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Role of Agricultural Extension in Promoting Crop Residue Management Practices

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Introduction:

Agricultural ecosystems provide a variety of provisioning and regulating services, including food, fiber, soil fertility, and climate mitigation **(FAO, 2022)**. Crop residues, such as rice and wheat straw, are an essential resource for maintaining soil health, organic matter, and nutrient cycling. However, in many regions of India and other parts of the world, residues are often burnt in fields due to convenience, lack of awareness, or machinery constraints. Stubble burning leads to severe air pollution, loss of valuable nutrients, greenhouse gas emissions, and long-term degradation of soil health **(Singh & Sidhu, 2022).**

Sustainable agricultural practices, including proper crop residue management, soil conservation, water management, and crop diversification, can enhance soil fertility, improve nutrient uptake, promote biodiversity, and increase crop yields **(FAO, 2022)**. Agricultural extension plays a pivotal role in bridging the gap between research knowledge and farmer adoption, making it a cornerstone for promoting sustainable residue management practices. The production of crop residue in modern input-intensive agricultural practices was also linearly increased. Farmers often burn these crop residues in-situ, which leads to serious environmental impacts. burning of crop residues has a serious negative impact on human health as well as environmental consequences.

Crop residue management is a well-known and widely accepted practice for controlling various soil physical, chemical, and biological functions. Crop residues incorporate a large number of nutrients in the soil for crop production and affect soil water movement, runoff, and infiltration. In a conservation agriculture (CA) system, successful management of crop residues is an integral part, and the maximum benefit of CA can only be achieved with in-situ management.

Definition of Crop residue:

Crop residues, in general, are parts of the plants left in the field after crops have been harvested and thrashed or left after pastures are

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grazed. These materials have at times been regarded as waste materials that require disposal but it has become increasingly realized that they are important natural resources and not wastes.

Crop residue production in India:

India generates around 682.6 MT (dry weight basis) of residue biomass annually, with 58.6% generated in the kharif or rainy season (June-October), 38.9% in the rabi or winter season (November-April/May) and 2.5% in the summer/dry season. As per the data presented by **Jain et al. (2018),** Uttar Pradesh is the highest biomass-producing state (19.1% share) in the kharif season followed by Maharashtra (16.2%), Gujarat (8.8%), and Punjab (7.5%). For the rabi season crop, again Uttar Pradesh tops the list in biomass production (17%), followed by Madhya Pradesh (12.7%), Rajasthan (10.7%), and Bihar (8.5%).

Why do crop residues need proper management?

India is primarily an agrarian country, with agriculture employing 58% of the population. It is the world's second-largest producer of rice and wheat, resulting in significant agricultural waste. The main food crops in key Indian states such as Gujarat, Maharashtra, Haryana, Rajasthan, Punjab, and Uttar Pradesh are rice, wheat, and maize. In North Indian states, wheat is generally cultivated immediately after kharif rice, so the farmer gets very less time for making the land ready for wheat sowing after harvesting of rice that's why the farmers are forced to burn those rice residues to prepare the field. About 62% of all emissions related to stubble burning come from burning wheat and rice residue, and 20% come from burning sugarcane residue. Burning of agricultural leftovers in open fields not only contributes substantially to air pollution, but also deprives the farmers from generating revenue from alternate sustainable use of crop residues. Every year, India produces over 500 MT of crop waste, of which 100 MT are burnt **(Lan et al., 2022).**

Management of crop residues :

Crop Residue Management is a conservation technique that aims to reduce the number and intensity of tillage operations, including ploughing (primary tillage), Crop residue to keep residue on the soil surface. Its purpose is to prevent wind and water erosion **(USDA, 1997).**

In situ management options :

Proper monitoring of crop residue production:

Crop residue is a hidden treasure. Monitoring is an important part of crop residue management. It is an essential process to monitor the different types of crop residue produced on a farm, as well as the quantity of crop residue for possible use. Crop residue

production can be tracked using a variety of methods and tools, including remote sensing, satellite imagery, and ground-based surveys. Remote sensing is a useful tool for monitoring crop residue production on a large scale. It entails the use of satellites or aircraft to collect data on vegetation cover, biomass, and other factors related to crop residue production. This data can then be analyzed to estimate crop residue production and identify areas where residue management practices may need to be improved **(Cai et al., 2018).**

Mulching:

The word "mulch" is derived from the German word "molsch," which means "easy to decay" **(Lightfoot, 1994).** Mulching is an effective agricultural residue management strategy that can help to reduce soil erosion. Although there are a lot of mulching materials available to use, such as plastic mulch, soil mulch, and organic mulch, organic mulching using crop residue is quite effective due to its easy availability and low cost. Organic mulching is the practice of spreading crop residue on the soil surface to retain moisture and reduce soil temperature.

Ex situ management :

Composting :

Composting of crop residue involves transforming it into a nutrient-rich soil amendment. This process requires creating an ideal environment that facilitates the growth and activity of naturally occurring microorganisms that decompose organic matter. Composting is a practice that has been long established in India. In India, traditional method of passive composting involves stacking crop residues in piles or pits and allowing them to decompose over a long period of time. This method can be improved by turning the piles a few times, which enhances passive aeration and reduces required time **(Goswami et al., 2020).**

Mushroom cultivation :

Mushroom cultivation is a new field where crop residue is being used as a substrate due to its high cellulose and lignin content. Several studies have shown that crop residues can be used as a growing medium for mushrooms. **Khan et al. (2018),** for example, reported on the use of wheat straw, maize stalk, and rice husk as substrates for oyster mushroom cultivation.

Environmental Impact of Crop Residue Burning

Residue burning is a major contributor to environmental pollution. Smoke and particulate matter from burning residues contain carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), which are potent greenhouse gases. These emissions contribute to climate change and degrade air quality, leading to health issues such as respiratory problems, eye irritation, and cardiovascular

disorders in nearby communities **(Singh & Sidhu, 2022).**

Repeated burning also causes significant loss of soil nutrients, including nitrogen, phosphorus, and potassium, which reduces soil fertility. Burning can deteriorate soil structure, decrease microbial activity, and negatively affect soil organic carbon content, ultimately impacting long-term crop productivity. Residue management, therefore, is not only an agricultural necessity but also an environmental and public health priority.

Role of Agricultural Extension

Agricultural extension services are essential for promoting sustainable crop residue management. Extension personnel act as a link between research institutions, government policies, and farmers, providing information, training, and practical demonstrations. The role of extension can be categorized as follows:

1. **Awareness Creation:** Extension services educate farmers about the harmful effects of residue burning and benefits of sustainable residue utilization. Awareness campaigns, farmer field schools, and demonstrations help to farmers understand the long-term economic and environmental benefits.
2. **Technology Dissemination:** Modern machinery and in-situ management technologies, such as the Happy Seeder, Super Straw Management System (SMS), and zero-till drills, enable sowing the next crop directly into residue-covered fields. Extension services facilitate access to these technologies, often linking farmers to custom hiring centers or government subsidy schemes.
3. **Capacity Building:** Training programs, workshops, and field visits help to farmers acquire practical knowledge on residue incorporation, composting, mulching, alternative uses of crop residues for animal feed, bioenergy, mushroom cultivation.
4. **ICT and Digital Tools:** Mobile apps, SMS advisories, WhatsApp groups, and social media platforms have enhanced the reach and effectiveness of extension services. Timely information about machinery availability, weather conditions, residue management practices can now be delivered directly to farmers' phones.
5. **Behavioural Change Communication:** A key challenge is changing farmer behaviour. Many farmers continue burning residues due to convenience or lack of immediate economic benefit. Extension services promote participatory learning, farmer-

to-farmer knowledge sharing, and demonstrations of economic advantages to encourage adoption of sustainable practices.

Strategies for Effective Residue Management

Effective residue management requires a combination of technology, knowledge, supportive policies:

- **Participatory Extension Approaches:** Farmer field schools, demonstration plots, and participatory rural appraisal (PRA) methods help to farmers learn by doing and encourage peer-to-peer learning.
- **Government Policies and Subsidies:** Extension personnel guide farmers to access government schemes, subsidies for machinery, and support from Krishi Vigyan Kendras (KVKs) and farmer producer organizations (FPOs).
- **Integration with Sustainable Practices:** Residue management should be integrated with soil fertility management, water conservation, and organic farming practices for maximum benefits.
- **Youth and Women Engagement:** Training rural youth and women farmers enhances the spread and adoption of sustainable practices within communities.
- **Monitoring and Feedback:** Continuous follow-up and monitoring by extension agents help ensure adoption and allow adjustments based on local challenges.

Benefits of Residue Management

1. **Soil Health Improvement:** Incorporating residues improves organic matter, enhances soil structure, and supports microbial activity.
2. **Climate Mitigation:** Reduced burning lowers greenhouse gas emissions and contributes to climate-smart agriculture.
3. **Economic Benefits:** Farmers save on fertilizers, improve crop yields, and can generate additional income from residue-based enterprises like composting or bioenergy.
4. **Environmental Protection:** Cleaner air, reduced smog, and conservation of biodiversity are major environmental gains.

Challenges in Extension Implementation

- High initial cost of machinery for small and marginal farmers.
- Limited awareness about long-term benefits of residue management.
- Social and cultural barriers; traditional reliance on residue burning.
- Need for coordinated efforts among government agencies, NGOs, and

private sector for effective dissemination.

Conclusion

Agricultural extension is central to promoting crop residue management practices. Through awareness creation, technology dissemination, capacity building, and behavioral change initiatives, extension services help farmers adopt sustainable, eco-friendly practices. Effective residue management not only reduces environmental pollution and greenhouse gas emissions but also enhances soil fertility, crop productivity, and climate resilience. Strengthening extension systems, integrating digital tools, and linking farmers to supportive policies can ensure that sustainable residue management becomes a norm, contributing to a cleaner, healthier, and more productive agricultural landscape.

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