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MITIGATING AIR POLLUTION THROUGH AGRICULTURAL REFORM: COMPARATIVE ANALYSIS OF STUBBLE MANAGEMENT TECHNIQUES FROM CHINA, THAILAND, AND THEIR POTENTIAL APPLICATION IN INDIA

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Abstract
India is the second largest Agro based economy that generates a large amount of agricultural waste, including crop residues. In the absence of proper sustainable management practises about 92 metric tons of crop waste is burnt almost every year in India, leading to excessive particulate matter emissions and air pollution. Burning of the residue has become a major environmental problem, caused global warming as well as contributed to health issues. The government of India has attempted to curtail this problem through numerous measures and decided to promote sustainable management methods such as converting crop residue to energy.
However, a rapidly growing demand for food translates into a constant ramping up of yield production, which increasingly forces farmers to burn fields after harvest. What motivated me to take on this topic was the increased the pollution in Delhi. Burning paddy stubble has become a big issue for air pollution in Delhi and surrounding areas.
Every year during October and November, farmers in Punjab and Haryana are blamed for polluting the Delhi air by burning stubble. The state governments have imposed a penalty of Rs 2,500 per acre to dissuade farmers from burning stubble, but this has not deterred the farmers in both Punjab and Haryana.
Let us look into why these farmers opt to burn the stubble instead of managing it scientifically. They only have a window of about a month between harvesting rice and planting wheat, earlier, farmers used to manually cut the rice, with this method, the rice stalk would be cut close to the ground, but now, they use a machine called the combined harvester. It leaves a foot-and-a-half-long paddy stalks in field, which the farmers burn, furthermore, we have talked about what is stubble farming, what are its effects and what are some cost-efficient methods that are undertaken in Thailand and china. Methods used in Thailand include free gazing ducks in paddy field and rice straw compacting, and China includes subsidies and straw return. Thailand has used methods from a more ecocentric point of view while China has used opted for methods from a more technocentric point of view.

Key words*: India; agricultural waste; crop residue; field residue; process residue; crop residue burning*

Introduction

Stubble burning can be defined as the intentional incineration of stubbles by farmers after crop harvest. Stubbles are the cut stalks left on the field after the grains of cereal plants or stems of sugarcane are harvested. A large amount of the stubble generated is set to fire on the field itself. One of the major contributors to atmospheric pollution is stubble farming releasing particulate and gaseous pollutants that have severe impacts on environment and human health

The yearly practice of "stubble burning" in Northern India has far-reaching effects. Delhi, some 250 kilometres away, once again faces dangerous levels of smog as farmers burn off their fields to prepare for the next crop. It's a major cause of air pollution in the country.

Winter has been linked to biomass burning as it matches with the stubble burning periods. In India, New Delhi, and other cities, mainly the national capital regions have been experiencing harsh pollution from s caused by various anthropogenic activities and low temperatures during winter. Apart from contributing to air pollution, burning the stubble also deteriorates soils, long-term productivity. about 2.5 to 3 metric ton paddy straw contains 1/3 of nitrogen and sulphur 75% of potage and 25%, phosphorus, present and strong when contacted with heat and oxygen due to burning results in emission of harmful oxides in the environment. The problem of acute respiration, infection (ARI) is particularly increasing in children due to higher respiration rate among children. The poisonous gas carbon monoxide, which is released due to paddy burning when reacted with red particles, reduces the blood efficiency to take oxygen and generates respiratory problems. A recent study found that 12.5% of the total debts in India in 2017-18 were attributable to air pollution.

A farmer needs to spend around Rs 5,000 to Rs 6,000 per acre if he uses Super-SMS and Happy seeder machines. This is much more expensive than burning his field and paying Rs 2,500 per acre as penalty to the government. Punjab has only 7,500 Super-SMS fitted harvesters. These can only cover about 30 per cent of the total 2.8 million hectare of area under paddy cultivation in Punjab. In 2017, 50 per cent subsidy was announced for farmers wanting to buy Happy seeders, but the same year, the cost of a Happy seeder increased from Rs 90,000 to Rs 1,70,000 management practices.

As the combined harvester collects the paddy, the Super SMS cuts the straw and spreads it evenly around the field but, there is a catch here. The catch being if the super SMS is used along with the combined harvester, the farmer must use another machine called Happy Seeder. The Happy Seeder is a tractor-mounted machine that cuts and lifts the remaining stubble and drills the wheat seeds into the soil. It then deposits the straw over the sown area as a mulch cover. Furthermore, we are going to be talking about cost efficient method that can be used to reduce the excessive particulate matter emissions caused by the burning of crop residue and why they have not been implemented in India. We are also going to talking about the downsides of the methods.

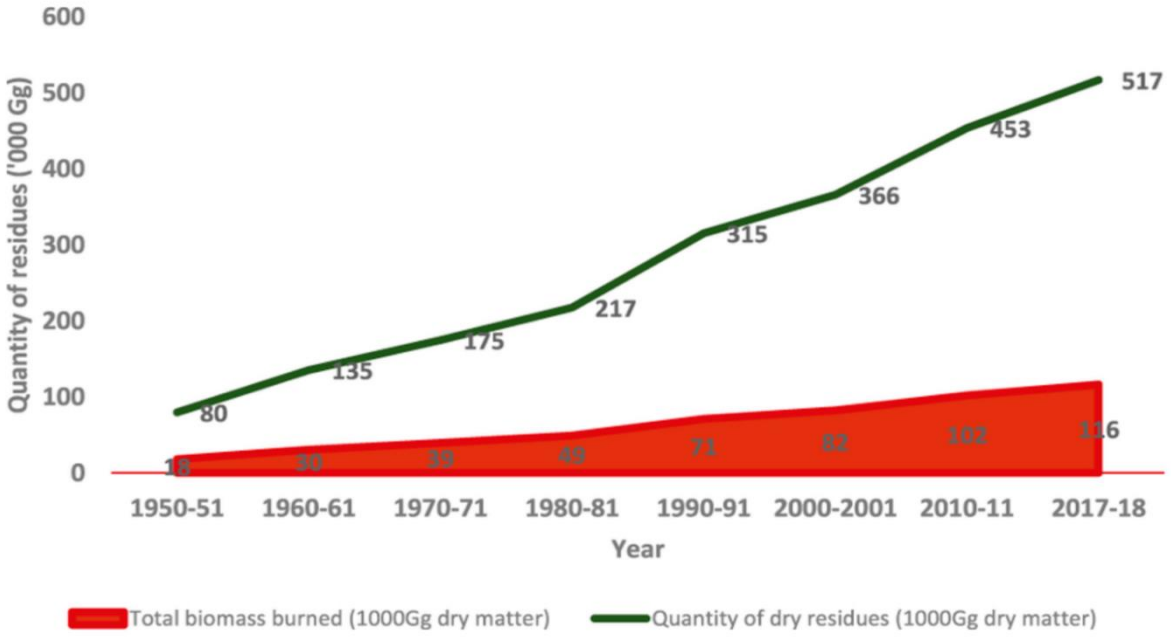
Stubble farming and its effects

Crop stubble is the straw and crown of plants left on the soil surface after harvest. Stubble also includes straw and chaff discharged from the harvester. It is also known as 'residue' or 'trash'. It is a significant source of gaseous pollutants such as, carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NO_x), sulfur oxides(SO_x), and methane (CH_4) as well as particulate matters (PM_{10} and $PM_{2.5}$) causing serious damage to human health and the environment. It was reported that the burning of 63 Mt of crop stubble releases 3.4 Mt of CO, 0.1 Mt of NO_x, 91 Mt of CO_2, 0.6 Mt of CH_4 and 1.2 Mt of PM into the atmosphere.

Burning, the residue leads to loss of nutrients and resources, apart from the deteriorating the air-quality, the flames, cross soil, nutrients, loss of organic carbon, nitrogen, phosphorus and potassium and discharges volumes of various air pollutants and particulate matters. The government encourages farmers for alternate practices like using the agricultural waste for animal folder for the generation of electricity, growing mushroom, and paper industry. The farmers from Punjab and Haryana cannot do anything about the situation as there are no practical alternative available to them to clear the fields but burning. On an average burning the stubble also causes itchiness in eyes, minimise respiratory organ performance and Irregular heartbeat and similar alternative smoke connected issues. The pollutants are toxic, and some are teratogenic in nature, causing respiratory, inhalation asthma, and can even worse symptoms of bronchi attacks. In addition to emission of air pollutants and the associated health affects the living organisms. The fertility of the soil also decreases over a period. Indiscriminateincineration of these remnants has led to numerous ecological hazards, including substantial dispersal of particles in the air and the release of gases that contribute to the greenhouse effect [1]. It has been reported that the combustion of 116.3 Teragrams (Tg) of agricultural remains resulted in the emission of approximately 176.1 Tg of carbon dioxide, 10 Tg of carbon monoxide, 313.9 Gigagrams (Gg) of methane, 8.14 Gg of nitrous oxide, and 151.14 Gg of ammonia. The potential ramifications of these consequences hold the ability to impact the overall composition of the Earth's atmosphere as well as the chemical makeup of the environment.

Crop burning statistics of India 1950-2018

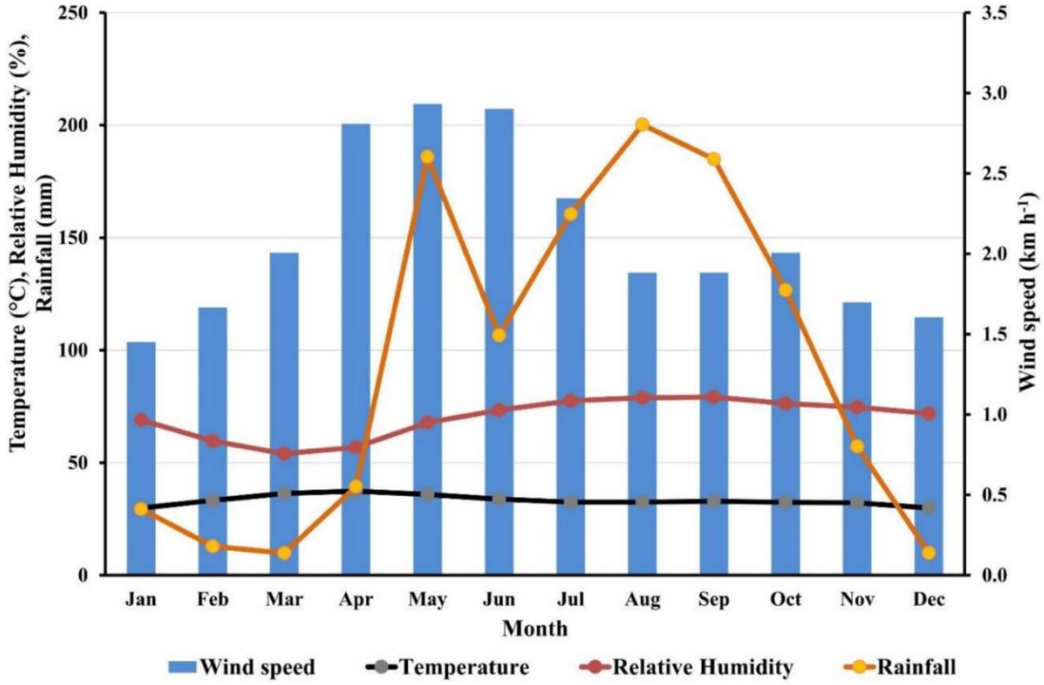
As seen in two figures, the given linear regression graph represents the total biomass burned and quantity of dry residues from the year 1950 to 2018. as seen in the model, the graph seems to be progressing every year which is not a good sign the total wires burn in 19 50-51 is 18,000 g of dry matter however over the period of 68 years the total biomass burnt comes out about 517000 gms having a difference of about four 99,000 g. Analysing the quantity of dry residue burned in 1950 which is about 80,000 g progressing to about 517,000 gms In the year 2017 to 18, having a difference of about 437,000 gms.



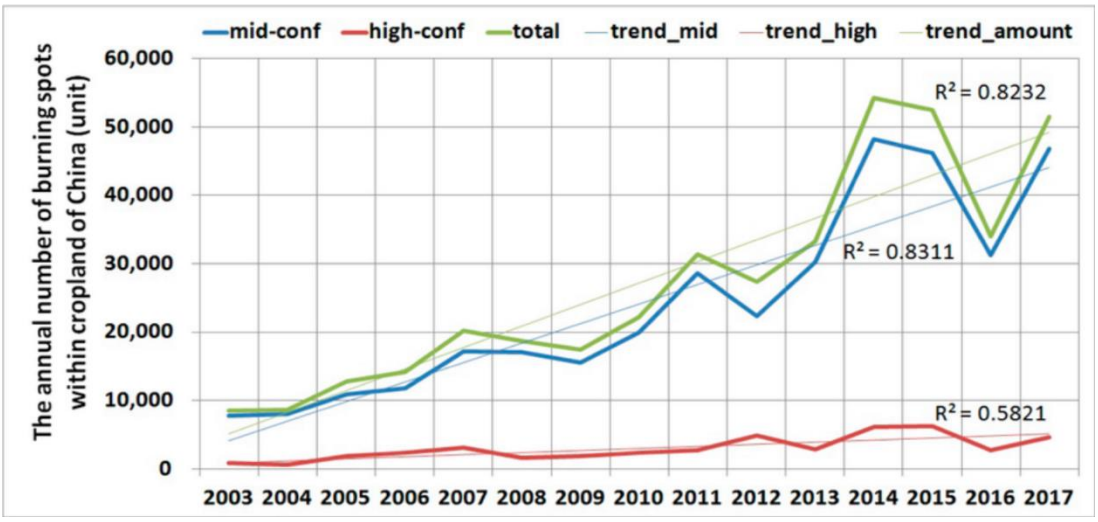
Air pollutant emissions from agricultural burning in Mae Chaem basin, Chiang Mai province (Thailand) during the 2012-2017

The given data collected during the period of 2012 to 2017 shows that the monthly average rainfall range from 9.8 mm to 200.2 mm. The average, relative humidity and wind speed range from 54% to 79% and 1.5km h do it loudly I want and 2.9 h accordingly. as seen in the

figure, the rainfall peaked in the month of August, which up to 200 m of rate while the temperature stayed moderate ranging from 30°C to 37.5°C. important parameter is PM, especially $PM_{2.5}$ that causes the negative effects on human health (such as impeded breathing, chronic asthma and lung cancer), visibility, radiation and climate change.



Crop burning statistics of China between 2013-2017



As seen the figure where the high concentration of annual number is of burning sports with crop plant of China however, it does maintain a stable equilibrium from the year 2013 to 2017, the highest point being in 2014 at 54, 000 units. However, the total concentration increased rapidly from 2003 to 2014 and then dropping to 31,000 in the year 2016 and then rising again in 2017, the approximately 51,000 units. Seen in the figure the difference in the units between 2003 and 2017 (9000-51,000) is approximately 42,000 units. The trend can also be seen increasing through the years.

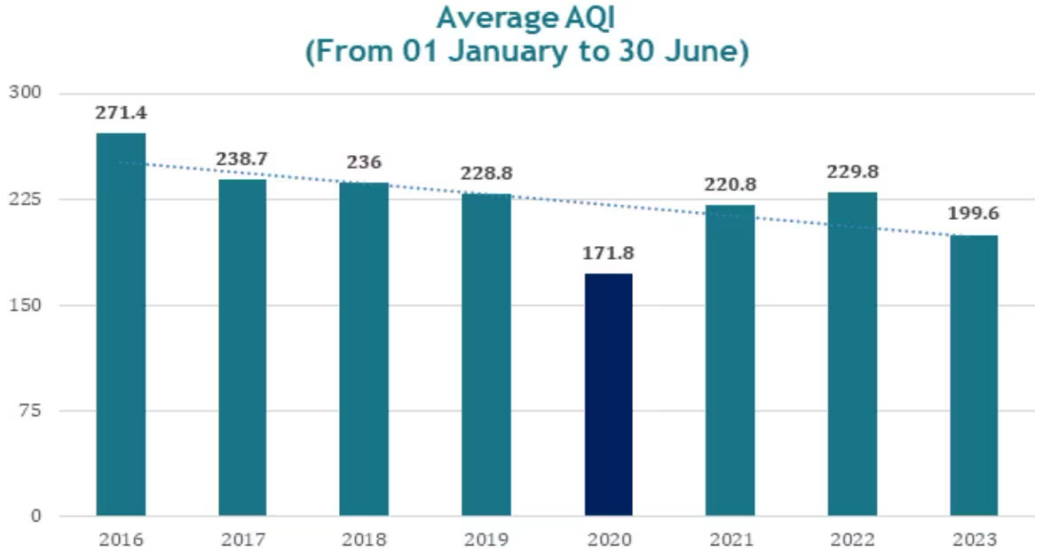
Method used in India to combat Stubble farming

1.1 Open burning

Each year in late September and October, farmers, particularly from Punjab and Haryana, burn an estimated 35 million tons of crop residue from their paddy fields after harvesting, as this practice serves as a low-cost method of disposing of the straw while reducing the turnaround time between harvesting and sowing for the second (winter) crop. However, burning the residue not only leads to the loss of nutrients and resources but also deteriorates the ambient air quality, causing soil nutrient loss. Additionally, the gases released have toxicological properties and are potential carcinogens, and the high levels of CO2 and CO in animals' blood can convert normal haemoglobin to deadly haemoglobin, potentially decreasing the yield of milk-producing animals.

Pollution in Delhi

In the first half of 2023, Delhi has observed the lowest levels of daily average PM10 and PM2.5 concentration compared to the same period in the last seven years (excluding 2020, which was affected by the Covid-19 lockdown). This indicates a significant improvement in air quality in terms of particulate matter pollution. During the period from January to June this year, the average Air Quality Index (AQI) for Delhi has consistently remained in the Moderate category, which is below 200. This year, Delhi has recorded its lowest average AQI compared to the same period in the last seven years. Furthermore, Delhi has also experienced the fewest number of days witch ‘poor to severe’ air quality in 2023 compared to a similar period in the past seven years. The number of days has progressively decreased from 147 in 2016 to 80 in the current year 2023.



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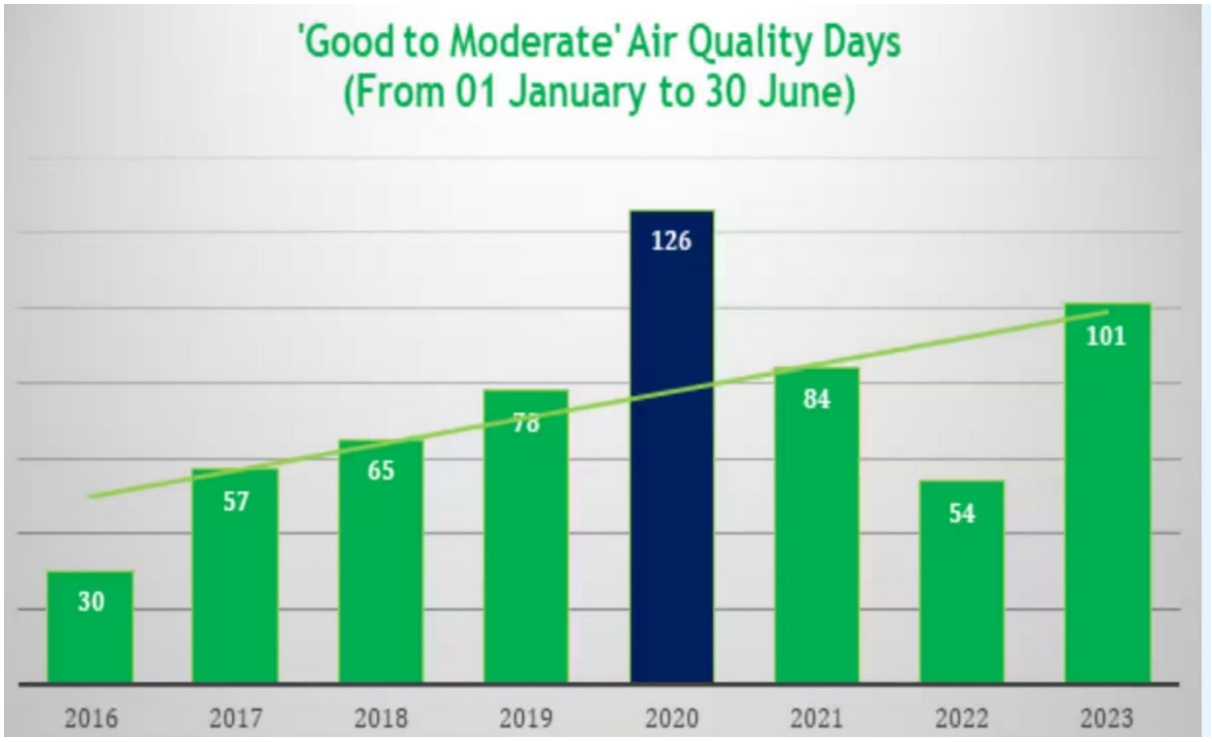

(https://www.hindustantimes.com/cities/delhi-news/delhi-air-quality-index-best-ever-during-first half-of-2023-in-past-8-years-since-2016-101688127398875.html)

Criteria for evaluating Crop residue management options

Crop residue management options are evaluated using criteria of productivity, profitability, environmental impact and sustainability. To implement and make decisions about residue management, it is necessary to understand the short- and long-term effects of crop residue and ways to develop residue management technologies that can be accepted environmentally and are cost efficient.

Crop residue management in Thailand

In Thailand, a stepwise multiple linear regression analysis was used to decode the psychological factors affecting farmer's rice straw ans stubble management. most of the respondents were male. Their average age, form, size, and levels of education were 51 years old 19. Five main and management practices were founded in the area consisting of compacting, free gazing ducks, mixed methods, burning and incorporating. The burning behaviours are in line with the supportive weather conditions for burning. The pollution control department also reported that open burning in agricultural forests produced vast smoke/haze during the dry season hence opted for different methods that included free gazing ducks in paddy field and rice straw compacting.

1.1 Free- gazing ducks

Free-grazing ducks are used in Thailand to keep rice paddies pest-free after a harvest. This traditional farming method involves releasing "field chasing ducks" into the paddies to eat golden apple snails and unwanted rice husks left from the previous harvest. The ducks also step on the rice stubble, flattening the ground and making it easier to plow. This integrated farming system is common in Thailand and other Asian countries, where small-scale farms are prevalent.

The ducks are brought to the rice fields after spending 20 days in a nursery and are raised on the move for the next few months. After roaming free for about five months, they are returned to the duck farm, where they produce eggs for up to three years.

This practice of having free-grazing ducks in paddy fields has been in place for about 1-2 years because duck farmers offered to raise ducks in the fields after the harvest and provide duck eggs in return. Additionally, farmers recognised the benefits of duck manure as a fertiliser, which nourishes their soil. These factors motivated farmers to adopt this approach, as it aligns with their farming values.

1.2 Rice straw compacting

Rice straw compacting is a practice that helps Thai farmers reduce costs. It involves the collection and compression of rice straw into bales of varying forms and densities. This process is essential for managing abundant rice straw in Thailand after harvest season. The compacting straw can be used for various purposes such as feeding livestock, which helps farmers save on management costs.

Farmers who chose compact rice straw perceived the benefit of this option especially for generating income, reducing air pollution and saving costs for rice straw and stubble management and appropriateness for available resources in the area. Rice straw compacting is convenient and generates income for farmers because the private sector that buys straw directly

contact the farmers at their field and offers a price for rice straw, concluding that farmers get to decide whether they want to sell their paddy or not. Compacting can also be viewed as solution for as it helps reduce air pollution because there is no involvement of burning of the paddy. Farmers have stated that they will continue to use the method if in the future the private sector continues to buy their rice straw.

Crop residue management in China

Crop residue burning is particularly prominent in China, the world's largest crop residue producer, which produces about 600–800 Tg of crop residues per year, accounting for around 20% of total global production. On average, about 20–30% of crop residues are burned by Chinese farmers in the field after harvest. About 2200 Tg of crop residues, accounting for 22% of China's total crop residue production, were burned during 1996–2013. China in comparison to India is looking towards a more economic point of view.

1.1 Subsidies provided by the government

Subsidies are financial assistance given by the government to low-income workers to for various reasons including providing adequate wages, protect infant industries from foreign competition etc. the government of china has been providing subsidies and other policies to encourage farmers to retain crop residue. One type of subsidy agricultural machinery operation subsidies and agricultural machinery purchase subsidies have been provided to farmers who retain their crop residues in 10 pilot provinces including Hebei, Shanxi, Inner Mongolia, Liaoning, Jilin, Heilongjiang, Jiangsu, Anhui, Shandong, and Henan. Conducting a cost benefit analysis can also be really helpful, there is still a dearth of quantitative studies conducted at national or regional scales to analyse the benefits and costs associated with shifting from burning to retaining crop residues. This study attempts to fill gaps in the existing literature in China by combining biophysical simulations with economic analyses conducted at the national and regional scale.

1.2 Straw return

Straw return is a practice in agriculture where crop straw (stubble/residue) is retained in fields to improve soil quality and productivity. Straw return is an effective method for disposing agricultural residues. It not only utilises agricultural waste but also improves soil. Straw contains abundant organic matters, potassium, phosphorous, nitrogen and other trace elements, which is considered to be desirable fertilizer for crop growth. Information collected from this review proposed that straw return and straw biochar return or in combination with fertiliser is an applicable way for improving soil fertility and enhancing crop production. Straw return is beneficial to soil physicochemical properties and soil microbial features. The rice straw has positive impacts on crop growth. Straw could be regarded as an organic fertiliser and straw return could increase soil organic matter and enrich soil nutrients. Hence, straw return is also an important management tool for improving crop yield as well reducing chemical fertiliser application.

Conclusion

A growing demand for food results in a constant ramping up a field production, which increasingly forces farmers to burn fields after the harvest. The reason why farmers of to burn the stubble instead of managing it is because there is very less time period left for the next harvest. However, farmers do use happy Cedar machines that needs spending of around ₹5000 to ₹6000 per acre which is much more expensive than burning. Monitoring the crop residue burning using traditional measures. Include remote sensing as a technique capable of long-term and large-scale observations that has been applied in numerous fields. However, it becomes imperative to monitor crop residue burning. A type of wildfire occurring in cultivated areas through remote sensing, giving it a negative impact on air-quality, agriculture, production and economic development. The reason why free, gazing ducks in paddy fields. A method used in Thailand could not be implemented because it is not cost efficient to take care of the ducks and taking care of them adds to the budget of the farmers as it has an opportunity cost. Instead, the farmers opt for burning the paddy which has no cost, and the penalty is only about ₹2500 which is much cheaper than raising ducks and using them as a fertiliser to nourish their soil and to eat their paddy. Straw return, whereas that is practiced in China is also effective as not only utilise agricultural waste, but also nourishes the soil, the only problem that arises is that not many farmers are educated about such methods to combat stubble farming. Even if an initiative is taken to educate these farmers on such methods that are not only cost efficient, but also improve the fertility of the soil and nourish it then stubborn farming can be combated. However, providing such information to farmers is not only the time consuming but also has an opportunity cost. Farmers might also not follow these practices; hence the best possible solution is to provide subsidies (as followed in china) to the farmers as it will decrease their cost of production and will increase their production too. A cost benefit analysis can be beneficial too.

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