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Promising integrated farming systems for dryland agro-ecosystems

K. A. Gopinath*, B. Bhargavi, V. Visha Kumari, G. Venkatesh and V. K. Singh

ICAR-Central Research Institute for Dryland Agriculture, Hyderabad, Telangana 500 059

Rainfed agriculture, predominant in arid, semi-arid and sub-humid regions of the country, plays a crucial role in sustaining the economy and food security of India. At present, about 51% of the net sown area is rainfed contributing to 41% of the total food production and supporting 40% of human and 60% of livestock population. Low agricultural productivity, soil degradation and other factors, both endogenic (e.g. land size, water, cultural, and demographic) and exogenic (e.g. weather, markets, and migration) are pervasive constraints in the dryland smallholder farming systems of India. There is a need to address agricultural productivity to meet the needs of the growing population and enable sustainable rural livelihoods in the dryland regions. The location specific integrated farming systems (IFS) are important and relevant especially for the small and marginal farmers as they are more resilient, productive and adaptive to climate variability. The IFS approach also has the potential to overcome multifarious problems of farmers including resource degradation, declining resource use efficiency, farm productivity and profitability.

Keywords: Dryland areas, Farm productivity, Integrated farming system, Sustainability

INDIA, being predominantly a rainfed country, relies heavily on the monsoon for its agricultural production. However, the erratic and often insufficient rainfall patterns pose significant challenges to farmers, leading to low and unstable yields. As a result, a substantial portion of the population, particularly in rural areas, remains vulnerable to food insecurity and poverty. Integrated farming systems (IFS) have emerged as a promising approach to address the challenges faced by rainfed agriculture. By synergistically integrating crops, livestock, and other enterprises, IFS can enhance resource use efficiency, diversify income sources, and improve overall farm resilience. Moreover, by enhancing soil carbon sequestration, reducing greenhouse gas emissions, and promoting biodiversity, IFS contributes to building resilience to climate change impacts and enhance ecosystem services.

Farming systems are highly location-specific depending on the natural resources available in a given agro-climatic situation. The success of an IFS and its sustainability depends entirely on strengths and weaknesses of the internal factors like natural resources (soil and water), farm size, availability of recyclable residues, labour and external factors such as market prices, infrastructure and the level of post-harvest processing. Development and adoption of location-specific rainfed integrated farming system modules would result in (i) *In-situ* recycling of organic residues including farm wastes generated at the farm to reduce the dependency on external inputs, (ii) reduction in cost of production through effective use of byproducts and enhanced input use efficiency, (iii) minimize risk associated with dependence on a single farming enterprise, (iv) conservation of natural resources, and (v) food security, employment generation, enhanced system productivity and income/unit area.

In India, rainfed farming systems are practiced in regions contrasting in climate, soil, water resources and biodiversity. The climate of rainfed-dryland farming ranges from arid, semiarid to subhumid, with mean annual rainfall varying between 412 and 1,378 mm. Length of the growing season ranges from 60–90 days in the arid regions to 180–210 days in the subhumid regions. The dominant soil orders in rainfed production systems are Inceptisols followed by Entisols, Alfisols, Vertisols, Mixed soils, Aridisols, Mollisols, Ultisols, and Oxisols. Hence, it is necessary for development and adoption of location-specific integrated farming system modules.

Watershed-based farming systems

In rainfed areas, rainfall is the only source of water and its efficient utilization is important for successful crop production. In the 1980s, ICAR-Central Research Institute for Dryland Agriculture (CRIDA) provided technical support to 30 of the 47 ICAR Model Watersheds and many alternate land use systems such as agroforestry, agri-horticulture and silvi-pasture systems which were developed to suit variable agroclimatic zones of the country. An initial evaluation of Model Watershed Programmes implemented by GOI-ICAR-State Departments during 1984-1988 at 47 locations across the country has clearly revealed the beneficial impact of watershed approach in terms of increased water availability (both surface and ground water), increase in productivity of crops, increase in the availability of fodder and fuel and generation of employment in rural (watershed) areas.

In regions with rainfall of 500 to 700 mm, the farming systems should be based on livestock with promotion of low water requiring grasses, trees and bushes to meet fodder, fuel and timber requirements of the farmers. In 700 to 1,100 mm rainfall regions, crop, horticulture and livestock based farming systems can be adopted depending on the soil type and the marketability factors. Runoff harvesting is a major component in this region in the watershed based farming system. In areas where the rainfall is more than 1,100 mm, IFS module integrating paddy with fisheries is ideal. There are several modules of rainfed rice cultivation along with fisheries in medium to lowlands of rainfed rice growing regions in the eastern states of India.

Alternate land use systems

Livestock and crop production are always intrinsically linked in risk prone rainfed farming. Agri-silvi-pastoral systems ensure supplementarity of resources, feed availability for livestock and food grain for farmers. Agri-silvi-pastoral system approach is an attempt to tackle fodder shortages in winter (December–February) and summer (March–June), which can help to meet the small ruminants' food requirements in addition to food grains for human consumption in rainfed areas. In a study at ICAR-CRIDA, Hyderabad, the Anjan tree (*Hardiwickia binata)* + finger millet + stylos and Indian rose wood (*Dalbergia latifolia)* + finger millet + stylos based agri-silvi-pastoral systems produced 1.32 and 1.28 t/ha of finger millet yield and 7.64 and 7.95 t/ha green fodder respectively, from fodder trees, finger millet straw and stylos together. These agri-silvi-pastoral systems ensured improved fodder availability from crop, legume and trees for small ruminants, improved soil health from fodder legume in wet season, grain availability for farmers from finger millet, and the fodder leaves from trees in the late dry season.

Agro-ecology-specific alternate land use systems/ agroforestry systems based on land capability were promoted for risk resilience and staggered income, biomass production, and ecosystem services. Co-cultivation of arable crops with *Prosopis cineraria* in arid region provided a good yield of arable crops along with a bonus yield of dry leaves and twigs (0.65-1.05 t/ha) and

Indian rose wood + finger millet + stylos system

fuelwood (1.8-2.6 t/ha) from the tree. A study conducted in hot arid region at Central Arid Zone Research Institute (CAZRI) demonstrated that production system consisting of arable crops (pearl millet, green gram, moth bean and cluster bean) with *Hardwickia binata*, *Prosophis cineraria*, *Ziziphus mauritiana* produced 2.50, 2.95 and 7.55 t/ha pearl millet equivalent yield compared to 1.77 t/ha under sole cropping. Thus, the IFS had 1.4 to 4.3 times higher yields than sole cropping.

The Agri-horti Integrated Farming System (IFS) designed by Indian Institute of Farming Systems Research (IIFSR), Modipuram for rainfed farming in Rajasthan demonstrates a sustainable agricultural model that integrates both crop cultivation and livestock rearing. This 2-ha system employs an innovative mix of crops and livestock to ensure not only profitability but also resource efficiency in the challenging rainfed conditions typical of the region. The cropping system includes a combination of pearl millet, green gram, dew gram, and cluster bean in a balanced 3:1:1:1 ratio. Additionally, the system incorporates Ber (*Ziziphus mauritiana*), a drought-tolerant fruit-bearing tree. The livestock component, which includes one cow and ten goats or sheep, plays a significant role in the farm's overall productivity. This integrated system produces 15 tonnes of agricultural output per year, resulting in a net income of ₹ 1.32 lakh annually. It also generates 350 man-days of employment each year, which is vital for improving the livelihoods of smallholder farmers in rural Rajasthan.

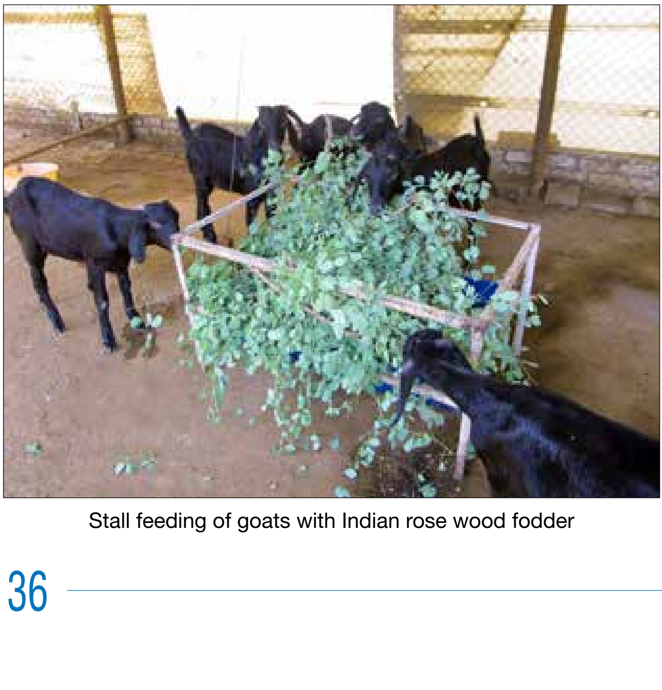
Livestock integration

Farmers in rainfed areas depend on livestock to augment income, and provide manure for soil and crops. However, the full potential of the livestock is not realized due to the non-availability of quality fodder. The deficit in fodder supply may be attributed to limitation in expansion of cultivable land as well as non-availability of fodder from the protected forest areas. It is possible to enhance the productivity of the livestock by crop-livestock systems. In a study at ICAR-CRIDA, Hyderabad, it was found that sorghum +

Sorghum + pigeonpea-hedge lucerne system

pigeonpea-hedge lucerne on average can produce 3865 kg/ha of sorghum grain equivalent yield and 37,820 kg/ha of sorghum fodder equivalent yield. The sorghum + pigeon pea-guinea grass would benefit the farmers with no animals, by selling the high biomass grass fodder and minimizing the risk of crop failure. These two systems are also help in providing green fodder for at least 8–9 months without any supplementary irrigation. There was reduction in runoff (by 51–52%) and sediment loss (by 52%), and reduced pest and disease incidence in these systems.

The integrated farming system model in dryland vertisols at Kovilpatti (Tamil Nadu) showed that crop + goat (4) + poultry (20) + sheep (6) + dairy (1) recorded the highest net income (₹17,598/ha/year) followed by crop + goat + poultry + dairy (₹ 14,208/ha/year), while the conventional system having crop cultivation alone gave a net income of only ₹ 2,057/ha/year (Table 1). The animal waste from cow (20-22 kg/animal/day), sheep and goat (400-450 g/animal/day) and poultry litter (40 kg/batch of 20 broilers) were collected and applied to the field, which resulted in improved soil fertility and crop yields. Employment increased from 185 man-days/ha/year in conventional cropping system to 389 man-days/ha/year in integrated farming system model.



Stall feeding of goats with Indian rose wood fodder

In Banaskantha district (Gujarat), in a rainfed farming system of 1.76 ha, introduction of improved crop varieties, integrated nutrient management, *in-situ* moisture conservation, mineral nutrition to livestock and cultivation of napier grass on bunds improved the system productivity by 18.8% compared to traditional farming system and gave higher net returns (₹ 92,444/year) and employment generation (353 man-days/year) compared to traditional farming system (₹ 77,800/year).

The 1.0 ha IFS model comprising of goat + crop developed for rainfed areas of Maharashtra integrates cropping, horticulture, and goats to optimize resource use and enhance farm productivity. The cropping system includes combinations like cotton, pigeon pea, soybean, cowpea and fenugreek. Horticultural activities involve a mixed orchard of custard apple and drumstick. Livestock comprises 12 goats, and 25 poultry birds and 5 rabbits, providing an essential source of manure, milk, meat, and eggs. This IFS model yields a total production of 51 tonnes per year and generates a substantial net income of ₹0.67 lakh annually. Employment opportunities are also significantly enhanced, with 951 man-days per year. The area share shows that cropping systems dominate with 80%, followed by livestock (10%) and horticulture (10%). This model underscores the importance of diversification, reducing risk while enhancing farm sustainability. Moreover, it is included in the zonal package for wider popularization among farmers through government initiatives and training programs.

The IFS provides an excellent opportunity to increase the small holders' income with the integration of crops + livestock + agro-forestry. The results of various studies conducted in arid and semi-arid regions of India have demonstrated that IFS had higher yields than sole arable cropping.

Location	Farming system	Productivity/ profitability
Jodhpur, Rajasthan	*CFS: Pearl millet IFS: Pearl millet + *Hardwickia binata* Pearl millet + *Prosopis cineraria* Pearl millet + *Ziziphus mauritiana*	1.77 t/ha 2.5 t/ha 2.9 t/ha 7.5 t/ha
Uttar Pradesh	CFS: Crops IFS: Crops + dairy Crop + dairy + horticulture	₹ 66,371/ha ₹ 103,615/ha ₹107,467/ha
Nagpur, Maharashtra	CFS: Cotton IFS: cotton + legume + Indian jujube (*Ziziphus mauritiana*) + custard apple (*Annona retieulata L.)* + Indian gooseberry (*Phyllanthus emblica*) + goatery	3 times higher net returns
Adilabad, Telangana,	CFS: Cotton + pigeonpea IFS: CFS + goatery + cow	₹ 65,000/ha ₹154,937/ha
Indore, Madhya Pradesh	CFS: Crops IFS: Crops + vegetables + cow	₹ 213,000/ha ₹ 891,180/ha
Kovilpatti, Tamil Nadu	CFS: Crops IFS: Crops + goat + sheep + dairy	7 times higher net returns

*CFS: Conventional farming system; IFS: Integrated farming system

In Anantapur district of Andhra Pradesh, integrated farming system involving crop production (groundnut + pigeonpea intercropping) and rearing of small ruminants (90 sheep and 30 goats) was found to be better with a net return of ₹1,57,855/year, than the other farming systems. In Adilabad district of Telangana, among the farming systems of marginal farmers, integrated farming system involving crop production (cotton + pigeonpea intercropping) and livestock rearing (4 bullocks, 3 *desi* cows and 1 buffalo) gave higher net return (₹ 40,180/ year) compared to others. Similarly, among the three farming systems of small farmers, integrated farming system involving crop production (cotton + pigeonpea intercropping) and livestock rearing (2 bullocks, 1 *desi* cow and 40 goats) performed better, with a net return of ₹ 89,937/year, compared to other farming systems.

SUMMARY

Climate change and climate variability are expected to adversely impact natural resources quality and agricultural productivity. The farming systems approach is considered as important and relevant especially for the small and marginal farmers as location-specific IFS are more resilient and adaptive to climate variability. The IFS approach also has the potential to overcome diverse problems of farmers including resource degradation, declining resource use efficiency, farm productivity and profitability. The case studies exemplify the efficacy of IFS, demonstrating a significant surge in farm income through a judicious blend of crop diversification, livestock integration, and water management strategies. On-station and on-farm research in different regions of the country has resulted in identification of a number of climate resilient and profitable IFS models for rainfed regions. These models need to be validated and replicated in respective domain areas. Although the advantages of IFS are well established, there are still several constraints in upscaling the IFS models. The most important is the location specificity of the models and declining family labour availability for farming.

*Corresponding author email: ka.gopinath@icar.gov.in