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Earth Observation and Law Enforcement: Satellite Monitoring Against Crop Burning in Northwestern India

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Air pollution in northwestern India increases every year due to farmers burning crop residue in agricultural States, such as Punjab and Haryana.[1] Effective enforcement to curb the phenomenon has often been hindered by the scale of the country's territory, the remoteness of affected areas, and the high costs associated with deploying law enforcement officials to monitor these crimes. To address these challenges, India has tried to promote satellite technologies as a tool for environmental monitoring and enforcement. The advantages would be numerous. Satellites allow for large-scale observation with greater efficiency and accuracy, reducing the need for on-the-ground patrolling and related costs. This solution also enhances the ability to record data and compare them across years and geographical areas in a systematic way, facilitating the design of solutions that consider a larger oversight. However, when looking from space, one does not always get the whole picture as they would think.

Satellites' potential in India and operationalisation challenges

India has been a pioneer in satellite technology, becoming one of the earliest nations to enter the sector.

[1] Manish Swarup and Rishi Lekhi, "India's Capital Chokes as Air Pollution Levels Hit 50 Times the Safe Limit", in *AP News*, 18 November 2024, https://apnews.com/article/ae1ec1e6292009db198f18b113047cd5.

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The country's space programme saw its first major milestone in 1975 with the manufacturing of the Aryabhata, a satellite then carried into orbit by a Soviet rocket.[2] This was followed by the launch of the Rohini in 1980, carried out autonomously by the country, marking India's first fully independent satellite mission.[3] The long experience in the sector and the large number of research organisations also create opportunities for the use of satellite technologies also in other sectors, such as environmental monitoring.

India's remote sensing sector is highly advanced and the country has the capabilities to systematically deploy these tools. Indeed, in addition to the Indian Space Research Organisation (ISRO), which is among the largest space agencies in the world, the country hosts several research organisations focused on high-resolution satellite imagery, remote sensing and geographic information systems. Some of them are national agencies, such as the Indian Institute of Remote Sensing (IIRS), the Aryabhatta Geo-informatics and Space Application Centre (AGiSAC) and the Bhaskaracharya National Institute for Space Applications and Geo-informatics (BISAG-N), but there are also a number of state-level autonomous organisations, such as the Remote Sensing and Application Center (RSAC), in Uttar Pradesh, or the Kerala State Council for Science Technology and Environment, in Kerala. This distribution shows a high level of diffusion of expertise between the federal and state levels, creating opportunities for utilising satellites not just by central authorities.

However, despite opportunities for operationalisation, India has lagged in integrating these technologies into legislation and legal proceedings related to environmental crimes. Challenges lie in an outdated legislative framework, which has historically under-addressed environmental issues and has not integrated new technology. For example, due to a lack of amendments, the Wildlife Protection Act of 1972, a cornerstone of India's conservation policies, makes no reference to remote sensing technologies despite their growing relevance and use in the sector.[4]

Additionally, the country's multi-level governance complicates the designing of unified legislative, legal and enforcement frameworks to address environmental crimes. This is particularly relevant as these violations often span across multiple states and territories and do not have a single identifiable perpetrator. Regulations vary from state to state and can be quite discordant, while the federal level often shows constraints due to an overly bureaucratic central system.[5]

[2] ISRO website: *Aryabhata*, https://www.isro.gov.in/aryabhata_1.html.

[3] ISRO website: *Rohini Satellite RS-1*, https://www.isro.gov.in/RohiniSatellite_RS_1.html.

[4] Shubham Prakash Mishra and Shambhavi Thakur, "The Fault in Our Artificial Stars: Efficacy of Satellite Surveillance Systems in India's Conservation Efforts", in Sujatha S. Patil et al. (eds), *The Interface between Law and Technology*, Navrachana University and Gujarat National Law University, 2021, p. 4-18, http://27.109.7.66:8080/xmlui/handle/123456789/677.

[5] Louise Reardon et al., "Analysing Multilevel Governance Dynamics in India: Exercising Hierarchy through the Smart Cities Mission",

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As a consequence, designing a unified framework to operationalise satellite technologies for environmental monitoring may be quite challenging. Indeed, as satellite technologies are not systematised into legal proceedings against environmental crimes,[6] enforcement mechanisms scarcely rely on them. Decisions regarding requesting satellite data as evidence are left to individual judges or prosecutors. This discretionary approach leads to low reliance on remote sensing technology, as some judges may be hesitant to trust the validity or origin of satellite-derived data. Public prosecutors' concerns over the admissibility of such evidence and a general lack of technical expertise within the judiciary are traditionally elements limiting the role of satellite data in legal proceedings against environmental crimes.

In the past years, however, there has been a shift in this trend. In 2010, the National Green Tribunal (NGT) was established, a specialised judicial body dedicated to handling environmental disputes. The NGT was created to address environmental violations with more efficient and scientifically informed proceedings.[7] Given the nature of the cases brought before the tribunal – many of which involve environmental damages that require large-scale monitoring techniques – the NGT has been among the judicial bodies most actively requesting satellite data.[8]

Crop burning in Northwestern India and Supreme Court mandate on satellite monitoring

Judicial attitudes toward deploying remote sensing have also evolved due to high-profile environmental cases that have catalysed public attention. Among these major environmental issues, air pollution due to crop burning has increasingly drawn the attention of India's Supreme Court and sparked interest in using satellite monitoring to counteract it.[9]

Air pollution in India has historically provoked debate, but it caused particular outrage after reports linked the phenomenon to approximately 1.8 million deaths in 2015.[10] Annually, the country sees severe cases of air pollution in the months preceding winter. During this period, cold winds trap pollutants from multiple sources, including vehicle emissions, industrial

in *Territory, Politics, Governance*, Vol. 12, No. 8 (2024), p. 1217-1235, https://doi.org/10.1080/21622671.2022.2107559.

6 Ridhhi Choudhury and Agniva Bhattacharya, "Environmental Crimes: A Felony under Green Criminology", in *Indian Journal of Law and Legal Research*, Vol. 5, No. 2 (April-May 2023), p. 3827-3831, https://www.ijllr.com/post/environmental-crimes-a-felony-under-green-criminology.

7 Sudha Shrotria, "Environmental Justice: Is the National Green Tribunal of India Effective?", in *Environmental Law Review*, Vol. 17, No. 3 (September 2015), p. 169-188, DOI 10.1177/1461452915595548.

8 Based on an interview with a satellite data analyst working in the environmental conservation sector.

9 Shivam Patel, "India's Top Court Tells States to Stop Crop Burning as New Delhi's Air Turns Hazardous", in *Reuters*, 7 November 2023, https://www.reuters.com/world/india/indias-top-court-tells-states-stop-crop-burning-new-delhis-air-turns-hazardous-2023-11-07.

10 Ravindranath Prasad, "Most Pollution-linked Deaths Occur in India", in *The Hindu*, 3 December 2021, https://www.thehindu.com/article62033894.ece.

activity, construction dust, and, most notably, agricultural crop burning. Agricultural fires are particularly diffuse in the Northwestern States of Punjab and Haryana, where farmers burn crops left after the rice harvest in early November to quickly clear their fields before planting wheat. In some cases, this practice has been exacerbated by state policies. For example, in Punjab, the 2009 Preservation of Subsoil Water Act, which aimed at preventing groundwater depletion, mandates that farmers delay rice transplantation until mid-June, aligning with the arrival of monsoon rains.[11] As a result, the subsequent rice harvest is also delayed. With limited time for alternative disposal methods to clear fields before sowing wheat, farmers in Punjab have increasingly resorted to burning, intensifying the concentration of smoke across the Indo-Gangetic Plain and worsening air pollution in the nearby National Capital Region (NCR).[12] The World Health Organisation has repeatedly identified New Delhi as the world's most polluted city and in 2017, air quality levels were so low that Delhi Chief Minister Arvind Kejriwal referred to the Capital as a gas chamber.[13]

The Supreme Court has actively tried to mitigate the situation, invoking Article 21 of the Indian Constitution, which guarantees the right to life, and extending its interpretation to include the right to a clean and healthy environment.[14] Over the years, the Court has attempted to implement bans on crop burning in the northwestern states of Punjab, Haryana, and to a lesser extent, Uttar Pradesh.[15]

These measures have sparked political and social debates, with farmers opposing the high costs associated with alternative methods of agricultural waste disposal and the limited time to carry them out. Authorities have responded with a combination of punitive measures, such as fines for violations, and incentive-based approaches, including subsidies for alternative crop management techniques.[16] However, these subsidies have generally been regarded as insufficient and non-competitive, and state authorities struggle with

[11] Punjab Government, *Punjab Preservation of Subsoil Water Act, 2009*, 28 April 2009, https://www.fao.org/faolex/results/details/en/c/LEX-FAOC202088.

[12] Tianjia Liu et al., "Cascading Delays in the Monsoon Rice Growing Season and Postmonsoon Agricultural Fires Likely Exacerbate Air Pollution in North India", in *Journal of Geophysical Research: Atmospheres*, Vol. 127, No. 24 (27 December 2022), https://doi.org/10.1029/2022JD036790.

[13] Umair Irfan, "How Delhi Became the Most Polluted City on Earth", in *Vox*, 25 November 2017, https://www.vox.com/energy-and-environment/2017/11/22/16666808/india-air-pollution-new-delhi; and Chandrashekar Srinivasan, "Delhi a 'Gas Chamber', Says Arvind Kejriwal; Government Distributes Masks", in *NDTV*, 1 November 2019, https://www.ndtv.com/india-news/-50-2125560.

[14] Astutya Prakhar and Raj Shekhar, "Air Pollution and the Constitution of India: A Critical Analysis of the Right to Clean and Healthy Environment", in *Manupatra Articles*, 29 June 2020, https://articles.manupatra.com/article-details/Air-Pollution-and-the-Constitution-of-India-A-Critical-Analysis-of-the-Right-to-Clean-and-Healthy-Environment.

[15] Shivam Patel, "India's Top Court Tells States to Stop Crop Burning", cit.

[16] "Punjab CM Urges Farmers to Avail Subsidy Scheme to Curb Stubble Burning", in *Business Standard*, 6 October 2024, https://www.business-standard.com/industry/agriculture/punjab-cm-urges-farmers-to-avail-subsidy-scheme-to-curb-stubble-burning-124100600462_1.html.

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monitoring vast agricultural regions with a limited number of officials, who frequently encounter resistance from farmers, leaving the situation largely unchanged. This is again exacerbated by regional differences as states with limited resources like Punjab and Haryana struggle to both finance alternative solutions for farmers and to deploy high numbers of officials to patrol the area. Given these enforcement issues, the Supreme Court has turned to satellite solutions as both a tool for monitoring and a deterrence measure, believing that simply the knowledge that such surveillance exists may discourage farmers from engaging in illegal burning.

Discrepancy on the ground

In November 2024, the Supreme Court directed ISRO to collect satellite data on farm fires over Punjab and Haryana.[17] ISRO utilised data from NASA's orbiting satellites, including the Suomi NPP satellite equipped with the Visible Infrared Imaging Radiometer Suite (VIIRS) and the Terra and Aqua satellites operating the Moderate Resolution Imaging Spectroradiometer (MODIS).[18] These satellites pass over the NCR twice daily, detecting thermal anomalies indicative of active fires.

However, initial reviews of the satellite data revealed anomalies. The number of detected fires appeared to have dropped significantly compared to previous years. Closer analysis revealed that the decline did not correspond to an actual reduction in burnings but rather a discrepancy between the satellite data and on-the-ground realities.[19] Air quality assessments showed little to no improvement in pollution levels, confirming that the number of reported fires did not reflect the true extent of the problem.

The discrepancy can be attributed to the technical limitations of the satellites employed, particularly due to their orbital patterns. Indeed, ISRO's initial satellite monitoring relied on satellites that collected data on their scheduled passes over the NCR at around 10:30 AM and 1:30 PM. While two daily observations may seem sufficient, their fixed timing and the public availability of this information allowed perpetrators to adjust their practices. Farmers adapted by shifting their burning activities to other times of day outside of satellite observation windows, evading detection. Independent research conducted at NASA's Goddard Space Flight Center, and then utilised by the Supreme Court to show the extent of the discrepancy, proved these suppositions.[20] By using geostationary images obtained from the Korean GEO-KOMPSAT-2A satellite – which provides observations every

[17] Sophiya Mathew, "After SC Asks Centre to Procure Farm Fire Data from Geostationary Satellites, ISRO to Enhance Algorithms", in *The Indian Express*, 22 November 2024, https://indianexpress.com/article/cities/delhi/supreme-court-farm-fire-data-9683345.

[18] Adam Voiland, "Is Fire Activity Declining in Northwestern India?", in *NASA Earth Observatory*, 8 November 2024, https://earthobservatory.nasa.gov/images/153826.

[19] Ibid.

[20] "Daily Court Digest: Major Environment Orders (November 19, 2024)", in *Down To Earth*, 20 November 2024, https://www.downtoearth.org.in/governance/daily-court-digest-major-environment-orders-november-19-2024.

ten minutes, although at a lower resolution – it was confirmed that there was a rise in total burned areas.[21]

Looking ahead

As crop burning has now shifted in the afternoon to avoid ISRO's surveillance and overall fires may also have increased undetected, it is key to assess the flaws of a solution that in principle holds big potential but was so easily fooled. The main issue resided in a lack of integration between old and new strategies. A disproportionate faith in the technical tool and its preventive deterrence led to over-relying on it rather than using it to aid traditional patrolling. Thus, instead of simply dismissing these tools as failures, the next steps should focus on incorporating satellite data with on-the-ground enforcement.

An example of this integration is offered by the Mining Surveillance System (MSS). The MSS was developed by BISAG-N and the Bureau of Mines to identify illegal mining across the country.[22] While covering another category of crime, it offers an important blueprint on how to integrate on-the-ground patrolling and remote sensing that could be used to monitor agricultural fires as well. The MSS combines remote sensing technology with multi-layer analysis of mining leases, individuating instances of illegal mining activities outside the authorised areas and triggering alarms in real time directly to dedicated patrols to check the situation. This allows the deployment of units only when there is a reasonable suspicion of finding an infringement while directing them towards a specific location, therefore cutting personnel needed and reducing resources spent.

The MSS offers an example of satellite and patrolling synergy on which to build upon. To do so, there is a need to foster capacity-building between various actors, such as ISRO, other remote sensing organisations and law enforcement agencies, improving the accessibility and organisation of satellite data. This can be achieved by organising training courses for officials enabling them to develop the skills necessary to effectively utilise remote sensing data within their enforcement agencies.

The Indian case, with both its successes and shortcomings, offers lessons for others interested in using satellite monitoring to combat environmental offences, combining it with on-the-ground efforts. The Indian model highlights that the focus should be not only on data collection but also on sharing this data in publicly accessible, standardised and easily digestible formats, facilitating the integration of remote sensing into environmental enforcement. Additionally, users interested in promoting these tools should consider how widespread and effective coordination is between data analysts from research organisations and public authorities in their country. Similar efforts should be made to

[21] Adam Voiland, "Is Fire Activity Declining in Northwestern India?", cit.

[22] Indian Ministry of Mines, *Mining Surveillance System*, Lok Sabha Starred Question No. 346 answered on 17 July 2019, https://sansad.in/getFile/loksabhaquestions/annex/171/AS346.pdf?source=pqals.

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involve relevant ministries in the agricultural and resource sectors to foster environmental enforcement in other contexts too.

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