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Climate-Smart Agriculture and Animal Husbandry

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INTRODUCTION

Climate change has emerged as one of the most critical challenges affecting agricultural and livestock production systems worldwide. Rising temperatures, altered precipitation patterns, frequent occurrence of extreme weather events, water scarcity and the increasing prevalence of pests and diseases are adversely impacting crop productivity, livestock performance and the livelihoods of farming communities (IPCC, 2023). Agriculture and allied sectors are particularly vulnerable to these changes, especially in developing countries where a large proportion of the population depends on farming and livestock rearing for income and food security (FAO, 2023). Integrated crop-livestock production systems offer a climate-resilient and sustainable approach to address these challenges. In such systems, crop residues and by-products are utilized as feed and fodder for livestock, while animal manure serves as a valuable source of organic nutrients, improving soil fertility and reducing dependence on synthetic fertilizers (FAO, 2023). This complementary interaction enhances nutrient recycling, resource-use efficiency and farm profitability while increasing the adaptive capacity of agricultural ecosystems under changing climatic conditions (IPCC, 2023). Therefore, the integration of agriculture and animal husbandry plays a vital role in promoting sustainable food production and strengthening the resilience of rural livelihoods.

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Impact of Climate Change on Agriculture and Livestock

Climate change has emerged as a major threat to global agricultural and livestock production systems. According to the Food and Agriculture Organization (FAO), droughts alone have caused losses worth nearly USD 3.8 trillion in crop and livestock production over the last three decades, with more than 65% of agricultural losses attributed to drought events (FAO, 2023). Moreover, heat stress has reduced the overall agricultural total factor productivity by approximately 21% since 1961, equivalent to losing seven years of productivity gains (FAO-WMO, 2025).

Livestock production is equally vulnerable to climate change. Studies have shown that heat stress causes an average annual reduction of nearly 1% in milk yield, while dairy cows exposed to temperatures above 26°C experience a decline of 0.5% in milk production for every hour of heat stress (FAO, 2025). In addition, mortality rates in beef cattle may increase by up to 24% during severe heat waves, further threatening the economic stability of livestock-dependent households.

Importance of Integrating Agriculture and Animal Husbandry

The integration of crop and livestock enterprises improves the efficient utilization of farm resources and enhances the sustainability of agricultural systems. Crop residues can be recycled as animal feed, whereas livestock manure enriches soil fertility and lowers the requirement for chemical fertilizers (FAO, 2023). Research indicates that integrated crop-livestock systems enhance land productivity and nutrient cycling while providing additional income through milk, meat, eggs and wool, thereby reducing the vulnerability of farmers to climate-induced crop losses and strengthening livelihood security (Peterson *et al.*, 2020; Herrero *et al.*, 2021).

Emerging Innovations in Integrated Agriculture and Animal Husbandry for Climate Resilience

Recent advancements in integrated farming systems have highlighted the importance of combining crop production and livestock enterprises to sustain productivity under changing climatic conditions. Unlike conventional monocropping systems, integrated crop-livestock systems promote efficient utilization of natural resources, nutrient recycling and diversification of farm outputs, thereby improving both economic returns and environmental sustainability (FAO, 2023).

One notable example is the Integrated Crop-Livestock System (ICLS), which has been extensively adopted in Brazil under the "Low Carbon Agriculture Program". In this approach, crop residues are utilized as animal feed, while livestock manure is returned to croplands, improving soil fertility and reducing dependence on synthetic fertilizers. Research has shown that such systems can enhance land productivity by 20–25% and improve resilience against climatic variability compared with specialized farming systems (Peterson *et al.*, 2020; Carvalho *et al.*, 2022).

Another promising approach is the Silvopastoral System, which combines trees, pasture and livestock on the same land. Studies have demonstrated that tree cover reduces heat stress in animals, enhances carbon sequestration and improves biodiversity. In tropical regions of Latin America, silvopastoral systems have increased meat and milk productivity while simultaneously mitigating greenhouse gas emissions (Brunetti et al., 2025). The concept of Regenerative Agriculture coupled with Managed Grazing has also gained considerable attention. By integrating livestock with conservation agriculture practices such as minimum tillage and cover cropping, farmers can improve soil organic carbon, increase water-holding capacity and enhance drought tolerance. Long-term experiments indicate that

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regenerative systems are more resilient to extreme weather events and maintain higher productivity under water-limited conditions (Romanoski *et al*., 2025).

Several countries are now adopting Circular Bioeconomy Models, where crop residues and livestock wastes are transformed into biofertilizers and renewable energy through biogas production. Germany and China have successfully implemented such systems, reducing methane emissions and dependence on chemical fertilizers while promoting sustainable nutrient cycling (IEA, 2024). In addition, Precision Livestock Farming (PLF) technologies based on artificial intelligence, wearable sensors and automated monitoring systems are increasingly being used in Europe and North America. These technologies enable early disease detection, optimize feed efficiency and minimize heat stress, thereby improving animal productivity and welfare (FAO, 2023).

India has also introduced several climate-resilient initiatives. The National Innovations on Climate Resilient Agriculture (NICRA) project of ICAR promotes integrated farming systems involving crops, dairy, poultry, fisheries and agroforestry to minimize climate-related risks. Similarly, mixed crop-livestock systems practiced in smallholder farms across South Asia have been reported to improve nutrient-use efficiency and provide stable income under variable climatic conditions (ICAR, 2024).

Netherlands has pioneered the concept of Circular Agriculture, where livestock are fed primarily on agricultural by-products and food-processing residues, reducing competition between feed and food crops. Likewise, New Zealand is investing in methane-reducing feed additives and low-emission grazing systems to sustain dairy productivity while lowering greenhouse gas emissions.

These examples clearly demonstrate that integrating agriculture and animal husbandry through innovative and climate-smart approaches can enhance productivity, improve resource-use efficiency, and strengthen the resilience of farming systems. Such integrated models are likely to play a crucial role in ensuring sustainable agricultural growth and food security in the face of future climate challenges.

CONCLUSION

Climate change presents significant challenges to global food systems, but the integration of agriculture and animal husbandry offers an effective pathway toward sustainability and resilience. The complementary relationship between crops and livestock enhances resource efficiency, improves soil health, diversifies income sources, and ensures food and nutritional security. Climate-smart practices and sustainable livestock management further strengthen the capacity of farming systems to adapt to changing environmental conditions. Therefore, promoting integrated agriculture and animal husbandry is essential for achieving sustainable rural development, protecting natural resources, and securing the livelihoods of present and future generations in the era of climate change.

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