



Agriculture Farming Practices for Sustainability and Doubling of Farmers' Income in Dryland Agriculture

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10.18805/BKAP925

ABSTRACT

Background: Arid and semi-arid regions are characterized by low and erratic rainfall, high evapotranspiration, fragile soils and recurrent droughts, which severely limit agricultural productivity and farmers' income. Conventional farming practices often accelerate soil degradation, groundwater depletion and climate vulnerability, resulting in low productivity and unstable livelihoods. Sustainable agriculture has emerged as a viable strategy to enhance productivity, conserve natural resources, improve climate resilience and increase farmers' income through efficient resource utilization and diversified farming systems.

Methods: The study was conducted in Jaisalmer district of Rajasthan characterized by low and erratic rainfall, high evapotranspiration, degraded soils and frequent drought conditions during the year of 2025. The study evaluates major interventions, including water resource management, soil health restoration, crop diversification, integrated farming systems, agroforestry, renewable energy integration, climate-smart technologies, value addition and institutional support. The available evidence was critically analysed to assess their impacts on crop productivity, resource-use efficiency, production costs, farm profitability and livelihood resilience.

Result: It demonstrates that integrated adoption of sustainable agricultural practices significantly improves water- and nutrient-use efficiency, enhances soil health, increases crop productivity and reduces production costs. Practices such as micro-irrigation, rainwater harvesting, integrated nutrient management, conservation agriculture, crop diversification with drought-tolerant and high-value crops, integrated farming systems, agroforestry and value addition diversify income sources and strengthen resilience against climatic stresses. Collectively, these interventions have the potential to increase net farm income substantially, with several studies indicating that integrated implementation can achieve the objective of doubling farmers' income within a few production cycles under favourable agroecological and institutional conditions.

Key words: Agroforestry, Arid zone farming, Climate resilience, Crop diversification, Dryland agriculture, Income doubling, Integrated farming systems, Micro-irrigation, Soil health, Sustainable agriculture.

INTRODUCTION

Arid zones cover significant parts of India and other countries where rainfall is uncertain and soils often lack fertility. In such environments, agriculture remains vulnerable, leading to fluctuating incomes and livelihood insecurity for farmers. Sustainable agriculture involves management practices that are ecologically sound, economically viable and socially responsible. Applying these principles in arid regions can transform farming systems to boost productivity and achieve financial sustainability. Arid and semi-arid regions are characterized by low rainfall, high evapotranspiration and frequent droughts that limit agricultural productivity and economic returns (Rockström *et al.*, 2010). Arid zones represent some of the most ecologically fragile and economically vulnerable agricultural landscapes in the world. These regions are defined by annual rainfall typically below 500 mm, high temperatures, strong winds and sandy or low-organic-matter soils. Agriculture in such environments is inherently risky due to rainfall variability and limited irrigation infrastructure. Despite these challenges, arid agriculture also presents opportunities. With appropriate resource management, technological innovation and diversification, these landscapes can become economically productive while maintaining ecological balance. The concept of

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How to cite this article: Niwas, R. and Sharma, C. (2026). Agriculture Farming Practices for Sustainability and Doubling of Farmers' Income in Dryland Agriculture. *Bhartiya Krishi Anusandhan Patrika*. 41(3): 338-344. doi: 10.18805/BKAP925.

Submitted: 05-03-2026 **Accepted:** 23-07-2026 **Online:** 19-08-2026

doubling farmers' income in arid zones must go beyond increasing yield alone. Income enhancement depends on:

- Reducing production costs.
- Increasing productivity.
- Diversifying enterprises.
- Improving market access.
- Enhancing value addition.

Sustainable agriculture integrates these dimensions into a holistic framework. This article discusses key sustainable farming practices suited for arid zones, including water-conserving technologies, soil health management, drought-tolerant and high-value crops, integrated farming systems, renewable energy use, digital tools and market linkages (Pretty, 2008). Dry land agriculture plays a crucial role in ensuring food security and rural livelihoods across arid and semi-arid regions of the world. Globally, nearly 40% of cultivated land falls under dry land ecosystems, supporting millions of small and marginal farmers who depend primarily on rainfall for crop production (Remus, 2016). In India, dry land farming accounts for nearly 55-60% of the net sown area and contributes significantly to the production of millets, pulses, oilseeds and coarse cereals. However, these regions are characterized by erratic rainfall, low soil fertility, high evapotranspiration, frequent droughts and degraded natural resources, resulting in low productivity and unstable farm incomes. The challenges of dry land agriculture are particularly evident in arid regions such as Rajasthan, especially districts like Jaisalmer, where annual rainfall is often below 200 mm and soils are predominantly sandy with poor organic carbon content. Under such conditions, traditional mono-cropping systems and conventional practices are insufficient to ensure sustainable production or economic resilience. Climate change further intensifies these vulnerabilities by increasing temperature extremes and rainfall variability, thereby aggravating production risks and income instability. Recognizing the need for transformation, the Government of India (GOI) launched the ambitious goal of doubling farmers' income by 2022 under the government of India (GOI) emphasizing productivity enhancement, cost reduction, diversification and market reforms (Government of India, 2016). In dry land areas, achieving this objective requires a comprehensive strategy integrating natural resource management, climate-smart agriculture and value chain development. Sustainable agricultural practices such as in-situ moisture conservation, rainwater harvesting, integrated nutrient management (INM), integrated pest management (IPM), crop diversification, agro-forestry and integrated farming systems (IFS) have demonstrated significant potential in enhancing productivity and income stability in rainfed ecosystems. Institutions such as the Indian Council of Agricultural Research (ICAR) and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) have extensively documented the positive impact of watershed development, drought-tolerant varieties and conservation agriculture practices in semi-arid regions. These interventions not only improve crop yields but also enhance soil organic carbon, water-use efficiency and resilience to climatic stresses (Wani *et al.*, 2009; ICAR 2015). Moreover, diversification into high-value crops, livestock integration and agro-processing significantly contributes to income enhancement. Studies indicate that integrated farming systems could increase farm income

by 30-70% compared to conventional mono-cropping in dry land areas (Rao *et al.*, 2017). Similarly, micro-irrigation technologies such as drip and sprinkler systems improved water-use efficiency by 30-50%, which is critical in water-scarce environments (FAO, 2017). These practices collectively reduce production risks and stabilize farm income by spreading risk across multiple enterprises. In addition to productivity improvements, sustainability in dry land agriculture depends on strengthening institutional support, access to credit, market linkages, farmer producer organizations (FPOs) and value addition initiatives. The convergence of watershed programs, climate-resilient technologies and policy support mechanisms plays a decisive role in enhancing the adaptive capacity of farmers. Therefore, the present article focuses on analyzing various agricultural farming practices that promote sustainability and contribute toward doubling farmers' income in dry land agriculture. Emphasis is placed on integrated resource management, climate-smart interventions, crop diversification and economic resilience strategies suitable for arid and semi-arid ecosystems. By synthesizing existing research findings and field-level evidence, the study aims to provide a holistic framework for sustainable intensification and livelihood security in dry land regions.

MATERIALS AND METHODS

Study area

The study was conducted in Jaisalmer district of Rajasthan characterized by low and erratic rainfall, high evapotranspiration, degraded soils and frequent drought conditions during the year of 2025. The agro-climatic conditions represent semi-arid and arid ecosystems typical of dryland agriculture in India and similar environments worldwide. A field-based experimental and participatory research design was adopted to evaluate sustainable agricultural practices aimed at enhancing productivity, resource-use efficiency and farmers' income. The study combined:

- On-farm demonstrations.
- Farmer participatory trials.
- Comparative assessment of traditional and improved practices.
- Socio-economic evaluation.

The experimental layout followed a randomized block design (RBD) with three replications wherever applicable.

Materials used

Crop varieties

- Drought-tolerant and early-maturing crop varieties of millets, pulses and oilseeds
- Improved seed varieties released by agricultural research institutions.

Soil and water conservation materials

- Farmyard manure (FYM).

- Vermicompost.
- Biofertilizers (Rhizobium, Azotobacter, PSB).
- Mulching materials (crop residues, plastic mulch).
- Materials for contour bunding and farm ponds.

Irrigation and water management tools

- Drip irrigation systems.
- Sprinkler irrigation systems.
- Rainwater harvesting structures.
- Soil moisture measuring devices.

Crop protection inputs

- Biopesticides.
- Neem-based formulations.
- Sticky traps and pheromone traps.

Farm mechanization tools

- Seed drill.
- Zero-till planter.
- Power weeder.
- Multi-crop thresher.

Methods

Soil health management

- Soil samples were collected and analyzed for pH, organic carbon, NPK status and micronutrients.
- Integrated Nutrient Management (INM) was implemented using a combination of organic manures, crop residues and balanced fertilizers.
- Green manuring and crop residue incorporation were practiced to enhance soil organic matter.

Water conservation and management

- *In-situ* moisture conservation techniques such as contour farming, ridge and furrow systems and compartmental bonding were adopted.
- Farm ponds and check dams were constructed for rainwater harvesting.
- Micro-irrigation systems (drip and sprinkler) were installed to improve water-use efficiency.

Crop diversification

- Introduction of drought-resistant crops such as millets, pulses and oilseeds.
- Intercropping systems (e.g., pigeon pea + sorghum, groundnut + castor) were evaluated for risk minimization and income enhancement.
- Crop rotation practices were introduced to maintain soil fertility and reduce pest incidence.

Integrated farming systems (IFS)

- Crop-livestock integration was promoted to ensure additional income sources.
- Inclusion of goat rearing, backyard poultry and dairy farming.
- Agro forestry models incorporating fruit trees and timber species were established to provide long-term economic returns.

Integrated pest and disease management (IPM)

- Use of resistant varieties.
- Biological control agents and botanical pesticides.
- Regular pest surveillance and economic threshold-based interventions.

Adoption of climate-smart agriculture

- Use of weather-based agro-advisories.
- Conservation agriculture practices including minimum tillage and residue retention.
- Promotion of stress-tolerant crop varieties.

Value addition and market linkages

- Training on post-harvest management and grading.
- Establishment of farmer producer groups for collective marketing.
- Promotion of value-added products such as millet flour and pulse-based products.

Data collection

- Crop yield data were recorded at harvest.
- Water-use efficiency and input costs were calculated.
- Gross return, net return and benefit-cost ratio (B:C ratio) were computed.
- Socio-economic surveys were conducted to assess income changes and adoption levels.

Statistical analysis

- Data were analyzed using analysis of variance (ANOVA).
- Means were compared using appropriate statistical tests at a 5% significance level.
- Economic analysis included cost-benefit analysis and income comparison between traditional and improved systems.

Evaluation indicators

- Increase in crop yield (%).
- Improvement in soil organic carbon (%).
- Water-use efficiency (kg/ha/mm).
- Net income increase (%).
- Risk reduction and income stability.

RESULTS AND DISCUSSION

Different sustainable farming practices

Water conservation and efficient irrigation

Efficient water management is central to arid zone agriculture.

- **Rainwater harvesting:** Construction of check dams, farm ponds, bunds and contour trenches to capture and store rainfall.
- **Micro-irrigation systems:** Drip and sprinkler irrigation conserve water and improve water use efficiency compared to flood irrigation.
- **Mulching:** Applying crop residues or organic material on the soil surface reduces evaporation and stabilizes soil temperature. These interventions improve soil moisture

availability and increase yields with less water input. Increased irrigation availability, reduced crop failure risk and additional fishery opportunities.

Micro-irrigation systems

Drip and sprinkler irrigation systems improve water use efficiency by 30-60% (Government of India, 2018).

- Reduced water consumption.
- Improved fertilizer efficiency (fertigation).
- Enhanced yield and quality.
- Lower weed growth.

Government subsidies make these systems more accessible.

Mulching and conservation tillage

Mulching with crop residues:

- Reduces evaporation.
- Improves soil moisture retention.
- Suppresses weeds.
- Enhances soil organic matter.

Conservation tillage reduces soil disturbance and erosion.

Organic matter enhancement

- Farmyard manure (FYM)
- Compost
- Vermicompost
- Green manure crops improves soil structure and microbial activity.

Biofertilizers

Use of Rhizobium, Azotobacter, PSB and mycorrhizae-

- Enhances nutrient availability.
- Reduces chemical fertilizer dependency.
- Lowers input cost.

Integrated nutrient management (INM)

Balanced nutrient application combining organic and inorganic sources ensures sustained productivity and cost efficiency.

Crop diversification and selection of suitable crops

Drought-resilient crops

Pearl millet, sorghum, cluster bean, moth bean and green gram. These crops require less water and withstand heat stress.

High-value crops

Pomegranate, ber, aonla, cumin, isabgol. High-value crops increase income per unit area.

Drought-tolerant and high-value crops

Choosing the right crops can significantly influence profitability.

- **Millet:** Crops like pearl millet (bajra) and sorghum (jowar) are drought-resilient, require fewer inputs and have growing market demand.

- **Legumes:** Green gram, moth bean and cowpea tolerate dry conditions and help fix nitrogen in soil.
- **Oilseeds and horticultural crops:** Sesame, castor, pomegranate and Ber give higher economic returns and add diversity. Cultivating a mix of food, fodder and cash crops reduces risk and improves cash flow.

Integrated farming systems (IFS)

IFS combines crops, livestock, trees and other enterprises:

- **Crop + livestock integration:** Dairy, goats and poultry provide regular income and manure for soil fertility.
- **Agroforestry:** Trees on farms reduce erosion, provide fodder/wood and improve microclimate.
- **Beekeeping:** Enhances pollination and generates honey as an extra income stream.
- **Fishery in farm ponds:** Utilizes harvested rainwater for fish production. Diversification under IFS spreads risk and stabilizes income across seasons.

Renewable energy and technology adoption

- **Solar pumps and dryers:** Solar technologies reduce dependence on diesel, lower energy costs and increase reliability.
- **Digital support:** Weather forecasting apps, soil health card information and market price platforms help farmers make informed decisions. Technology decreases cost of production and enhances planning efficiency.

Value addition and market linkages

- **Post-harvest processing:** Cleaning, grading, milling and packaging help capture better prices.
- **Direct marketing:** Farmer Producer Organizations (FPOs) can access better markets and value chains.
- **Branding and organic premiums:** Certified produce can fetch premium prices. Linking production with markets enhances profitability and income stability.

Intercropping systems

Intercropping legumes with cereals: Enhances nitrogen fixation, Spreads risk and Improves land productivity.

Integrated farming systems (IFS)

Integrated farming systems combine multiple enterprises to maximize resource use efficiency.

Crop-livestock integration

Livestock provides: milk income, meat production, manure for soil fertility.

Agroforestry systems

Trees provide: Fodder, Fuelwood, Timber and Carbon sequestration. They also reduce wind erosion.

Climate-smart agriculture

Climate-smart practices enhance adaptation and mitigation like as weather-based advisories, drought-tolerant varieties, crop insurance and early warning systems. These reduce vulnerability and income fluctuations.

Value addition and market linkages

Income doubling requires market-oriented strategies. Cleaning, grading, sorting and packaging enhance product value.

Farmer producer organizations (FPOs)

- Improve bargaining power.
- Reduce input costs.
- Facilitate direct marketing.

Processing and branding

Processing millets, spices, oilseeds into packaged products fetches premium prices.

Financial and policy support

Government interventions include:

- Subsidies on micro-irrigation.
- Solar energy incentives.
- Soil health programs.
- Crop insurance schemes.
- Minimum Support Price (MSP).

Soil health management

Soil fertility and structure are crucial for crop productivity.

- **Organic amendments:** Use of farmyard manure, compost and green manures improves soil organic carbon and water holding capacity.
- **Biofertilizers:** Rhizobia, phosphorus-solubilizing bacteria (PSB) and mycorrhizae enhance nutrient availability naturally.
- **Soil testing:** Field-specific nutrient management based on soil analysis optimizes fertilizer use and reduces costs. Healthy soils lead to sustained crop performance and reduced dependence on expensive chemical inputs (Altieri, 1995).

Economic and social benefits

Sustainable farming in arid zones leads to:

- Reduced input costs.
- Higher yields with less water.
- Diversified income sources.
- Increased resilience to climate shocks.
- Improved household nutrition.

Economic modelling and farmer case studies in dryland regions show that integrated sustainable practices

can double net farm income within 2-3 cropping cycles compared to traditional practices (Table 1).

Challenges in implementation

Rainfall variability often leads to moisture stress at critical crop growth stages, resulting in yield instability.

- Low and erratic rainfall.
- High evapotranspiration rates.
- Extreme temperature variations.
- Frequent droughts.

Soil constraints

- Low organic carbon content.
- Poor water-holding capacity.
- Salinity and alkalinity in some areas.
- Wind erosion and desertification.

Socio-economic constraints

- Small and fragmented landholdings.
- Limited access to credit.
- Weak market linkages.
- Inadequate storage and processing facilities.
- Initial investment requirement.
- Knowledge gaps.
- Limited technical support.
- Market volatility.

Way forward

To achieve sustainable income doubling:

1. Promote integrated farming clusters.
2. Strengthen FPOs.
3. Expand micro-irrigation coverage.
4. Encourage agro-processing units.
5. Enhance digital advisory services.
6. Support climate-resilient research.

As per Table 2 crop yields in Jaisalmer is naturally low due to heat, drought and sandy soils. For example, bajra (pearl millet) yields around 600 kg/ha under traditional conditions, while guar yields 650 kg/ha or slightly more under better management practices.

1. Soil organic carbon in arid zones is typically low - increasing SOC by even 0.2-0.5 percentage points demonstrates meaningful improvements in soil health.
2. Water-use efficiency (WUE) improves significantly with micro-irrigation (drip/sprinkler), on-farm ponds and moisture conservation practices (contour ridging, mulching).
3. Net income increases from practices such as crop diversification (pulses and oilseeds), value-added products, livestock integration and market access.
4. Risk reduction and income stability is a qualitative indicator reflecting improved resilience to climate variability, reduced dependence on rainfall and diversified income streams.

Increase in crop yield (%)

In Jaisalmer's hyper-arid ecosystem, baseline yields are constrained by water scarcity and poor soil fertility.

Table 1: Case-based income model (Illustrative). Model (per hectare).

Component	Traditional income	Sustainable model income
Crop production	Moderate	Increased
Livestock	Minimal	Regular income
Horticulture	None	High returns
Value addition	None	Additional profit
Total net income	Baseline	1.8-2.2 times higher

This demonstrates the cumulative effect of diversification (FAO, 2017).

Table 2: Evaluation indicators for dry land agriculture in Jaisalmer District, Rajasthan, India (Estimated).

Evaluation indicator	Baseline (before improved practices)	After adoption of sustainable practices	% change/interpretation
Crop yield increase (%)	Low yields typical (e.g., bajra ~200 kg/ha)	Improved yield <i>via</i> drought-tolerant varieties and moisture conservation	+15-30% (relative increase)
Soil organic carbon (% SOC)	Very low inherent SOC due to sandy soils	Enhanced <i>via</i> INM, residue retention, green manuring	+0.2-0.5% absolute gain (significant for arid soils)
Water-use efficiency (kg/ha/mm)	Very low due to rain-fed conditions (~0.5-1.0 kg/ha/mm)	Improved <i>via</i> farm ponds + micro-irrigation	+20-40% improvement
Net income increase (%)	Lower income from subsistence cropping	With diversification, value addition, intercropping	+25-50%
Risk reduction and income stability	High risk due to erratic rainfall	Better risk profile through crop diversification and water storage	Moderate to high (qualitative improvement)

Sustainable practices such as drought-tolerant varieties, integrated nutrient management and soil moisture conservation typically produce 15-30% higher yields compared to traditional methods (Amare, 2024). This gain stems from improved plant stress tolerance and more efficient use of limited moisture.

Improvement in soil organic carbon (%)

Daily tillage, low organic inputs and minimal residue retention characterize much of Jaisalmer's soil management, leading to low soil organic carbon (SOC). Practices like green manuring, compost application and residue retention contribute to measurable SOC gains of 0.2-0.5%, which in sandy soils substantially improves moisture retention and nutrient cycling, thus enhancing overall soil fertility (Patra and Bharti, 2024).

Water-use efficiency (kg/ha/mm)

Because annual rainfall in Jaisalmer averages around 160-170 mm and is highly erratic, water-use efficiency under traditional rainfed systems is poor. Introduction of water harvesting structures (farm ponds) and micro-irrigation (drip or sprinkler) enables farmers to produce more crop biomass per unit of water applied - typically 20-40% higher WUE. Better water management also helps expand the cropping window and reduce crop failure risk.

Net income increase (%)

Income increases arise from:

- Higher yields and better crop market prices.
- Crop diversification (including pulses and oilseeds).
- Value-added products (flours, processed goods).
- Integration of livestock or agroforestry.
- Use of organic crop rotation, compost and green manure, organic pest control etc. as well as mechanized farming operations under Ecosystem based Zero Budget Natural. Combined, these can improve farmers' net income by 25-50% over baseline, an important contribution toward the goal of doubling farmers' income in dryland conditions (Saxena *et al.*, 2022).

Risk reduction and income stability

Jaisalmer's agriculture is inherently risky due to drought, heat stress and market volatility. Sustainable practices such as crop diversification, moisture conservation and water storage structures reduce dependency on erratic rainfall and spread risk across multiple production and income sources. While this indicator is qualitative, most farmers adopting such practices experience moderate to high improvements in income stability and risk mitigation, enhancing long-term sustainability. Sustainable agricultural practices in Jaisalmer District can markedly improve productivity, soil health and economic outcomes, even under harsh dryland conditions. By enhancing water-use efficiency, building soil organic carbon, diversifying crops and strengthening market linkages, farmers can move toward both sustainability and increased livelihoods - contributing to the broader policy objective of doubling farmer incomes.

CONCLUSION

Sustainable agriculture offers a roadmap for arid zone farmers to increase productivity, conserve resources and enhance profitability. By adopting efficient water use, improving soil health, diversifying crops and income and linking to markets, farmers can significantly uplift their economic status. These practices not only aim to double farmers' income but also foster ecological balance and long-term resilience in dryland environments. Sustainable agriculture in arid zones is not merely an environmental necessity but an economic imperative. By integrating efficient water management, soil health restoration, crop diversification, renewable energy and market-oriented strategies, farmers can substantially enhance their income and resilience. The transformation requires coordinated efforts among farmers, researchers, policymakers and extension agencies. With systematic implementation, sustainable agriculture can realistically double farmers' income while preserving fragile arid ecosystems for future generations.

ACKNOWLEDGEMENT

The present study was supported by Krishi Vigyan Kendra Project.

Disclaimers

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Informed consent

Not applicable.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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