Satellite remote sensing-based analysis of agricultural stubble burning and its impacts on air quality in Haryana

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The present study assesses the agricultural stubble burning activities in Haryana, India, using satellite-derived enhanced vegetation index (EVI), fire counts and ultraviolet aerosol index (UVAI) data for the year 2024. Haryana, situated in the northwestern Indo-Gangetic Plain, is one of the states where the seasonal stubble burning following wheat and paddy harvests contributes significantly to regional air pollution. Using the monthly EVI, fire counts and UVAI analysis, we observe two separate periods of prominent stubble burning activities, during May and October–November. These months show very low EVI values close to 0, high fire counts (5746 and 2118 respectively) and UVAI values peaking above 1.0 in several regions in the state, directly related to the wheat (May) and paddy (November) harvesting seasons. In contrast, the monsoon season (July–September) is characterised by persistently low UVAI values, often below −0.75, indicating minimal aerosol loading due to reduced burning activity and effective wet deposition of particulates. Transitional months such as April (0.45) and October (0.80) show a gradual increase in UVAI, serving as precursors to the main burning phases. The December UVAI values show a steep post-burning decline from about 0.60 to −0.05 units, completing the seasonal cycle. Trajectory analysis indicates that during January and May, forward air parcel movements are directed toward the National Capital Region, potentially exacerbating the already severe air pollution in the area. Therefore, the present study demonstrates the seasonal cycle of stubble burning and its impact on the air quality of Haryana, and the potential of satellite measurements to be used for real-time monitoring of fire, smoke and pollution events for mitigating the pollution.

gaseous and particulate pollution in India and across the world[1–4]. Approximately one-fourth of global biomass burning activities, including household cooking, rural waste burning and wildfires is accounted for stubble burning practices, which also broadly encompass forest fires[5,6]. Stubble burning is a significant source of pollutants such as methane (CH_4), sulphur oxides (SO_x), particulate matter (PM_{10} and $PM_{2.5}$), nitrogen oxides (NO_x), carbon dioxide (CO_2) and carbon monoxide (CO)[7,8]. This practice is particularly common in South Asian countries like India, Nepal, Bangladesh, Pakistan and China[6,9]. Each year, during the post-harvest period, the crop residues are set to fire for quick removal of stubble[7]. In the Indo-Gangetic plain (IGP) of India, which covers states Punjab, Haryana, Uttar Pradesh and parts of Bihar and West Bengal, are the primary agriculture regions. Also, these regions are the major hotspots for AWB activities[10]. Mechanised harvesting in these regions leaves behind significant crop residues, which are often burned in open fields for quick preparation of soil for the next crop cycle[7,11].

In India, Haryana is an important region with high agricultural activity, urban development and specific seasonal weather systems. Frequent post-harvest fires, dust from the Thar Desert and emissions from urban centres of Gurugram and Faridabad together create a highly variable and challenging air quality scenario[12]. In Haryana, rice and wheat are sown during the period of June–July and November–December respectively, and then harvested in the following months of October–November and April–May respectively[13]. Following the harvest, farmers often go for in-field residue burning as it is a quick, cost-effective method for preparation of the field for the next cropping cycle[14,15]. Nevertheless, this seasonal practice of AWB, particularly, has been shown to severely deteriorate air quality in many regions. For instance, Srihari *et al.*[16] reported that