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Integrated sustainable farming model

for saline and sodic soils

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Saline and sodic soils significantly limit agricultural productivity due to their high salt and sodium content, which negatively affect soil health and crop growth. This article explores the effectiveness of integrated sustainable farming systems (IFS) in mitigating these challenges and enhancing farm productivity in affected regions. By combining crop diversification, efficient water management, livestock integration, and agroforestry, IFS promotes resource recycling, improves soil fertility, and maintains ecological balance. The adoption of these holistic practices results in enhanced biodiversity, climate resilience, and economic sustainability for smallholder farmers. Case studies from the Indo-Gangetic Plains highlight that enterprise diversification within IFS increases food and nutritional security, reduces environmental degradation, and boosts farm profitability. Despite challenges like limited funding and resource availability, integrated farming presents a viable solution for sustainable agriculture on saline and sodic soils, supporting both farmer livelihoods and long-term soil conservation.

Keywords: Climate resilience, Enterprise diversification, Integrated farming system (IFS), Nutritional security, Resource recycling, salt affected soils

SALINE and alkaline soils pose significant challenges to agricultural productivity worldwide. These soils are characterized by significant quantities of soluble salts as well as sodium ions, which adversely affect plant growth and soil fertility. Traditional farming practices often exacerbate soil salinity and sodicity, leading to reduced yields and environmental degradation. However, integrated sustainable farming models offer promising solutions to mitigate these challenges while promoting agricultural productivity and environmental stewardship. Saline and sodic soils are types of soil degradation characterized by high concentrations of salts. Saline soils contain soluble salts such as sodium chloride (NaCl), while sodic soils have elevated levels of exchangeable sodium ions (Na^+). These salts adversely affect soil structure and fertility, posing significant challenges to agricultural productivity.

Importance of addressing saline/sodic soils

- Ensuring the viability of agricultural land for future generations
- Mitigating the environmental impacts of soil degradation, including salinization of water bodies
- Enhancing the risk-bearing capacity of farming communities to climate change and market price fluctuation

Constraints of present agriculture

- Reduction in agriculture growth rate
- Reduction in factor productivity
- Increasing malnutrition
- Increasing environment pollution
- Increasing cost of production
- Depleting ground water table

Difference between IFS and mixed farming

IFS is that enterprise which is mutually supportive and depend on each other. Mixed farming system consists of components such as crops and livestock that coexist independently from each other. In this farming, integrating crops and livestock serves primarily to minimize the risk and not to recycle resources. Whereas in an IFS, crops and livestock interact to create a synergy, with recycling allowing the maximum use of available resources.

Advantages of IFS

***Enhanced resource efficiency*:** Integrated farming maximizes resource use by recycling nutrients, water, and energy within the system. Livestock waste serves as organic fertilizer for crops, reducing synthetic inputs, while crop residues feed livestock. Manure recycling and biogas generation further minimize waste. Diversifying crops and livestock improves land, labour, and capital use, boosting productivity and benefit-cost ratio. Water-saving practices like drip irrigation, rainwater harvesting, and recycling enhance efficiency, helping farmers manage scarcity and drought conditions.

Improved soil health and fertility: IFS improves soil health by adding organic matter and through crop rotation and cover cropping, which improve structure, nutrient cycling, and erosion control. Crop-livestock integration returns nutrients to the soil via grazing on residues and cover crops, boosting fertility. Agroforestry stabilizes soil, curbs erosion, and increases carbon sequestration, creating resilient soils. Efficient recycling of organic fertilizers, residues, and manure reduces synthetic fertilizer use and nutrient runoff, minimizing water pollution risks.

Biodiversity conservation: Integrated farming, by combining multiple crops, trees, and livestock, increases biodiversity on agricultural lands. This supports beneficial insects, pollinators, and soil microbes, strengthening ecosystem health and resilience.

Pest and disease management: Diversified farming disturbs pest and disease cycles by reducing monoculture and promoting ecological balance. Mixed cropping and habitats for beneficial insects provide natural pest control, minimizing chemical use. Livestock integration helps manage pests and weeds through grazing and interrupting their life cycles.

Climate resilience: IFS boost resilience to climate variability through diversified cropping and agroforestry, which protect against drought, floods, and temperature extremes. Conservation agriculture and water harvesting improve soil moisture retention, reduce runoff, and lessen climate change impacts on productivity.

Environmental conservation: IFS conserves biodiversity by creating diverse habitats through agroforestry, hedgerows, and riparian buffers, supporting varied plant and animal species. Reduced pesticide and fertilizer use lowers pollution and safeguards water quality, while prioritizing ecological balance and protecting natural resources from negative farming impacts.

Economic viability: IFS improve economic sustainability by diversifying income sources and lowering production costs. Alongside crop sales, farmers earn from livestock, agroforestry products, aquaculture, and value-added ventures like agro-tourism and farm-to-table sales. Reduced reliance on external inputs and efficient resource use increase returns and buffer against market and price volatility. Enterprise integration—crops, milk, eggs, mushrooms, honey, silkworm cocoons—ensures year-round cash flow.

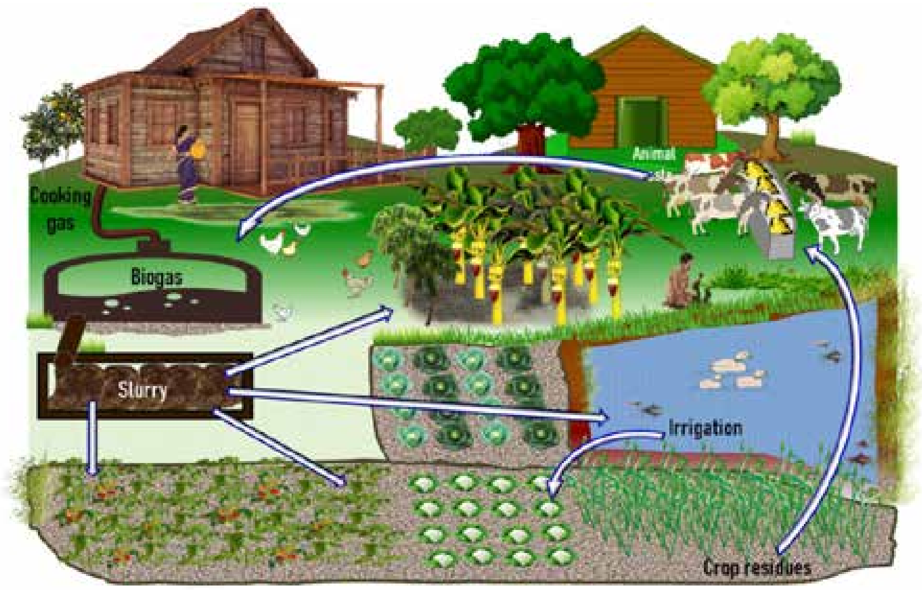
Community engagement and social benefits: IFS encourage community participation, fostering social cohesion and rural growth. Shared knowledge, resources, and labour help communities tackle challenges and improve livelihoods. Combining crops with livestock increases labor demand, reducing underemployment in rural areas.

Objectives of integrated farming systems

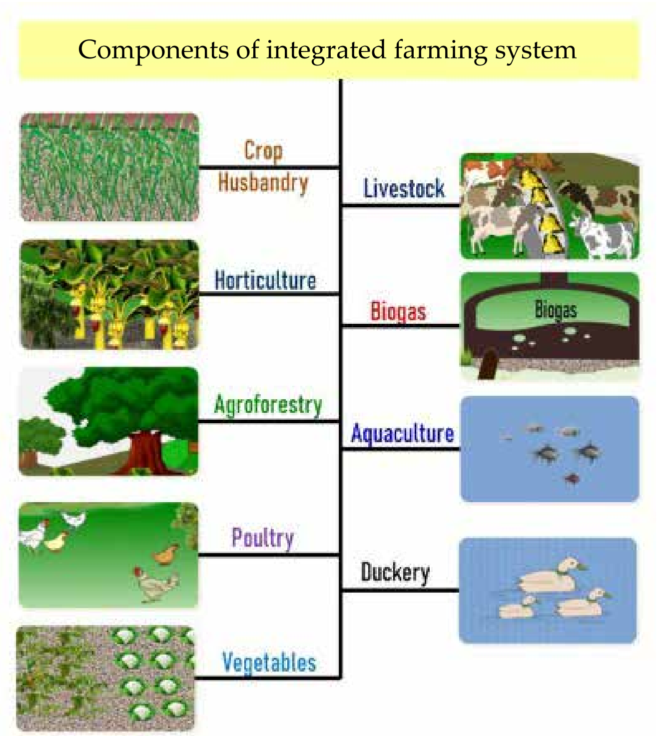
- To recognize the current farming systems, present in a particular area and evaluate their comparative viability.
- To develop farming system models that integrate primary and supplementary enterprises tailored to various farming conditions.
- To promote the optimal use and conservation of available resources while ensuring efficient recycling of farm residues within the system.
- To sustain production systems in a way that does not harm the resource base or the environment
- To enhance the overall profitability of farm households by harmonizing main and allied enterprises to complement one another.

Ideal situations for introduction of IFS

- When the farmer aims to enhance the quality of farm production.
- When the farmer's household is facing difficulties in affording sufficient food.
- When there is water storage available on the farm, such as ponds.



IFS model for smallholder farmers with around two-hectare land area



- When the farmer intends to maximize profits from the current landholding.
- When the farmer is motivated to minimize environmental pollution.

Table 1. Enterprises linked in different agro-ecosystem

Dry land	Dairy	Poultry	Goat/sheep	Agro-forestry	Farm pond	
Garden land	Dairy	Poultry	Mushroom	Bee Keeping	Piggery	Sericulture
Wet land	Dairy	Poultry	Mushroom	Fishery	Duckery	

Types of IFS

Crop-based IFS: Crop production is the main activity, complemented by livestock, agroforestry, or aquaculture to recycle organic waste, improve resource use, and boost productivity.

Livestock-based IFS: Livestock rearing is primary, with crops planned to meet fodder needs. Livestock improve soil fertility through manure recycling, provide meat, milk, eggs, and offer climate resilience, biodiversity enhancement, and income security. Examples: fish + crop, sheep/cattle + crop.

Tree-based IFS: Multipurpose trees are integrated with crops, livestock, or aquaculture to supply fuel, fodder, timber, and non-timber products. Trees support soil conservation, nutrient cycling, carbon sequestration, biodiversity, and diversified income, while enhancing environmental and social resilience.

Horticulture-based IFS: Incorporates fruits, vegetables, herbs, and ornamentals with livestock, poultry, aquaculture, or agroforestry. Offers higher yields, income diversification, biodiversity conservation, climate resilience, and improved rural livelihoods.

Principles of IFS

1. ***Diversification of crops***: Crop diversification, as opposed to monocropping, involves cultivating multiple species with varied nutrient needs and growth characteristics to maintain soil health. This approach breaks pest and disease cycles, improves soil structure, and strengthens farming system resilience to stresses such as salinity and sodicity. For instance, integrating salt-tolerant crops like quinoa, barley, or specific rice and wheat varieties alongside traditional crops can enhance soil management in saline or sodic areas.
2. ***Efficient water management:*** Efficient water management techniques in farming focus on optimizing water use, minimizing wastage, and preventing waterlogging that worsens soil salinity and sodicity. Methods such as drip irrigation deliver water directly to plant roots, reducing evaporation and salt buildup, while precision farming applies water only where and when needed to conserve resources. Proper water management helps mitigate salinity/sodicity effects, enhances crop productivity, and lowers agriculture's environmental impact. Techniques like rainwater harvesting and recycling supplement irrigation, reducing reliance on groundwater in saline and sodic regions.
3. ***Soil health improvement:*** Soil health improvement aims to enhance fertility, structure, and biological activity, which are vital for sustainable crop production. Techniques like composting, green manuring, and vermiculture increase soil organic matter, boosting nutrient and water retention. Healthy soils are more resilient to salinity and sodicity stresses and support diverse microbial communities that aid nutrient cycling and plant health. For example, incorporating cover crops and legumes in rotations fixes nitrogen, improves soil structure, and reduces erosion in saline/sodic conditions.
4. ***Integration of livestock:*** Integrating livestock into farming systems creates synergies between crop and animal production, enhancing nutrient cycling and soil fertility. Livestock supply manure that serves as organic fertilizer, improving soil structure and reducing dependence on chemical inputs. This integration not only boosts soil health but also diversifies farm income. Practices like rotational grazing on cover crops or fallow fields help evenly distribute manure while minimizing soil compaction, further supporting sustainable and productive farming.
5. ***Agroforestry practices:*** Integrating agroforestry into farming systems offers multiple benefits such as soil improvement, biodiversity conservation, and additional income sources. In saline and sodic areas, planting salt-tolerant tree species like *Tamarix* and *Populus* helps lower water tables, reduce soil salinity, and stabilize soil structure. For example, windbreaks or shelterbelts made of these trees can mitigate wind erosion, decrease soil salinity and

sodicity, and provide extra income through timber or fruit production. Overall, agroforestry contributes to long-term soil health, enhances climate resilience, and promotes sustainable land use practices in challenging saline/sodic environments.

Case study: Coastal farming community, Gujarat, India

This case study focused on a coastal farming community in Gujarat, India, facing challenges of high soil salinity due to proximity to seawater.The community adopted a multi-faceted approach involving crop diversification, efficient water management, and soil health improvement. Over a span of three years, the implementation of salt-tolerant crops such as quinoa and halophytes led to a noteworthy increase in overall crop yield. Drip irrigation systems and rainwater harvesting techniques were implemented, resulting in a 30% reduction in water usage while maintaining or increasing crop productivity. Additionally, the integration of agroforestry and livestock helped enhance soil fertility and biodiversity.

The implementation of integrated sustainable farming practices improved soil health as well as increased crop yield. Furthermore, it also increased the resilience of the farming community to climate change and market fluctuations.

Table 2. Enterprise mix diversification: An option for ecologically sustainable food and nutritional security of small holders in Indo-Gangetic plains

Crop components		Horticulture	subsidiary components		
Grain production	Fodder	Vegetables	Fruit trees	Livestocks/Poultrr	Fisheries
(1.0 ha) Rice *(Oryza sativa)* - Wheat *(Triticum aestivum)* (0.2) Rice-Wheat-Moong *(Vigna radiate)* Maize (*Zea mays*)- Wheat-Moong (0.2) Soybean (*Glycine max*)-Winter Maize (0.2) Pigeon pea (*Cajanus Cajan*)-Mustard (*Brassica spp.*)/Fodder maize (0.2)	(0.2) *Sorghum (Sorghum bicolour) - Berseem* (Trifolium alexandrinu (0.2)	(0.2) Cabbage *(Brassica oleracea var. capitata) - Tomato (Solanum lycopersicum)-Khira (Cucumis sativus)* (0.1) Bottlegourd (Lagenaria sicerarial)- Cauliflower (Brassica oleracea var. botrytis) (0.1) Potato *(Solanum tuberosum)-Onion (Allium cepa)-Okra (Abelmoschus esculentus)*	(0.2) Guava *(Psidium guajava)* + Papaya (Carica papaya) + Banana (Musa paradisiaca)	(0.2) 3 Buffaloes +2 Cows 120 Birds	(0.2) Catla Rohu Mirgal Common carp Grass carp

Source: Yadav *et al.* 2021

Table 3. Diversification of enterprise mix: An alternate for ecologically sustainable food and nutritional security for smallholder farmersof Indo-Gangetic plains

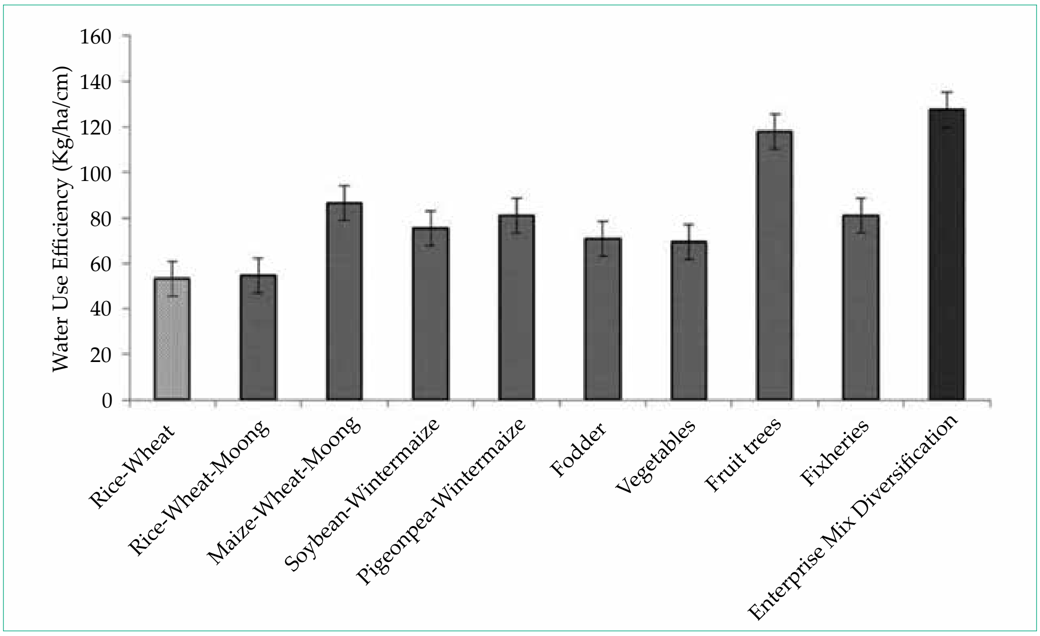
Component	Area (Ha)	Rice equivalent yield (t/ha)	Gross Income USS	Expenditure USS	Net Income USS	B.C. Ratio
Rice-Wheat	0.2	11.1	755	290	465	2.6
Rice-Wheat-Moong	0.2	12.2	833	302	531	2.8
Maizd-Wheat-Moong	0.2	*7.0*	479	180	299	2.7
Winter Maize-Soybean	0.2	*3.7*	250	99	151	2.5
Pigeon pea-Mustard-maize	0.2	*4.3*	295	134	161	2.2
Fodder	0.2	*4.4*	297	103	194	2.9
Vegetables	0.2	*6.4*	434	225	209	1.9
Fruit trees	0.2	*6.6*	451	108	343	4.2
Livestocks	0.2	*67.7*	4602	2070	2532	2.2
Fisheries	0.2	*9.3*	631	153	478	4.1
Enterprise mix diversification	2	*13.3*	9027	3664	5363	2.5

Source: Yadav *et al.* 2021

Table 4. Alterations in chemical and physical properties of soil underdifferent production systems after eight years of research

Cropping Systems	Year	pH2	EC(dS/m)	OC(%)	N (kg/ha)	P (kg/ha)	K	Sat. Hydr.	Cond. (cm/h)
Grain production	Initial	8.3	0.28	0.14	106.0	24.8	300.0		1.5
	Final	8.3	0.48	0.35	138.5	36.4	188.1		1.8
Fodder production	Initial	8.2	0.35	0.14	103.5	26.8	301.5		1.7
	Final	8.1	0.33	0.58	133.3	20.8	214.3		1.8
Horticulture production	Initial	7.9	0.41	0.14	121.0	24.2	379.9		1.8
	Final	8.1	0.30	0.98	128.1	39.8	253.1		2.0
Vegetable production	Initial	7.7	0.46	0.14	123.0	28.1	409.0		1.6
	Final	*7.7*	0.49	0.23	135.9	49.1	324.0		1.8
Pond dykes	Initial	*10.3*	4.00	0.14	55.3	15.0	213.5		1.8
	Final	*9.0*	0.93	0.35	120.2	18.9	294.8		2.0

Source: Yadav *et al.* 2021



Water use efficiency (Kg/ha/cm) of various components under enterprise mix diversification

Source: Yadav *et al.* 2021

Table 5. Credit worthiness of different components of IFS

Cropping systems	Cost of cultivation (Kg)	Total income (₹)	Net return (₹)	BC Ratio
Rice-wheat	5235	10103	4868	1.93
Forage	1198	2228	1030	1.85
Vegetables	2989	7472	4483	2.50
Fruit	3600	2100	-	1.70
Fish	16254	42840	26586	2.63
Total	29276	64743	36967	2.21

Source: Technical bulletin, CSSRI, Lucknow

Table 6. Yield and benefit cost ratio of different crop

Crop	Yield (Kg)	Expenses (₹)	Income (₹)	BC Ratio
Fish	1820	66000	163800	2.5
Potato	1000	3000	10000	3.3
Onion	400	1000	6000	6
Garlic	100	500	2000	4
Turmeric	100	500	2000	4
Maize	200	500	2000	4
Pigeon pea	40	500	2000	4
Total		72000	187800	

Source: Singh *et al.* 2014

Constraints in IFS

- Inadequate funds.
- Unavailability of animal supplements round the year
- Unavailability of labour.
- Lack of procurement of high yielding breeds of livestock.
- Non-availability of fish seed and feed timely.
- Low-cost energy efficient pumping machine.
- Lack of awareness to government schemes and credit support from financial institutions.

SUMMARY

Diversifying existing farming systems through changes in crops and cropping patterns, integrating and improving livestock, adding horticulture, introducing processing activities, and establishing boundary plantations can significantly improve the income of small and marginal farmers in India. Various IFS models have shown 2–3 times higher productivity and 3–5 times greater net returns, along with 40–50% resource savings, daily household incomes of ₹400–500, and 70–80% higher employment generation, while ensuring nutritional security. IFS offers progressive economic growth, employment, optimal resource use, and family nutrition, enhancing farmers' confidence by increasing productivity, profitability, and sustainability, especially for those with small holdings. Although numerous IFS models exist across the country, they remain insufficiently documented, highlighting the need for systematic recording and wider dissemination to benefit more farmers.

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