Aakash International Workshop 2024:
Air Pollution in Delhi NCR and Toward Mitigation of Crop Residue Burning (CRB)

Scientific programme

Date: August 28(Wed)-30(Fri), 2024

Venue: Lecture room, Research Institute for Humanity and Nature, Kyoto

28 August 2024 (Day 1)

Opening Session (9:30-10:00 JST/6:00-6:30 IST)

09:30 Welcome by Prof. Makoto Taniguchi (Program Director, RIHN) / Director General, Prof. Juichi Yamagiwa (RIHN)

09:35 Natsuko Yasutomi (RIHN): Workshop logistics (access, accommodation and food arrangements)

09:40 Sachiko Hayashida (RIHN/Nara Women's Univ.): Summary of Aakash project results: how far have the original targets been achieved?

Session 1 (10:00 – 12:30 JST/ 6:30 – 9:00 IST): Understanding of the socio-economic conditions leading to CRB

10:00 Haruhisha Asada (Nara Women's Univ.): Regional characteristics of the crop residue burning in Punjab, India

10:20 Takahiro Sato (Hirosaki Univ.): Straw burning in Punjab from farm management perspective - A village case study in Moga District

Tea/coffee break: 10:40 – 11:00

11:00 Kamal Vatta (Punjab Agriculture Univ., online): Crop Residue Management in Punjab: Insights from a Large Survey

11:20 Kaoru Sugihara (RIHN): Development of the Procurement Policy and the Double-cropping System in Punjab

11:40 Arindam Samaddar (IRRI): Farm on fire – rice straw management strategies in mixed-farming system of Punjab

12:00-12:50 General discussions, *Session 1* (*Moderator: Prof. Sugihara/Prof. Asada*)

Lunch break at RIHN Cafeteria: 12:50 – 14:20

Session 2 (14:20 – 17:30 JST/10:50 – 14:00 IST): Solutions to crop residue burning and capturing emissions

14:20 Shigeto Sudo (NARO): Technology development for processing crop residue without releasing air pollutants or greenhouse gases

14:40 Chandra Mohan Mehta (Lovely Professional Univ.): A sustainable approach of rice residue management and possible alternatives to the rice-wheat cropping system in Punjab

15:00 Kazuyuki Inubushi (Tokyo Univ. of Agriculture): Sustainable soil and organic matter managements in Punjab for reducing straw burning and greenhouse gas production

15:20 Dong-Gill Kim (Hawassa University, Ethiopia & RIHN Visiting Researcher): Effects of rice residues management on greenhouse gas dynamics in rice-wheat systems in Punjab: preliminary results

Tea/coffee break: 15:40 – 16:00

16:00 Sachhida Nand Tripathy (Indian Institute of Technology, Kanpur) :

16:20 Kedar Mahapatra/Inami Tomoya (Shizuoka Institute of Science and Technology): Development of new technology to process crop residues
16:40-17:30 General Discussion, *Session 2* (*Moderator Dr. Sudo/Prof. Chandra*)

Session 3 (17:30 – 18:10 JST/14:00 – 14:40 IST): Measurements of air pollution – new understanding

17:30 Yutaka Matsumi (Nagoya Univ.): Introduction to CUPI-G sensors and measurement strategy for capturing emissions from crop residue burning
17:50 Tomoki Nakayama (Nagasaki Univ.): Stability and calibration of CUPI-G for the measurements of $PM_{2.5}$, carbon monoxide, nitrogen oxides and ozone

18:30 Dinner at RIHN Cafeteria ---

29 August 2024 (Day 2) .

Day 2 Session 3 cont. (09:00 – 12:30 JST/05:30 – 09:00 IST): Measurements of air pollution – new understanding

09:00 Suman Mor (Panjab Univ.): Learning from the COVID-19 pandemic: Implications on education, environment, and lifestyle
09:20 Pradeep Khatri (Soka Univ.): Unveiling the effects of post-monsoon agricultural biomass burning on aerosols, clouds, and radiation in northwestern India
09:40 Surendra Dhaka (University of Delhi): Long-term meteorology-adjusted and unadjusted trends of $PM_{2.5}$ over Delhi
10:00 Dilip Ganguly (IIT Delhi): Characteristics of haze pollution events during biomass burning period at an upwind site of Delhi

Tea/coffee break: 10:20 – 10:40

10:40 Prakhar Misra (IIT Roorkee): Top-down emission inventory using remote sensing – glimpses from the windows of opportunity (COVID19)
11:00 Anamika Anand (Univ. of Tokyo): Understanding the agricultural burn area dynamics using a deep learning segmentation approach: A case study in Punjab, India
11:20 Sachiko Hayashida (RIHN/NWU), Masao Moriyama (Nagasaki Univ): Interpreting data records of fire detection parameters observed by satellites - usefulness and limitations for stubble burning
11:40-12:30 General discussions, *Session 3* (*Moderator: Prof. Dhaka/Prof. Nakayama*)

Lunch break at RIHN Cafeteria: 12:30 – 14:00

Session 4 (14:00 – 18:00 JST/10:30 – 14:30 IST): Modelling/analysis of air pollutants – new understanding

14:00 Poonam Mangaraj (RIHN): Weak coupling of observed surface $PM_{2.5}$ in Delhi-NCR with rice crop residue burning in Punjab and Haryana
14:20 Mizuo Kajino (Meteorological Research Institute): Impact of post monsoon crop residue burning on $PM_{2.5}$ over North India: Optimizing emissions using a high-density in situ surface observation network
14:40 Kazuyo Yamaji (Kobe Univ.): Modelling study for the heavy $PM_{2.5}$ pollution during the dry season in northwestern India
15:00 Akash Biswal (RIHN): Impact of autumn crop residue burning emission estimations on $PM_{2.5}$ concentration over northwest India using WRF-Chem
15:20 Masayuki Takigawa (JAMSTEC): Air pollutants flux calculation using FLEXPART-WRF

Tea/coffee break: 15:40 – 16:00

16:00 Manish Naja (ARIES): Long-term and campaign-based measurements of volatile organic compounds in northwest India
16:20 Tomohiro Sato (NICT): Aerosol measurement using commonly-used camera and SNAP-CII algorithm: From Japan to India
16:40 A.P. Dimri (JNU): Intertwined physico-chemical interactions of air pollutants during COVID-19 lockdown
17:00-17:50 General discussions, *Session 4* (*Moderator: Prof. Mor/Dr. Kajino*)

18:30 Workshop Dinner at RIHN Cafeteria --

30 August 2024 (Day 3) .

Session 5 (9:00 – 13:30 JST/5:30 – 10:00 IST): Air pollution and human health

09:00 Kayo Ueda (Hokkaido Univ.): Analysis of the questionnaire survey about air quality and health – case of crop residue burning in Punjab
09:20 Ravindra Khaiwal (PGIMER): Air Pollution and Climate Change: Connecting Communities for Sustainability and Better Health
09:40 Pallavi Joshi (IIT-Delhi/Amity Univ.): Impacts of crop residue burning on air quality and premature deaths in unjab, Haryana and Delhi: A district level analysis
10:00 Akash Biswal (RIHN): Assessment of various impacts of observed $PM_{2.5}$ air pollution on human health

Tea/coffee break: 10:20 – 10:40

10:40 Sanat Das (Bose Institute): Structural variation in winter-time airborne bacterial communities enriched with pathogens: A study over New Delhi, India
11:00 General discussions, *Session 5* (*Moderator: Prof. Ueda/Prof. Khaiwal*)

11:50 **Data sharing and collaborative research initiatives** (*Moderator: Prof. Patra*)
12:40 Prabir Patra (RIHN/JAMSTEC): Summary of the Aakash International Workshop

13:00 Workshop Adjourn
Lunch at Yumenoki Okonomiyaki restaurant: 13:30 –

Abstracts

Summary of Aakash project results: how far have the original targets been achieved?

Sachiko Hayashida, RIHN; Nara Women's University; NICT, Japan

The birth of the Aakash project dates back to 2017. I proposed the following issue as an Incubation Study (IS): 'Short-lived climate pollutant (SLCP) emissions from the Asian region: a proposal for mitigation measures in collaboration with society.' However, this challenge was not adopted in the end. In 2018, I again proposed a new project to reduce air pollutants emissions from agricultural residue burning and to improve air pollution in India, which was decided to be adopted at the review meeting in February 2019. In addition, a preparation period was set in 2019 as Pre-Research (PR) and the project started in 2020 after a total of three years of preparation. Unfortunately, however, the corona disaster broke out at the same time as the project started. International travel was severely restricted and our research plan severely delayed. However, some unexpected new results emerged from the implementation of mission DELHIS.

Due to the excessive length of time leading up to the adoption of the project, I had to retire during the project period, but I would like to thank Dr Patra for taking over the project and continuing it to the present day.

In this presentation, I will reflect on what the Aakash project has aimed for and how far it has achieved its goals. During this workshop we should discuss how we should collectively disseminate the results of the project over the next six months.

Indian national environmental protection projects – air pollution mitigation to river water cleaning

Sachhida Nand Tripathy, IIT-Kanpur, India

T.B.D.

Socio-economic analysis of rice stubble burning in Punjab

Haruhisa Asada, Nara Women's University, Japan

In this project, we analyzed statewide questionnaire surveys conducted in 2020 and 2022 to find that the proportion of stubble burning after rice harvest was higher in the southern part of the state, particularly in the Moga, Barnala, and Sangrur districts. In these areas, double cropping of long-duration varieties of rice and wheat is particularly popular, as these crops are guaranteed to be purchased at the Minimum Support Price (MSP) by government

agencies. As a result, the number of days between rice harvest and wheat sowing is shorter, making it difficult to dispose of residues without burning.

To clarify the socio-economic status of farmers who burn rice stubble, we conducted a questionnaire survey in October 2023 targeting all 104 farm households operating farmland in B Village of Moga District. The households were classified into five classes according to land ownership size, and their cultivated varieties, post-harvest residue disposal methods, and machinery ownership were examined.

The results showed that most farmers in the village burned rice stubble regardless of their economic class. Households with smaller land ownership burned relatively less area, while households with larger land ownership burned more area. The use of machinery for sowing wheat differed between small and large farmers. Small farmers managed the crop residue by renting Happy Seeders and Super Seeders, while large farmers owned these machines. Middle farmers used Zero Till Drills for sowing wheat after residue burning. The use of machinery depends on availability, rental cost, and landholding structure. Many farmers in the village try to lease lands whose owners have migrated abroad. These leased lands are often located in remote areas, making it difficult to operate rental machines.

Straw burning in Punjab from farm management perspective - A village case study in Moga District

Takahiro Sato, Hirosaki University, Japan

Moga district is located at the center of straw burning zone in Punjab. This case study investigates how farmers decided to burn rice straw in their field based on the results from questionnaire survey conducted in 2023.

Crop Residue Management in Punjab: Insights from a Large Survey

Kamal Vatta, Punjab Agriculture Univ (online)

The study titled "Crop Residue Management in Punjab: Insights from a Large Survey" provides a comprehensive analysis of agricultural practices related to crop residue management (CRM) in Punjab, India, based on a large-scale baseline survey conducted in 2020. The survey encompassed 2,029 farming households across 22 districts, focusing on socio-economic profiles, CRM practices, and factors influencing the adoption of CRM technologies. The findings reveal that while 68% of farmers have adopted CRM practices, 38% of the crop residue is still burned, highlighting ongoing environmental challenges. The study identifies key factors influencing CRM adoption, including farm size, asset ownership, and perceptions of environmental and health impacts. Larger landholders and those with more assets are more likely to adopt CRM practices, while public awareness of the health effects of crop burning also plays a significant role in motivating farmers to manage crop residue more sustainably.

Economic incentives, such as compensation for not burning crop residue, are crucial in encouraging CRM adoption. The research suggests that targeted financial support and enhanced public awareness campaigns could significantly improve CRM practices. However, the study also notes that the effectiveness of CRM technologies varies across regions, indicating the need for region-specific policies and interventions. The conclusions underscore the importance of tailored support and education to address the diverse agricultural practices and socio-economic conditions in Punjab.

Development of the Procurement Policy and the Double-cropping System in Punjab

Kaoru Sugihara, RIHN

This presentation discusses the evolution of the procurement policy in India, and the importance of the double-cropping system of paddy and wheat in Punjab from the 1970s to the present.

Rice is a crop not largely consumed in Punjab. The introduction of high-yielding variety in the 1970s was driven by the guaranteed government purchase at the minimum support price (MSP). Procurement and storage were organized by Food Corporation of India and state agencies, while a hierarchy of regulated local markets were developed by the state government. Farmers sale was intermediated by Arhtiyas (middlemen) who received a commission from the purchasers. The procurement-driven markets were not well developed for crops other than paddy and wheat. Thus the production of paddy and wheat was generally found more profitable and secure than that of other crop or crops. The more recent trends of simultaneous rise of prices and costs only highlight the crucial importance of the guarantee of sale of products at MSP for both farmers and actors of the regulated markets (hence the protests against the Farm Laws aiming at the less regulated market regime).

The analysis of 2018-19 CCPC (Comprehensive Scheme for Studying Cost of Cultivation of Principal Crops in India) data on Moga District shows that the cost structure of small farmers was more labour-intensive, depending on family labour, while that of medium farmers was more capital-intensive, with greater inputs of fertilizers, insecticide and machines. The rent consisted of a high percentage of factor inputs, especially for small farmers. Overall, technological progress since the Green Revolution brought high land productivity through the capital-intensive and land-intensive methods of cultivation. This path of development was also water-intensive, since rice is a water-intensive crop and the double-cropping system means the use of more water per land. The system therefore became dependent not only on the MSP guarantee but on high subsidies for electricity for the agricultural use of groundwater.

Punjab agriculture has been endowed with water, in spite of its dryland characteristics. It benefitted from summer rainfall, river and canal irrigation and wells in various stages of the growth of the double-cropping system. Unlike other parts of North India, the region does not suffer from periodic floods, while Himalayan snowmelts have helped both surface water flows and groundwater recharge (though the effects of climate change are uncertain). The serious lowering of groundwater table is a relatively recent phenomenon for the 50-year history of the development of paddy-wheat cycle. Institutionally embedded expectation of a ready availability of water for the increase of production under intensive land use needs to be revised. Further increase of production of water-intensive crops should be avoided.

Stubble burning in Punjab probably began with the introduction of the double-cropping system of paddy and wheat, but its necessity increased during the 1990s, with the coming of PUSA-44, a high-yielding but a long-duration rice variety, which reduced the length of time available for preparation between the harvest of rice and the sowing of wheat. The Water Act delayed the timing of rice planting and harvesting, which served for a further shortening of preparation time, contributing to the increase of stubble burning. The historical trajectory suggests the replacement of rice seed by the high-yielding, shorter-duration variety would mitigate the stress to some extent. The effect of the switch to the shorter period of cultivation on water use should also be assessed.

Farm on fire – rice straw management strategies in mixed- farming system of Punjab

Arindam Sammadar

Punjab, a northwestern state in India, produces 20 million tonnes of rice stubble annually. Most of it is burnt in the fields, producing GHG emissions and $PM_{2.5}$, which affects the regional air quality of Punjab, Haryana, western Uttar Pradesh states, and the National Capital Region. Despite Central and State government initiatives, the prevalence of burning remains high, and a re-examination of farmers' in-situ and ex-situ straw management is required.

Fieldwork was conducted across three villages in the Ludhiana district of Punjab state, including household-level personal interviews and key informant interviews at district and state levels, covering experts from agriculture, livestock, energy, and policy domains.
The study reveals that the value of paddy straw and its usage are influenced by the belief system and age-old cultural traditions at the community level. Farmers consider non-Basmati paddy straw inedible by dairy animals. Off-farm opportunities and the unavailability of household labour directly impact dairy intensification and reduce overall household herd size, determining the supply and demand of paddy straw at the household and community levels. Labor scarcity and higher wages lead farmers to adopt labour- and cost-efficient combine harvesting, further devaluing the straw quality. With conflicting information about its environmental effects, farmers find burning the most economically viable option for managing paddy straw within the narrow window between paddy harvesting and wheat sowing activities. Industry involvement works towards reducing burning by using crop residues for energy, supporting farmers' incomes, and promoting sustainability. Challenges in market and infrastructure hinder broader adoption. Government policies incentivize non-burning practices but face implementation gaps. Economic shifts in livestock farming affect residue demand.

The study underscores the complex interplay of physical, financial, human, and informational factors influencing agricultural practices and residue management decisions. The research calls for integrated strategies involving technological advancements, policy reforms, and community engagement to transition towards sustainable residue management practices. Addressing these challenges is crucial for fostering resilience and sustainability in agricultural landscapes, ensuring both environmental stewardship and livelihood security in Punjab's mixed-farming system.

Technology development for processing crop residue without releasing air pollutants or greenhouse gases

Shigeto Sudo, NARO, Tsukuba, Japan

We have to not only reduce CO_2 emissions, but also remove atmospheric CO_2 to meet the Paris Agreement target. The term CDR is now used, shortened from Carbon Dioxide Removal. Removing CO_2 from the atmosphere is called CO_2 negative emissions. Negative emissions technologies is called NETs. Bio-char is one of the representative nature-base NETs. There are three kinds of major nature-based NETs: afforestation & reforestation (AR), soil carbon sequestration (SCS), and Bio-char (BC). Biochar's global potential for CO_2 removal is estimated at from 0.5 to 2.3 Giga ton CO_2 equivalent per year. The application cost of bio-char is from 25 to 125 US$ per ton CO_2. Japan's target for CO_2 reduction through biochar in 2050 is 14 million tons. Biochar resources include rice husk, bamboo, livestock dung, and sludge. Biochar soil amendment became the fourth methodology in the agricultural sector of the J-Credit system in 2020. J-Credit is the Japanese government's carbon offset mechanism. Bio-char is a low cost and easy-to-use method among various negative emission technologies. The barriers for bio-char social dissemination are as follows. First, people are not aware of the importance of reducing CO_2 emissions. Second, the agricultural benefits of amending bio-char on farmland are not clear. Some series of operations are required for bio-char utilization in agricultural fields. We transport biomass resources to make bio-char. Then we make biochar in several kinds of char-making machines. Finally, we scatter bio-char in farmland. Carbon offset credit is one of potential candidate for incentive of bio-char application. The Green Innovation Fund supports public institutions and private companies to collaborate in achieving ambitious goals for implementing decarbonization projects for zero emissions. Japanese government will support up to 10 years, including everything from research and development to social implementation. So, the Ministry of Economy, Trade and Industry has established a fund totaling 2 trillion yen at the New Energy and Industrial Technology Development Organization (NEDO). We aim to establish technology for supplying and using high-functional biochar in the agricultural field of the Green Innovation Fund of projects. We will develop high-functional biochar for soil amendment. Then we increase agricultural yields by 20% and continuously store 3 tons of carbon dioxide equivalent per hectare. We will also create environmental evaluation system for eco-friendly farming methods including bio-char soil amendment.

A sustainable approach of rice residue management and possible alternatives to the rice-wheat cropping system in Punjab

Chandra M Mehta, School of Agriculture, Lovely Professional University, Punjab, 144411, India

Rice and wheat are the primary crops grown in Punjab. Over the past few decades, the continuous cultivation of these crops has significantly strained the groundwater table. Additionally, the burning of rice residue poses a major environmental challenge in northern India, particularly in Punjab. To address the issue of rice straw burning, government and scientific initiatives have been implemented, resulting in a reduction of fire incidents in recent years. However, the problem persists. In response to these challenges, an experimental study was conducted at the agriculture farm of Lovely Professional University, Punjab, India. The study focused on two main objectives: (i) exploring alternatives to the rice-wheat cropping system and (ii) sustainably managing rice residue by producing biochar. In this study, pigeon pea was introduced as an alternative to rice, which is a key component of the rice-wheat system. Other alternative crops, such as papaya and turmeric, were also evaluated for their effectiveness. Biochar made from rice straw and husk was applied at rates of 5, 10, and 15 t/ha in selected cropping systems. The application of biochar at 5 t/ha yielded promising results, including reduced fertilizer requirements and improved plant growth and yield attributes. Regular application of biochar before sowing was found to have a significant positive impact on crop health and yield. Additionally, papaya and turmeric, the alternative crops tested in the study, show potential for commercial food product development. Given the current situation, there is an urgent need to adopt alternative crops in the Punjab region. This shift can significantly reduce water stress and environmental pollution.

Sustainable soil and organic matter managements in Punjab for reducing straw burning and greenhouse gas production

Kazuyuki Inubushi, Tokyo University of Agriculture, Setagawa, Japan

Rice-wheat cropping system in Northwest India has been established since green revolution starting in the 1960s, based on modern varieties of crops and sufficient supply of water and nutrients. However, due to decrease of water availability and intensive cropping, soil fertility and soil organic matter contents started to decline. Mismanagements (burning) of crop residues induce environmental problems such as air pollutions, affecting human health. To examine options for sustainable straw management, various alternatives to burning straw are being evaluated from agronomic viewpoint. As for mitigation to reduce greenhouse gases from soil, crop residue can be converted to biochar for various applications. We established field experiment to investigate the effects of two kinds of biochar (made from rice husk and rice straw) on engineering soil properties and greenhouse gas emissions from wheat fields. After 2 seasons of field experiments, soil total C and N were increased by rice-husk biochar application, but not by rice straw biochar nor the chemical fertilizers. Greenhouse gases (CO_2, CH_4 and N_2O) emissions were measured by chamber method and

GC, then calculated as CO_2eq by using Global Warming Potentials (GWPs). We find CO_2 emissions as dominant among three gases and not significantly increased by biochar application, compare with control case (chemical fertilizer application only). With wheat yield significantly increased, co-benefit of reduction in air pollution by rice-husk biochar application and contribution to international efforts of GHG emission mitigation envisaged for sustainable carbon neutrality in agriculture system in Punjab.

Development of new processing technique for sustainable use of rice husks and residues

Tomoya Inami, Masayoshi Matsui, Kedarnath Mahapatra, Kensaku Matsumoto; Shizuoka Institute of Science and Technology, Japan; Hiroshima Institute of Technology, Japan

This study was conducted to develop a new processing method for rice husks and residues generated after rice harvest and convert them into noncarbonized substances for sustainable use as fertilizer. The results derived from our study so far are as follows: 1) equipment was devised, and the processing method was successfully tested with the rice husks as input 2) After processing the rice husks for two minutes, when the processed and unprocessed rice husks were immersed in distilled water separately, the processed rice husks settled in contrast to the unprocessed samples, confirming the improvement of hydrophilicity. As a result, processed rice husks can decompose faster by making it easier for microorganisms and extracellular enzymes to break them down when spread on the soil and used as fertilizer. In the next step, we will use thermogravimetric analysis (TGA), saccharification, and other analytical and evaluation methods to determine the processing technique's effectiveness in more detail. We will also consider scaling up the process so that our equipment can handle large amounts of rice husks and residues, including the stubbles, which could potentially be a sustainable countermeasure to address North India's stubble/husk burning environmental problem.

Introduction to CUPI-G sensors and measurement strategy for capturing emissions from crop residue burning

Yutaka Matsumi et al., Nagoya University & RIHN, Japan

Aakash Project at Research Institute for Humanity and Nature (2020-2024) aims to address the problem of burning rice straw in northern India, to achieve clean air, public health and sustainable agriculture. The impacts of rice straw burning (RSB) on air pollution in the vicinity of Delhi national capital region (NCR) will be quantitatively assessed and the scientific basis will be clarified by determining the distribution of air pollutants generated from RSB over this wide area. The wide-range observation network of this project provides a more concrete scientific basis in this connection, as the lack of scientific evidence has been causing confusion in the community. Limited monitoring data in rural areas is a bottleneck in establishing scientific knowledge. Therefore, large units of compact air quality monitoring devices (named CUPI-G) were installed in rural areas of the target region to observe ambient

$PM_{2.5}$ and other pollutant levels resulting from RSB. We have installed 32 CUPI-Gs in rural sites between Punjab and New Delhi, that is, 400 km x 200 km wide range area. While usual public atmospheric observation sites are at the center of the large cities and their observation results are influenced by extremely high local emission of pollutants, the CUPI-G sites located in rural areas can detect relatively wide range concentrations. Data from each station can be obtained daily in real time via mobile phone lines. Using this observation network, high concentrations of $PM_{2.5}$, CO and O_3 due to rice straw burning were observed in October-November 2022 and 2023, and their spread and transport from straw burning emissions in Punjab and Haryana to the Delhi metropolitan area could be observed in real time. The results are analyzed in atmospheric chemical transport models and will be presented in separate presentations in this session.

Performance and calibration of CUPI-G for the measurements of $PM_{2.5}$, carbon monoxide, nitrogen oxides and ozone

Tomoki Nakayama, Nagasaki University, Japan

In the Aakash project, we have conducted the network observation campaigns to monitor $PM_{2.5}$ and gaseous compounds including carbon monoxide (CO), NO_x, and ozone (O_3) using >30 instruments named CUPI-Gs (compact and useful $PM_{2.5}$ instrument with gas sensors) in northwest India during CRB seasons in 2022 and 2023 and are planning to conduct in 2024. For the usage of network observation data in a variety of scientific discussion, the quality assurance / quality control (QA/QC) of low-cost sensors are critically important. For the evaluation of performance and calibration of the sensors, we (CUPI task team) have been conducted the simultaneous observation of $PM_{2.5}$ and traces gases by the CUPI-Gs and the standard instruments at Nagasaki University in Japan, before and after the observation campaigns in India. In this presentation, the results of these tests will be shared. In addition, the results of analyses on chemical evolution (secondary formation of $PM_{2.5}$ and loss of NO_x) in the crop residue burning plume during the transportation will be presented.

Learning from the COVID-19 pandemic: Implications on education, environment, and lifestyle

Suman Mor, Panjab University

T.B.D.

Intertwined physico-chemical interactions of air pollutants during COVID-19 lockdown

A. P. Dimri, JNU, New Delhi; IIG, Mumbai, India

T.B.D.

Long-term Meteorology-Adjusted and Unadjusted Trends of $PM_{2.5}$ Using the AirGAM Model Over Delhi, 2007–2022

S. K. Dhaka, et al., RAPL, Rajdhani College, University of Delhi, Delhi

This study investigates the impact of meteorological variations on the long-term patterns of $PM_{2.5}$ in Delhi from 2007 to 2022 using the AirGAM model. Generalized Additive Modeling was employed to analyze meteorology-adjusted (removing the influence of inter-annual variations in meteorology) and unadjusted trends (trends without considering meteorology) while addressing auto-correlation. $PM_{2.5}$ levels showed a modest decline of 14 µg m-3 unadjusted and 18 µg m^{-3} meteorology-adjusted over the study period. Meteorological conditions and time factors significantly influenced trends. Temperature, wind speed, wind direction, humidity, boundary layer height, medium-height cloud cover, precipitation, and time variables including day-of-week, day-of-year, and overall time, were used as GAM model inputs. The model accounted for 55% of $PM_{2.5}$ variability (adjusted R-squared = 0.55). Day-of-week and medium-height cloud cover were non-significant, while other covariates were significant ($p < 0.05$), except for precipitation ($p < 0.1$). Wind speed (F-value: 98) showed the strongest correlation, followed by day-of-year (61), years (41.8), planetary boundary layer height (13.7), and temperature (13). Meteorological parameters exhibited significant long-term trends, except for temperature. Inter-annual meteorological variations minimally affected $PM_{2.5}$ trends. The model had a Pearson correlation of 0.72 with observed $PM_{2.5}$, underestimating episodic peaks due to long-range transport. Partial dependencies revealed a non-linear $PM_{2.5}$ relationship with meteorology. Break-point detection identified two potential breakpoints in $PM_{2.5}$ time series. The first, on October 1, 2010, saw a significant increase from 103.4 to 162.6 µg m^{-3}, potentially due to long-range transport. Comparing meteorology-adjusted and unadjusted trends can aid policymakers in understanding pollution change causes.

Characteristics of haze pollution events during biomass burning period at an upwind site of Delhi

Dilip Ganguly, Indian Institute of Technology, Hauz Khas, New Delhi, India

The National Capital Territory (NCT) of Delhi is one of the most populated regions in the world. It experiences intense haze episodes during the post-monsoon and winter months which impacts air quality and climate, affecting human health and economy, but the underlying pathways remain poorly understood. Most research attributes the increase in particulate pollution over Delhi-NCT to the long-range transport of biomass burning aerosols from north-west states of Haryana and Punjab but lacking observational evidence and quantification of sectoral contributions. We established a state-of-the-art atmospheric science laboratory at Sonipat, IIT Delhi campus, which located upwind of Delhi in the post-monsoon season. We report comprehensive air pollutant observations during 25th October to 15th November 2023 covering biomass burning and Diwali events. Observations include

fine particulate matter ($PM_{2.5}$), non-refractory $PM_{2.5}$ (NR-$PM_{2.5}$), black carbon (BC), volatile organic compounds (VOCs), greenhouse gases, carbon monoxide (CO) and various meteorological parameters. Our observations show (1) sudden increases in $PM_{2.5}$, NR-$PM_{2.5}$, VOCs, and other pollutants causing severe haze conditions, (2) a low pollution conditions due to rainfall scavenging, and (3) reoccurring of severe haze conditions following the Diwali night. Two haze episodes are identified by very high $PM_{2.5}$ (>300 µg m^{-3}). During all the episodes, organics dominated the NR-$PM_{2.5}$ concentration, followed by BC, nitrate (NO3), ammonium (NH_4), sulphate SO_4), and chlorine (Cl). Higher levels of biomass burning tracers, such as levoglucosan (m/z 60, 73), mannosan (m/z 179), and emission ratios (ERs) coupled with shallow atmospheric boundary layer (ABL< 300m) are recorded during the severe haze conditions. Levoglucosan to mannosan ratio (LG/MN>10) suggest the prevalence of crop residue burning and hard wood during the haze periods, and backward trajectories arrived at Delhi-NCT mostly from the northwest.

Top-down emission inventory using remote sensing – glimpses from the windows of opportunity (COVID19)

Prakhar Misra, Geospatial Engineering Group, Civil Engineering Department, Indian Institute of Technology Roorkee, Uttarakhand 160012, India

Emission inventories serve as the backbone of environmental policy by providing a detailed account of pollutant sources and their magnitudes. They are critical for the development of reliable atmospheric models, which in turn are essential for predicting air quality. This talk introduces recent advancements in top-down emission inventory methods using remote sensing technologies, such as the European Space Agency's Sentinel 5P, to provide accurate and timely data on atmospheric pollutants. By leveraging top-down emission inventory methods, we can gain insights into the spatial and temporal variations of emissions. Furthermore, variation in NOx concentration and emission during the COVID-19 lockdowns over the North India region using remote sensing are discussed. The results indicated urban areas underwent significant decrease in NOx emissions while the rural areas did not show a substantial decrease.

Understanding the agricultural burn area dynamics using a deep learning segmentation approach: A case study in Punjab, India

Anamika Anand, The University of Tokyo, Japan

In this study, we investigate the capabilities of high-resolution Sentinel-2 observations and deep learning(DL) models, specifically convolutional neural networks(CNNs), to accurately map small agricultural burn areas in Punjab, India. Initially, the model was trained on data from Portugal to capture large fire and burn area delineation, achieving moderate accuracy. Subsequent fine-tuning with annotated data from Punjab significantly improved the model's ability to detect small burn patches, demonstrating higher accuracy and precision compared to the baseline Normalized Burn Ratio (NBR) Index method. On-ground validation using a buffer zone analysis around geolocated images confirmed the model's effectiveness, although cloud interference and temporal gaps in satellite data posed challenges. Despite these limitations, the study highlights the methodological advancements and potential of using DL models for burn area detection in agricultural settings. This research provides a promising approach for accurate burn area mapping, contributing to better emission estimation and management practices in regions with limited ground truth data.

Interpreting data records of fire detection parameters observed by satellites - usefulness and limitations for stubble burning

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The number of fire detections (FDCs) and fire radiation power (FRPs) from the Moderate Resolution Imaging Spectroradiometer (MODIS) and the Visible Infrared Imaging Radiometer Suite (VIIRS) for stubble burning in the area have been investigated and interpreted in relation to the social context in a number of studies. There is a high level of public interest, with the local media reporting annually on preliminary reports reporting year-on-year changes in the number of fires. However, MODIS and VIIRS are orbiting satellites and can only observe twice a day (day and night), each observation being instantaneous. The number of AFs detected as fires is known to be considerably underestimated compared to reality. To compensate for the disadvantage of orbital satellite observations, it is desirable to make use of geostationary satellites together with other orbital satellite observations at different observation times. We will present the results of INSAT-3D observations of long-term variations in cloud cover and more analysis from VIIRS board on NOAA-20 and Suomi.

Weak coupling of observed surface $PM_{2.5}$ in Delhi-NCR with rice crop residue burning in Punjab and Haryana

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The impacts of air pollution on human health in northern India, and over the Delhi National Capital Region (NCR) in particular has become a crucial issue. The crop residue burning (CRB) during Kharif season is customarily held accountable for deteriorated air quality in Delhi-NCR. Nevertheless, while fire detection counts (FDCs) from satellites in Punjab and Haryana decreased by 50% or more between 2015 and 2023, the concentration of fine particulate matter ($PM_{2.5}$) in Delhi remained stable. Further, we analysed the measurements of $PM_{2.5}$, carbon monoxide (CO) and related parameters in Delhi-NCR, Haryana and Punjab from a network of 30 low-cost sensors (CUPI-Gs) in a selected period (September–November) of 2022 and 2023. A lower $PM_{2.5}$ concentration was observed in 2023 compared to 2022 at Punjab and Haryana sites, in compliance with FDC reductions. Airmass trajectories, particle dispersion and chemistry-transport model simulations were conducted to depict the formation of air pollution events from CRB emissions. Through model sensitivity simulations, we estimated that only about 14% of $PM_{2.5}$ in Delhi-NCR was directly attributable to emissions from crop residue burning

(CRB) in Punjab during October-November 2022. The $PM_{2.5}$ model-observation comparisons, and day-night variations of $PM_{2.5}$ and CO indicates that the emissions from incomplete combustion are predominant in Delhi-NCR, which underscores the effectiveness of the Graded Response Action Plan (GRAP).

Impact of post monsoon crop residue burning on $PM_{2.5}$ over North India: Optimizing emissions using a high-density in situ surface observation network

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The impact of post monsoon crop residue burning (CRB) on surface $PM_{2.5}$ concentrations over the Punjab-Haryana-Delhi (PHD) region in North India was investigated using a regional meteorology-chemistry model, NHM-Chem, and a high-density in situ surface observation network comprising Compact and Useful $PM_{2.5}$ Instrument with Gas Sensors (CUPI-G) stations.

We optimized CRB emissions from November 1 to 15, 2022 using NHM-Chem and surface $PM_{2.5}$ observational data. The CUPI-G data from Punjab was found to be crucial for CRB emission optimization, as the CRB emissions in North India in October and November are predominantly originating from Punjab, accounting for 80%. The new emission inventory is referred to as OFEv1.0, with 12 h time resolution, in daytime (5:30-17:30 IST) and nighttime (17:30-5:30 IST). The total emissions in OFEv1.0, such as $PM_{2.5}$, organic carbon, and black carbon, were consistent with previous studies, except CO, which was overestimated. OFEv1.0 substantially boosted emissions, which were underestimated in satellite data due to clouds or thick haze on November 8 and 10, 2022. Large differences in optimized daytime and nighttime emissions indicated the importance of diurnal variations. Daytime emissions were larger than nighttime emissions on some days but not on others, indicating that diurnal variation shape may have differed each day. The mean contribution of CRB to surface $PM_{2.5}$ over PHD was 30%-34%, which increased to 50%-56% during plume events that transported pollutants from Punjab, to Haryana, to Delhi. Due to low performance of the meteorological simulation on November 8 and 9, 2022, emission optimization was not successful in the case of increased $PM_{2.5}$ concentrations observed in Haryana on these days.

The results of this study were obtained using a single transport model. Multi-model analysis is indispensable for better predictions and quantification of uncertainties in prediction results.

Modelling study for the heavy $PM_{2.5}$ pollution during the dry season in northwestern India

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The Aakash project conducted intensive field campaigns with the Compact and Useful $PM_{2.5}$ Instrument with Gas Sensors (CUPI-Gs) in the states of Punjab, Haryana and Delhi from

September to November in 2022 and 2023. It was found that $PM_{2.5}$ concentrations in this region rose above 400 µg m^{-3}. The highly polluted conditions in Delhi were sometimes associated with air mass transport from the Haryana and Punjab region. A regional air quality modelling system, WRF/CMAQ with emission inventories, HTAPv2.1, and GFASv2.1 reasonably simulated $PM_{2.5}$ concentrations over the Delhi-Haryana-Punjab region. During October to November, older versions of the modelling system significantly underestimated the observed $PM_{2.5}$ concentrations. The modelled sensitivity experiments required very high CRB emissions to explain the observed $PM_{2.5}$ in Punjab. The best model performance was found across all 30 monitoring sites when enhanced secondary organic aerosol (SOA) formation mechanisms were enabled in the updated model system. Based on this modelling study, we discuss the sources of the enhanced $PM_{2.5}$ concentrations and suggest that SOA may contribute up to 60% of the total $PM_{2.5}$ in the region during October-November 2022.

Impact of autumn crop residue burning emission estimations on $PM_{2.5}$ concentration over northwest India using WRF-Chem

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The October-November peaks in $PM_{2.5}$ levels across northwest India, particularly around the Delhi National Capital Region (NCR), are closely tied to crop residue burning (CRB) emissions from Punjab and Haryana. The precise impact of these emissions on $PM_{2.5}$ levels in Delhi NCR, however, remains debated due to meteorological factors, local emissions and government policies. To quantify this impact, the WRF-CHEM model was employed, incorporating CRB emission scenarios from the FINN biomass fire emissions (FINN v1) and EDGAR anthropogenic emission datasets for 2022 and 2023. By comparing scenarios with and without CRB emissions, the model assessed the varying levels of $PM_{2.5}$ at in-situ observation sites established under the AAKASH project at RIHN (https://aakash-rihn.org/en). This analysis provided a detailed understanding of the vertical and horizontal impact of CRB emissions on $PM_{2.5}$ concentrations across the region. Specific CRB emission plumes were identified, showing airmass transport towards Delhi for both years. The study also calculated the contributions of CRB emissions from Punjab and Haryana separately. These findings allow for a comprehensive quantification of the impact of CRB emissions and the evaluation of policy interventions targeting CRB hotspots, enhancing the effectiveness of strategies to mitigate air pollution.

Air pollutants flux calculation using FLEXPART-WRF

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Detecting hotspots, especially small ones, is essential to estimate the spatiotemporal variation of emissions from crop residue burning. For the estimation of $PM_{2.5}$ emission from crop residue burning in Punjab and Haryana, we have newly developed a method using the fire radiative power (FRP) detected by the Visible Infrared Imaging Radiometer Suite (VIIRS) instrument on Suomi and NOAA-20 satellites. The amount of daily emissions was estimated following the procedure of GFAS inventory. To eliminate double counting among two

instruments (Suomi VIIRS and NOAA-20 VIIRS), one of the pixels detected by two instruments on the same day was used to estimate the emission. The diurnal variation of $PM_{2.5}$ emission was estimated using the daytime (13:30LT) and nighttime (3:00LT) FRP ratio when VIRRS detected hotspot pixels within 375 m on the same day. The number of hotspots in Punjab and Haryana in October and November 2022 was compared with that by MODIS, and it was found that VIIRS hotspot was detected at 68 % of MODIS hotspots (12,445) within 1 km distance. The transport of $PM_{2.5}$ from hotspots was also estimated using the FLEXPART-WRF model simulation, and it was found that the model generally well captured eventual increases and diurnal variations observed by the CUPI network observation. FLEXPART forecast can be started within 3 hours after the satellite observation is available, and it would be utilized for the first-step analysis of observed variations.

Long-term and campaign-based measurements of volatile organic compounds in northwest India

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Northern South Asia is home to different air pollution sources, like many mega cities having very high vehicular emissions, coal-based power plants, large combustible industries, crop residual & domestic waste burning, forest fires, wetlands etc. The combinations of all these emissions sources are in proximity, thereby making it difficult to quantify their impacts. The pristine Himalayas, in this region, prevents dilution of these air pollutants and does not allow their passage to the wider areas and thereby the Himalaya region gets influenced. In this reference, ground-based observations of several trace gases (including greenhouse gases), aerosols and meteorological parameters and balloon-borne ozone observations are being made from ARIES, Nainital (29.4N, 79.5E, 1959 m amsl) in the Central Himalayas, since 2006. Observations of few trace gases and aerosols are being made at IGP sites to assess the sources region. Several field and mobile campaigns are also conducted in the Himalayan region (up to Munsayari) and IGP. Recently, a three days mobile field campaign is conducted for enroute (Nainital to Delhi to Nainital) observations of ozone and samples are collected for the analysis of volatile organic compounds. A 3-day campaign was conducted four times during January and February 2024 and the specific observations are also made in the National Capital Region (NCR) region.

Here, observed long-term changes in ozone, GHG, VOC, BC over the Central Himalayas will be presented. The influences of different emission sources, including biomass burning and meteorology are assessed in the long-term changes. Results from the mobile field campaigns in the much higher altitude (about 3500 m) remote regions of the Himalayas showed severely highly levels. The sample analysis from the recent NCR field campaign are yet to be completed. The preliminary analysis showed total VOCs value of more than 200 ppb in some region of NCR, while is it is only about 50 ppbv in enroute IGP site and about 10 ppbv at the mountain site (Nainital). A composition analysis suggests dominance of ethane in the Himalayan region, while propane/butane/acetylene showed dominance in IGP and NCR region. Health impact assessment is also being made and details will be presented.

Unveiling the effects of post-monsoon agricultural biomass burning on aerosols, clouds, and radiation in northwestern India

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The post-monsoon agricultural biomass burning activities in northwest India have been recognized as a significant socio-environmental problem in recent years, primarily due to their severe impacts on air quality degradation across a wide area, including the capital New Delhi. While these biomass burning activities have been extensively studied from an air quality perspective, their potential impacts on the climate system, particularly through their influences on cloud and radiation fields, have been largely overlooked. In this study, we aim to address this research gap by analyzing fire, meteorological parameters, aerosol, cloud, and radiation data spanning nearly two decades (2002-2021) obtained from satellite observations and reanalysis. Our analysis reveals a notable uptick in agricultural biomass burning intensity in northwest India over the past two decades, contributing significantly to air quality degradation. While the agricultural residue/biomass burning exhibit an increase in intensity and a delay in peak burning time (day number of the year), there is a paradoxical decrease in intense burning periods, suggesting evolving dynamics in agricultural practices. These agricultural biomass burning activities substantially elevate total and light-absorbing aerosol loadings, thereby influencing cloud properties and the radiation budget. The intensification of these burning activities coincides with an increase in cloud droplet size accompanied by a decrease in cloud optical thickness, indicating an enhancement of the cloud droplet collision-coalescence process during intense burning periods. Similarly, an increase in burning activities leads to an intensification of the overall cooling effects at the surface and top-of-the-atmosphere across both shortwave and longwave spectra, while inducing a heating effect within the atmosphere. These findings underscore the high potential impacts of agricultural biomass burning activities on the regional climate system and hydrological cycle, emphasizing the need for more detailed studies in the future.

Aerosol measurement using commonly-used camera and SNAP-CII algorithm: From Japan to India

Tomohiro Sato, National Institute of Information and Communications Technology (NICT), Koganei, Tokyo, Japan

Aerosol plays an important role for the radiative forcing, and also increases risk of morbidity and mortality. We developed the SNAP-CII algorithm to estimate the aerosol concentration from sky-photo images using machine learning technique. In this presentation, we show the observation results in Japan and perspectives to apply to India.

Analysis of the questionnaire survey about air quality and health – case of crop residue burning in Punjab

Kayo Ueda, Hokkaido University, Sapporo, Japan

Risk perception is a key component in the formation of attitudes towards policies on specific issues, as well as individuals' behaviors. Increasing number of studies have evaluated how people perceived air pollution and its health risks. However, these studies generally focused on urban air pollution and there are only a few studies examining the air pollution from agricultural burning. We examined the perception of air pollution and its health risks using questionnaire survey in Punjab where crop residue burning is pervasive. The survey was conducted in 22 districts of Punjab. Using a semi-structured questionnaire, the perception and knowledge about air pollution in Delhi and Punjab were inquired. The proportion of those who perceived the air pollution as "severe" varied by district. Various factors, both household- and district-level, were examined using multilevel modeling. The results are expected to enhance the understanding of air pollution-related health effects, encourage preventive actions, and promote sustainable agriculture among the local population.

Air Pollution and Climate Change: Connecting Communities for Sustainability and Better Health

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This talk focuses on motivating individuals and communities to fight against air pollution and climate change through community engagement and lifestyle modification. It highlights the evidence and cues for sustainable action that promotes health for all. Additionally, the talk underscores India's global initiative 'Lifestyle for Environment - LiFE', which focuses on the urgency of resolving the climate change crisis through human-centered 'mindful and purposeful utilization' of resources. By empowering individuals to join and nurture a worldwide community of eco-conscious people, known as 'Pro-Planet People', the talk promotes environmental stewardship at the local level. Further, In alignment with the mission LiFE, we aim to build a case study demonstrating how education activities and interventions can influence the behavior and perspective of vulnerable rural populations regarding air pollution due to crop residue burning and perceived health effects, ultimately fostering stainability and better health for all.

Impacts of crop residue burning on air quality and premature deaths in Punjab, Haryana and Delhi: A district level analysis

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Crop residue burning (CRB) contributes significantly to air pollution and related health burden in India. The northern states of Punjab, Haryana and Delhi see intensive episodes of CRB at the start of Rabi crop season i.e. October-November. Existing literature is focussed on modelling the resultant air pollution, weighing best residue management practices, benefits of shifting burning times etc. There are very limited studies on assessment of ground level health impact, specific to CRB pollution. As part of this study, we plan to estimate both short term and long-term health impact attributable to CRB at fine spatial scales. We estimate the district level $PM_{2.5}$ and crop residue specific health burden in the three problem states, which has not been explored before. The annual CRB attributable premature deaths are calculated using the MRBRT risk functions for five major diseases IHD, Stroke, COPD, Type 2 Diabetes and Lower Respiratory Infections. The annual district level $PM_{2.5}$ exposure and CRB share to total $PM_{2.5}$ are taken from the SAANS data and WRF simulations as part of the Aakash Project, respectively. We find that the CRB specific annual premature deaths are the highest in the districts of Punjab, counting more than 1000-1500 deaths in Ludhiana, Sangrur, Patiala, Firozpur and Amritsar. The short-term risk due to peaks in CRB pollution is estimated using existing meta risk functions. We find that daily peaks in CRB exposure could cause more than 20% increase in daily deaths in burning intensive districts. Our results will help highlight public health benefits of curbing crop residue burning in Northern India.

Structural variation in winter-time airborne bacterial communities enriched with pathogens: A study over New Delhi, India

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Structural variation of airborne bacteria plays a crucial role in understanding its effect on public health and climate change due to their substantial spatial and temporal variation by meteorological conditions, atmospheric chemistry, and air pollution. Current study presents the composition, diversity, and variability in urban airborne bacterial loading; samples were collected at 10m above the ground at two locations in a densely populated and highly polluted metropolitan city, New Delhi, India, from 09 January to 15 February 2024 to represent winter-time urban airborne bacteria. Illumina MiSeq platform was used to analyse the airborne bacterial samples with bacterium-specific primers targeting the v3-v4 region of 16S rRNA gene. Sampling sites were selected within the campus of Indian Institute of Tropical Meteorology (IITM, 28.63°N, 77.17°E); a site in close proximity of heavy traffic, and Jawaharlal Nehru University (JNU, 28.53°N, 77.16°E); a site isolated from local traffic and well within the local canopy. Ambient air samples were continuously collected for six hours duration, three times in a day during different weather conditions in winter season. According to meteorological conditions and pollution levels, total 36 samples are classified into four groups: low haze (Temperature = 11.4 ± 0.4 °C, $PM_{2.5}$ = 190.7 ± 8.8 μg m^{-3}), high haze (13.3 ± 0.7 °C, 278.9 ± 3.6 μg m^{-3}), wash out (16.9 ± 1.5 °C, 100.1 ± 22.9 μg m^{-3}), and seasonal transition (18.9 ± 1.0 °C, 187.6 ± 5.2 μg m^{-3}) days. Abundance of airborne bacterial loading over New Delhi varied strongly with air temperature (R^2 = 0.70, $p < 0.001$) and visibility (R^2 = 0.40, $p < 0.05$) with a strong positive correlation. However, Relative Humidity (R^2 = -0.41, $p < 0.05$), $PM_{2.5}$ (R^2 = -0.34, $p < 0.01$), and Air Quality Index (AQI) (R^2 = -0.31, $p < 0.05$) have a negative effect on airborne bacterial loading. Highest bacterial diversity was observed during high haze followed by seasonal transition, low haze, and wash out winter days over New Delhi. Beta diversities calculated based on Bray-Curtis dissimilarity distance formed separate ellipses exhibiting different atmospheric conditions; however, there was an overlap between low haze and high haze conditions, indicating a similar type of atmosphere

for survival of airborne bacteria. Human pathogens like Bacillus cereus, Acinetobacter lwoffii, and Clostridium sordellii, responsible for respiratory diseases and skin infections, are abundant over New Delhi. Present study highlights high loading of airborne pathogenic bacteria over most populated urban area in India, alarming for Indian public health.

Enhancing food security and mitigating greenhouse gas emission in smallholder farming systems in sub-Saharan Africa

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Smallholder farmers in sub-Saharan Africa face challenges in achieving food security. The need to identify practices that boost crop production without significantly increasing greenhouse gas (GHG) emissions is urgent. This review aims to identify such farming practices, assess their impact on GHG emissions, and propose strategies that enhance crop production and mitigate GHG emissions. Farmers often expand agricultural land, develop water harvesting and irrigation techniques, and increase cropping intensity and fertilizer use to improve crop production. However, these practices can alter carbon stocks and GHG emissions, creating a trade-off between food security and GHG mitigation. The primary source of GHG emissions in the region is the expansion of agricultural land at the expense of forests. Water harvesting and irrigation can increase soil organic carbon but can also trigger GHG emissions. Increasing cropping intensity can accelerate the decomposition of soil organic matter, releasing carbon dioxide. The use of nitrogen fertilizers can enhance soil organic carbon but can also increase nitrous oxide emissions. An integrated strategy for managing land, water, and nutrients is necessary to enhance crop production and mitigate GHG emissions. Agroforestry practices in degraded and marginal lands could serve as an alternative to expanding agricultural croplands. Proper water management through adequate rainwater harvesting and irrigation techniques, coupled with appropriate nutrient management, should be considered. A Land-Water-Nutrient Nexus (LWNN) approach can provide an integrated and sustainable solution for increasing crop production and mitigating GHG emissions. Implementing the LWNN approach faces various barriers, but these can be overcome by developing suitable technologies, disseminating them through farmer-to-farmer approaches, and formulating specific policies to address smallholder land tenure issues and encourage long-term investment.

Summary of the workshop and comprehensive outcome of Aakash Project

Prabir Patra (RIHN/JAMSTEC)

Aakash project consists of 3 working groups broadly - WG1 (Sustainable Agriculture), WG2 (Atmospheric Science) and WG3 (Public Health). Each of the WGs have performed significant number of surveys and data collection during the past 5-6 years, including the periods of pre-research and feasibility study, through field and paper surveys, laboratory experiments, in situ measurements, satellite data analysis etc. Our goals in the remaining 7 months of the project will focus on formal conclusions of each of the WG outcomes, and my effort to bring various components together to summarise the achievements of the Aakash project. I will present my view of the present status at the workshop based on the deliberations by our members and collaborating researchers.