

Intercropping Systems for Sustainable and Climate-Resilient Agriculture in Rainfed Ecosystems

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Abstract

Rainfed agriculture faces significant production challenges due to unpredictable rainfall, soil degradation, pest infestations, and climate variability. The practice of monocropping often exacerbates these challenges by making crops more susceptible to failure and decreasing the efficiency of resource use. Intercropping, which involves growing two or more crops together in a specific spatial pattern, offers a viable approach to boost productivity, profitability, and sustainability in rainfed agricultural systems. This review discusses the principles, benefits, and practical applications of intercropping in both field and horticultural crops. By improving the use of land, sunlight, water, and nutrients, intercropping helps to minimize weed growth, soil erosion, pest problems, and environmental risks. Systems that incorporate legumes enhance soil fertility through the biological fixation of nitrogen. Additionally, the use of trap crops, barrier crops, and climate-resilient management practices enhances the ability of farming systems to withstand drought and other climate-related stresses. Implementing scientifically developed intercropping systems can greatly enhance yield stability, farm income, and ecological sustainability in the face of changing climate conditions.

Keywords: Intercropping, Rainfed agriculture, Resource-use efficiency, Climate resilience, Sustainable farming, Trap crops, Soil fertility

Introduction

In regions reliant on rain for agriculture, production is often constrained by erratic rainfall, deteriorating soil quality, pest and disease challenges, and increasing climate unpredictability. Farmers typically rely on monoculture systems, which heighten the risk to crops and can lead to inefficient use of natural resources. Continuously growing the same crop can accelerate nutrient depletion, increase weed problems, and make crops more vulnerable to both biotic and abiotic stresses.

Intercropping is an ecologically sound and economically viable cropping strategy in which two or more

crops are grown simultaneously on the same piece of land following a predetermined spatial arrangement. By integrating crops with complementary growth habits and resource requirements, intercropping enhances resource-use efficiency, promotes biodiversity, and improves overall system productivity. The practice has gained renewed importance in the context of climate-smart agriculture and sustainable intensification.

Principles of Intercropping: The success of an intercropping system depends on the proper selection and spatial arrangement of component crops to ensure efficient utilization of available resources while minimizing competition. The following principles should be considered when designing an effective intercropping system:

- 1. Complementary Crop Combination:** Cereals or millets should preferably be combined with leguminous crops to achieve complementary utilization of resources and to improve soil fertility through biological nitrogen fixation.
- 2. Differential Crop Duration:** Long-duration crops should be paired with short-duration crops so that resource demand is distributed over time, thereby reducing interspecific competition.
- 3. Contrasting Rooting and Canopy Characteristics:** Component crops should possess different rooting depths and canopy architectures to enable efficient exploitation of soil nutrients, moisture, and solar radiation from different ecological niches.
- 4. Minimization of Resource Competition:** Crop combinations should be selected in such a way that direct competition for water, nutrients, light, and growing space is minimized.
- 5. Maintenance of Optimum Plant Population:** The recommended plant density of the principal crop should be maintained to ensure that its yield potential is not adversely affected by the intercrop.
- 6. Botanical Diversity:** Crops belonging to different botanical families should be preferred in

intercropping systems to reduce pest and disease incidence and to enhance biodiversity.

- Compatibility of Agronomic Practices:** Component crops should have similar requirements for sowing time, irrigation, nutrient management, and other cultural operations to facilitate efficient crop management.

Adherence to these principles enhances resource-use efficiency, improves system productivity, reduces production risks, and contributes to the sustainability of agricultural production systems.

Agronomic and Ecological Benefits of Intercropping

- Efficient Resource Utilization:** Intercropping enhances the capture and utilization of sunlight, soil moisture, nutrients, and available space. Crops differing in growth duration and canopy architecture utilize resources at different times and depths, thereby improving overall system efficiency.
- Soil and Water Conservation:** The presence of multiple crop species provides better ground cover, reducing runoff and soil erosion. Improved infiltration and reduced evaporative losses contribute to enhanced soil moisture conservation, particularly in rainfed environments.
- Improvement of Soil Fertility:** Leguminous intercrops enrich soil nitrogen through biological nitrogen fixation. Root nodules containing Rhizobium bacteria convert atmospheric nitrogen into plant-available forms, thereby improving soil fertility and reducing dependence on synthetic fertilizers.
- Weed Suppression:** Crop diversification creates dense canopy cover and may exert allelopathic effects that suppress weed emergence and growth. Consequently, intercropping can reduce weed pressure and associated management costs.
- Pest and Disease Management:** Increased plant diversity disrupts pest colonization and reduces the spread of crop-specific pathogens. Intercropping often supports beneficial organisms and enhances biological regulation of pests.
- Microclimate Modification:** Tall crops provide shade and wind protection to shorter companion crops. Such modifications reduce heat stress, lower evapotranspiration rates, and create favorable microclimatic conditions for crop growth.
- Yield Stability and Risk Reduction:** Intercropping acts as a biological insurance mechanism against

climatic fluctuations. When one component crop experiences stress, the companion crop may compensate through better performance, thereby stabilizing overall productivity.

- Enhanced Economic Returns:** The combined yield of component crops often exceeds that of sole cropping systems. Diversified production reduces economic risk and increases profitability, particularly under uncertain environmental conditions.

Recommended Intercropping Systems for Rainfed Agriculture

Several intercropping combinations have demonstrated superior performance under rainfed conditions:

S.No	Intercropping Systems	Required ratio
1.	Groundnut + Pigeonpea	7:1/11:1/15:1
2.	Castor + Pigeonpea	1:1/2:1
3.	Groundnut + Castor	5:1/7:1
4.	Groundnut + Pearl Millet	6:2
5.	Maize + Pigeonpea	2:1
6.	Sorghum + Pigeonpea	2:1
7.	Pearl Millet + Pigeonpea	2:1
8.	Foxtail Millet + Pigeonpea	5:1
9.	Green Gram/Black Gram + Pigeonpea	6:1/8:1
10.	Cotton + Pigeonpea	6:1/8:1
11.	Cotton + Green Gram/Black Gram	1:2
12.	Cotton + Soybean	1:1
13.	Sunflower + Groundnut	2:4
14.	Sunflower + Pigeonpea	4:2

These systems efficiently utilize available resources while providing greater yield stability and economic returns.

Role of Trap Crops and Barrier Crops: Trap crops are strategically planted to attract insect pests away from the main crop, thereby reducing pest damage. Barrier crops function as physical or biological obstacles that limit pest movement and disease transmission.

The integration of trap and barrier crops into intercropping systems can significantly reduce pesticide

dependence and contribute to environmentally sustainable pest management.

Intercropping in Perennial Horticultural Systems: Young orchards provide substantial inter-row space during the establishment phase. This space can be effectively utilized for cultivating short-duration crops, fodder species, medicinal plants, and legumes. Such systems generate additional income, improve soil fertility, and enhance biodiversity without affecting orchard development.

Examples include fodder crops in amla orchards and ginger cultivation in papaya plantations.

Climate-Resilient Intercropping Strategies: Climate variability has increased the importance of resilient cropping systems. Intercropping contributes to climate adaptation by:

- Improving drought tolerance.
- Enhancing water-use efficiency.
- Reducing crop failure risk.
- Conserving soil moisture.
- Stabilizing farm income.

Complementary practices such as seed pelleting, water-harvesting trenches, raised-bed cultivation, and conservation agriculture further strengthen the resilience of intercropping systems.

Conclusion

Intercropping is a scientifically validated and environmentally sustainable approach to improving agricultural productivity in rainfed ecosystems. By enhancing resource-use efficiency, improving soil fertility, suppressing pests and weeds, conserving natural resources, and reducing production risks, intercropping significantly contributes to sustainable agricultural development. The adoption of appropriate crop combinations, along with climate-resilient management practices, can strengthen food security, improve farm profitability, and enhance the resilience of agricultural systems under changing climatic conditions.

Future Perspectives: The integration of precision agriculture, conservation farming, biological pest management, and climate-smart technologies with intercropping presents significant opportunities to enhance productivity and sustainability. Further research should focus on optimizing crop combinations, spatial arrangements,

nutrient dynamics and economic returns under diverse agroecological conditions.

References

Chandra Shekara, P. (2016). *Farmer’s Handbook on Basic Agriculture*. National Institute of Agricultural Extension Management (MANAGE), Ministry of Agriculture and Farmers Welfare, Government of India.

Das, A., Layek, J., Babu, S., Krishnappa, R., Devi, M.T., Kumar, A., Patel, D.P., Ramkrushna, G.I., Yadav, G.S., Sarika, K., Tripathi, A.K., Ghosh, P.K., and Prakash, N. (2019). *Intercropping for Climate Resilient Agriculture in North Eastern Hill Region of India*. Technical Bulletin No. 1. ICAR Research Complex for North Eastern Hill Region, Umiam, Meghalaya, India.

Indian Council of Agricultural Research (ICAR). (2025). *Transforming Indian Agriculture*. ICAR, New Delhi, India.

Kumar, A., Rana, K.S., Rana, D.S., Bana, R.S., Choudhary, A.K., and Pooniya, V. (2015). Effect of nutrient and moisture management practices on crop productivity, water-use efficiency and energy dynamics in rainfed maize–soybean intercropping system. *Indian Journal of Agronomy*, 60(1), 152–156.

Maitra, S. (2021). Intercropping: A low-input agricultural strategy for food and environmental security. *Agronomy*, 11(2), 343.

Pal, B. (2019). *Agronomy*. e-Krishi Shiksha / KrishiKosh, Indian Agricultural Education Repository. ICAR.

Reddy, G.R., Prasad, Y.G., Osman, M., Himabindu, T., Raju, B.M.K., Sudhakar, N., and Rao, C.S. (2015). Climate-resilient intercropping systems for rainfed black soils of Andhra Pradesh and Maharashtra. *Indian Journal of Dryland Agricultural Research and Development*, 30(1), 35–41.

Yadav, G.S., Das, A., Lal, R., Babu, S., Meena, R.S., and Datta, M. (2017). Conservation agriculture and intercropping for sustainable intensification in rainfed agriculture of India. *Indian Farming*, ICAR Publications
