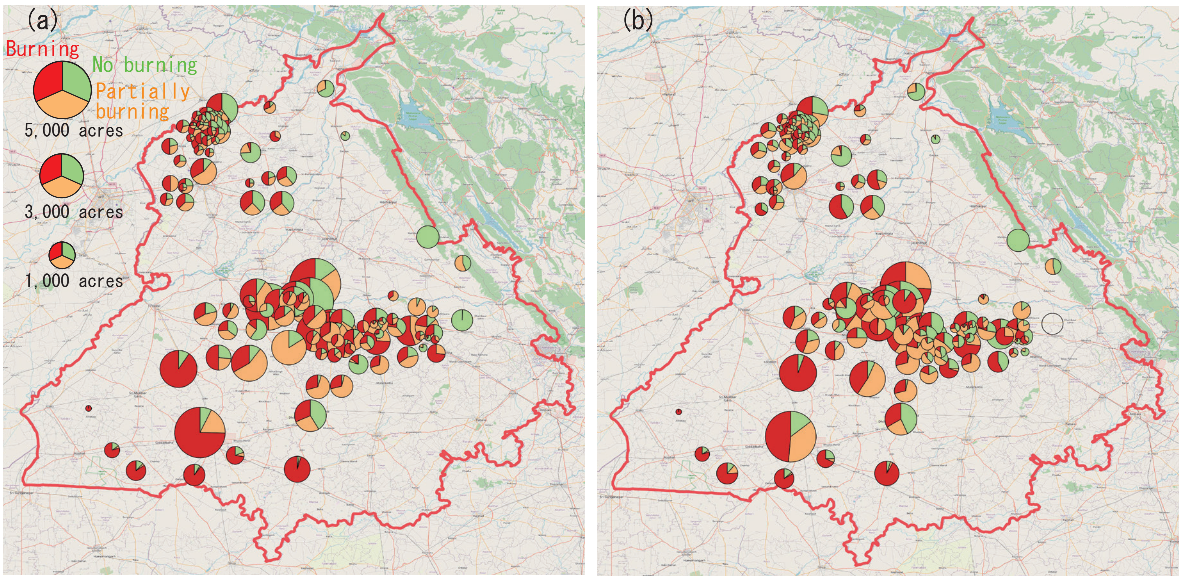

Figure 7. Areas of burning after the kharif harvest in (a) 2019 and (b) 2020

satellite observations (The Tribune 2020, November 28). In the 62 villages which showed a decrease in burning, the area under paddy cultivation and the area of transplanting were less, while the area of DSR and mechanical transplantation of rice were more. The mean planting date was later (average: June 24), but the mean harvest date was earlier (average: October 24) compared with the other villages. The inter-

Table 3. Relationship between the burning area and changes in agricultural practices in 2020

	Area of burning and partial burning		
	Decrease (N=62)	No change (N=26)	Increase (N=31)
Number of households	1473	870	1601
Number of farming households	469	351	556
Area under cultivation (acres)	230	162	249
Area under paddy cultivation (acres)	1069	389	1220
Paddy area per farming household (acres)	2.28	1.11	2.20
Area of transplanting (acres)	979	365	1090
Area of direct seeding (acres)	50	22	47
Area of rice planter use (acres)	46	2	42
Mean transplanting date of paddy rice (days)	175	173	171
Mean harvesting date of paddy rice (days)	297	292	300
Interval between kharif and rabi crops (days)	20	33	13

Note: N means the number of villages in each category.

val between the kharif and rabi seasons was longer (average: 20 days).

The correlation between the kharif–rabi interval and burning area in 2020 was negative, but the coefficient of determination was very low (Figure 8). Though the coefficient of determination is small, the slope is negative, indicating less burning for longer interval period. Notably, when the planting interval was less than 17 days, the burning area became very large in some villages. The relationship between the harvest date of kharif crops and burning area was also examined (Figure 9), revealing an increase in burning area when the harvest date was between October 22 and November 11 (around 295–315 DOY (days from January 1)). In villages in central and western districts such as Moga and Muktsar, the harvesting period was the first week of November, and more crop residue was burnt. Meanwhile, in villages in which the harvest date was earlier than the third week of October or later than the second week of November, less burning was carried out.

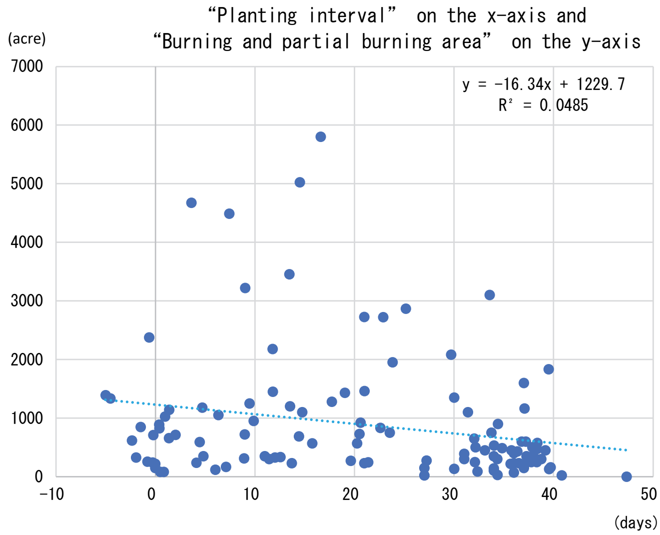

Figure 8. Relationship of the interval between kharif and rabi seasons with the burning area in 2020

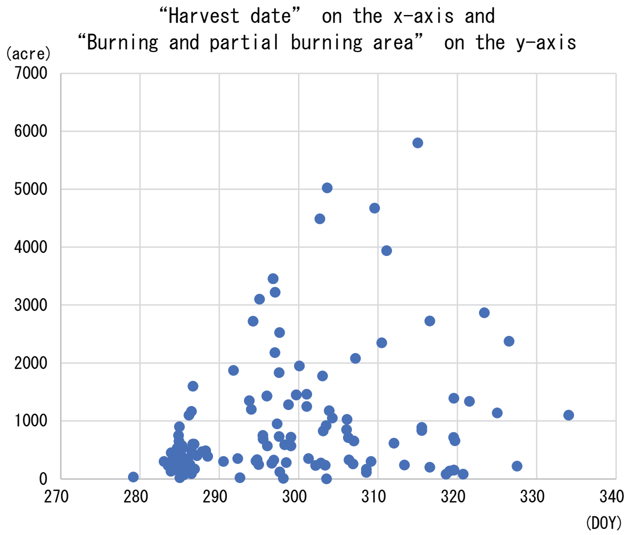

Figure 9. Relationship between the harvest date and burning area in 2020

Note: DOY is days of the year, which shows the sequential day number from January 1.

Burning area based on fire detection counts and fire radiative power

Satellite-based datasets of fire detection counts (FDC) and fire radiative power (FRP) were obtained from the Fire Information for Resource Management System (FIRMS) website provided by National Aeronautics and Space Administration (NASA). Those data were observed by the satellite sensors: MODerate resolution Imaging Spectroradiometer (MODIS) onboard EOS-Aqua, and Visible Infrared Imaging Radiometer Suite (VIIRS) onboard the Suomi NPP and NOAA-20. The spatial resolutions of MODIS and VIIRS are 1 km and 375 m, respectively. Those satellite data are often used in academic studies, and also by local governments to monitor fire events, although they are known to be underestimated (Liu et al. 2020), because of limited observation time and cloud cover. Therefore, these datasets should be interpreted by combining with ground-based data to improve reliability. In this study, the burning area of the 129 villages obtained from the questionnaire survey were compared with the total FDC and FRP data over the corresponding areas. The Pearson's correlations coefficients between FDC and FRP data obtained from different satellites (MODIS Aqua, VIIRS NOAA, and VIIRS SNPP) and the burning area determined in 2019 and 2020 are shown in Table 4. In 2020, for both of the FDC and FRP, the correlation coefficients between the burning areas and the VIIRS data are higher than those with

Table 4. Pearson's correlations coefficients between the burning area determined in the questionnaire survey and FDC/FRP data obtained with different satellites

Satellite	Burning area	
	2019	2020
FDC		
MODIS Aqua	0.62	0.61
VIIRS NOAA	–	0.67
VIIRS SNPP	0.60	0.74
FRP		
MODIS Aqua	0.46	0.46
VIIRS NOAA	–	0.61
VIIRS SNPP	0.54	0.70

Note: Burning areas include areas of partial burning.

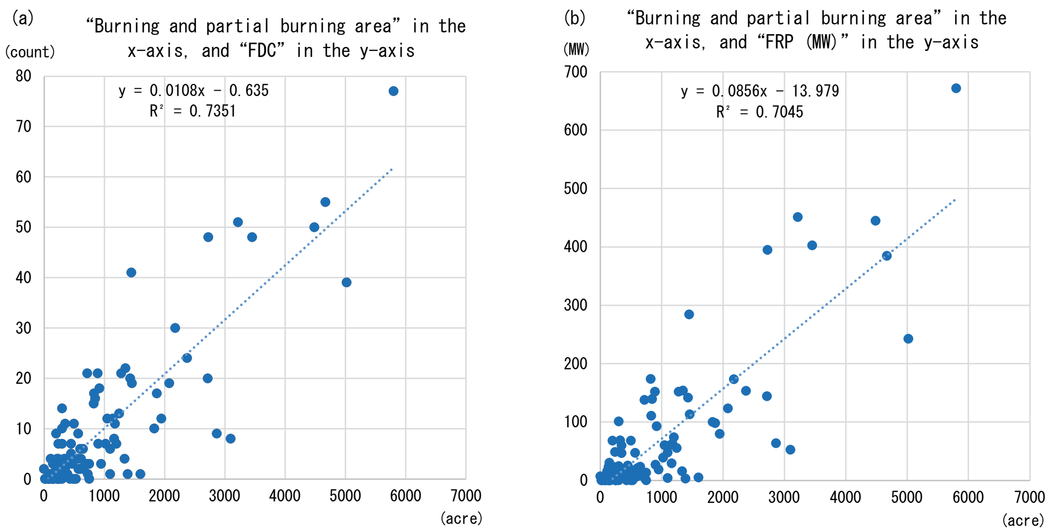

Figure 10. Correlation between the burning area determined in the questionnaire survey and (a) FDC and (b) FRP data obtained using the VIRS SNPP satellite in 2020

Note: MW is megawatt.

MODIS, possibly because of higher spatial resolution. As shown here, the burning areas obtained from questionnaire survey and satellite-based fire data showed good consistency (Figure 10), suggesting reliability of the data in this study.

Summary

In this study, a questionnaire survey was conducted in 129 villages across 12 districts in Punjab to determine the regional characteristics of stubble burning and the effect of the COVID-19 lockdown in 2020. The following findings were revealed:

1. Regional differences, especially north–south differences in agricultural practices, were notable within Punjab, probably due to differences in the choice of rice varieties cultivated based on local climatic conditions.
2. Stubble burning was more prevalent in villages in central regions around Moga, where paddy rice tends to be harvested in the 1st week of November.
3. The interval between the paddy rice harvest and rabi sowing was also shorter in central regions, which led to increases in stubble burning.
4. Direct seeding of rice and use of rice planters increased in villages near Ludhiana and Moga during the COVID-19 lockdown in 2020, probably due to acute labour shortages.
5. The date of transplanting of paddy rice was earlier, but the harvest date remained unchanged or was later in many villages in 2020. As a result, the interval between the kharif and rabi crops remained the same or was shorter, resulting in an increase in stubble burning in some villages.
6. The impact of the COVID-19 lockdown on stubble burning was negligible, except in villages near large cities where labour shortages were particularly apparent.

The above results suggest that the village-level questionnaire survey was effective in identifying the location and extent of stubble burning in Punjab. However, despite these findings, this study had limitations resulting from the non-uniform distribution of study villages across the state. Therefore, a second questionnaire survey is planned for 300 villages (2 villages per 150 blocks within the state) in

2022. The results will again be compared with satellite data in order to confirm reliability, as well as with data of socio-economic conditions in order to determine the effect of individual factors on stubble burning. The resulting data together with data on rice yield can then be used to improve inventories of PM2.5 emissions and help develop effective control measures for air pollution resulting from stubble burning.

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