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Definition and Characteristics of Dryland Farming and Cropping System and Cropping Pattern for Dry Land Farming

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Dryland farming refers to crop production practised in regions where annual rainfall is low, erratic and largely unevenly distributed, and where supplemental irrigation is generally unavailable or extremely limited. These regions, which constitute a substantial proportion of the world's and India's arable land, are characterised by frequent moisture stress, high evapotranspiration demand, fragile soils and high inter-annual yield variability. This review synthesises the definitions, classification and distinguishing characteristics of dryland, dry, and rainfed farming, and examines the agro-climatic, edaphic and socio-economic features that differentiate dryland agriculture from irrigated cropping systems. It further discusses the concepts of cropping system and cropping pattern as applied to dryland conditions, outlining the principal types of cropping systems — including mono-cropping, intercropping, mixed cropping, sequential and relay cropping, alley cropping and agro-forestry-based systems — that are used to stabilise productivity, conserve soil moisture and minimise the risk of crop failure under uncertain rainfall. Key agronomic principles governing cropping pattern selection, such as moisture conservation, length of growing period, soil depth, crop duration and complementarity between component crops, are reviewed along with representative cropping patterns followed in major dryland tracts. The review concludes by highlighting the constraints faced in dryland regions and strategies, including resource conservation technologies, drought-tolerant cultivars and diversified cropping systems, that can enhance the stability and sustainability of dryland farming.

Keywords: Dryland farming; Dry farming; Rainfed agriculture; Cropping system; Cropping pattern; Moisture conservation

Introduction

Agriculture across the semi-arid and arid tropics is predominantly dependent on rainfall, and a large proportion of the world's cultivated area falls under conditions where water availability, rather than land, is the principal constraint to crop production (Reddy, 2017; Rao et al., 2019). Globally, drylands cover nearly 41% of the earth's land surface and support a substantial share of the human population, much of which depends directly on rainfed agriculture and livestock for livelihood (Venkateswarlu & Shanker, 2009; Singh & Bhushan, 2021). In India, nearly 60% of the net sown area is rainfed, contributing a significant proportion of total foodgrain production, particularly coarse cereals, pulses and oilseeds (Rao, 2010; Reddy, 2017). Such regions are characterised by limited, erratic and unevenly distributed rainfall, frequent dry spells, shallow and low fertility soils, and high climatic uncertainty, all of which expose crops to recurrent moisture stress and yield instability (Venkateswarlu & Shanker, 2009; Wani et al., 2012). The terms dry farming, dryland farming and rainfed farming are frequently used interchangeably, yet each denotes a distinct agro-climatic situation defined primarily by the quantum and distribution of annual rainfall (Rao, 2010; Singh & Bhushan, 2021). A clear understanding of these definitions is fundamental to designing appropriate crop production strategies, since the choice of crops, cropping systems and management practices must be matched to the available moisture regime. Equally important is the selection of an appropriate cropping system and cropping pattern, since growing a single crop in monoculture under uncertain rainfall carries a high risk of total crop failure, whereas diversified and moisture-efficient cropping systems can buffer farmers against climatic aberrations and stabilise income (Hegde, 2011; Wani et al., 2012). This review consolidates the definitions and distinguishing characteristics of dryland farming, dry farming and rainfed agriculture, and examines the principles, classification and representative examples of cropping systems and cropping patterns suited to dryland conditions, with the objective of providing a coherent agronomic framework for sustainable dryland crop production.

Definition of Dryland Farming

Dryland farming is broadly defined as the practice of crop production in regions receiving an annual rainfall between approximately 750 mm and 1150 mm, where the rainfall, although higher than in arid tracts, remains erratic, poorly distributed and frequently interrupted by dry spells coinciding with critical crop growth stages (Rao, 2010; Reddy, 2017). Unlike dry farming, dryland farming areas do receive sufficient rainfall to permit at least one assured crop in most years, and in years of favourable distribution, a second or sequential crop may also be raised (Venkateswarlu & Shanker, 2009).

Dry Farming

Dry farming refers to crop cultivation under conditions of very low and uncertain rainfall, generally less than 750 mm annually, typical of arid and semi-arid regions where the length of the crop growing period is short and moisture conservation assumes overriding importance (Rao, 2010; Hegde, 2011). Dry farming areas are characterised by a high risk of crop failure, and cropping is largely confined to hardy, short-duration and drought-tolerant crops such as pearl millet, sorghum, and minor millets, often grown as a single crop per year (Reddy, 2017).

Rainfed Farming

Rainfed farming is the most inclusive term, encompassing all crop production that depends entirely on rainfall as the source of moisture, irrespective of the quantum of rainfall received, and therefore includes both dry farming and dryland farming as well as cultivation in relatively high rainfall areas (greater than 1150 mm) where moisture is generally adequate but may still be poorly distributed (Singh & Bhushan, 2021; Rao et al., 2019). Thus, while every dryland and dry farming situation is rainfed, not every rainfed situation is necessarily a dryland or dry farming situation.

Distinction among Dry Farming, Dryland Farming and Rainfed Farming

Feature	Dry Farming	Dryland Farming	Rainfed Farming
Annual rainfall	< 750 mm	750–1150 mm	Variable; includes > 1150 mm
Crop intensity	Usually one crop in two years or one short-duration crop	One assured crop; sequential crop in good years	One or more crops depending on rainfall and duration
Risk of crop failure	Very high	Moderate	Low to moderate
Typical region	Arid zones	Semi-arid zones	Semi-arid to sub-humid zones
Major crops	Pearl millet, minor millets	Sorghum, pearl millet, pulses, oilseeds	Cereals, pulses, oilseeds, cotton

Characteristics of Dryland Farming

Dryland farming regions exhibit a distinct set of climatic, edaphic, biological and socio-economic features that collectively distinguish them from irrigated agricultural systems and that govern the choice of crops, cropping systems and management practices (Venkateswarlu & Shanker, 2009; Wani et al., 2012). The principal characteristics are described below.

Climatic Characteristics

- Low and uncertain rainfall (750–1150 mm annually) with high coefficient of variability between years and within the season (Rao, 2010).
- Uneven temporal distribution of rainfall, with prolonged dry spells often occurring during critical crop growth stages such as flowering and grain filling (Hegde, 2011).
- High potential evapotranspiration relative to rainfall, resulting in a frequent and often severe soil moisture deficit (Reddy, 2017).
- Short and variable length of the crop growing period, frequently restricted to 90–150 days (Wani et al., 2012).
- High atmospheric temperature and intense solar radiation, particularly during the early and late phases of the cropping season, which accentuate moisture stress (Singh & Bhushan, 2021).

Soil Characteristics

- Predominance of shallow to medium-deep soils with low water-holding capacity, such as Alfisols and shallow Vertisols (Rao et al., 2019).
- Low organic matter content and inherently low to medium fertility status, necessitating judicious nutrient management (Venkateswarlu & Shanker, 2009).
- High susceptibility to wind and water erosion owing to sparse vegetative cover, especially during the pre-monsoon and immediate post-harvest periods (Hegde, 2011).
- Crusting and surface sealing tendencies in many dryland soils, which reduce infiltration and increase runoff losses (Reddy, 2017).

Crop and Cropping Characteristics

- Dominance of hardy, short-duration, drought-escaping or drought-tolerant crops such as sorghum, pearl millet, minor millets, pulses (pigeonpea, green gram, black gram) and oilseeds (groundnut, sesame, castor, safflower) (Rao, 2010).
- Lower and more variable yields compared with irrigated agriculture, with productivity strongly governed by the quantum and distribution of seasonal rainfall (Wani et al., 2012).
- Greater reliance on intercropping, mixed cropping and other diversified cropping systems as a risk-mitigation strategy against total crop failure (Singh & Bhushan, 2021).
- Limited scope for high-input, high-yielding cultivars without complementary moisture-conservation and risk-management practices (Hegde, 2011).

Socio-Economic Characteristics

- Predominance of small and marginal landholdings, with limited access to capital for inputs such as fertilisers, improved seed and farm machinery (Reddy, 2017).
- High dependence on livestock as a complementary enterprise, providing draught power, manure and an alternative income source during years of crop failure (Venkateswarlu & Shanker, 2009).
- Greater vulnerability to climatic risk and consequent income instability, often necessitating off-farm employment and risk-coping strategies (Rao et al., 2019).

Cropping System for Dryland Farming

A cropping system refers to the crops, crop sequences and management practices used on a given piece of land over a period of time, including the resources and technologies employed for production, while encompassing the biological, physical and socio-economic environment with which they interact (Reddy, 2017; Hegde, 2011). In dryland agriculture, the design of an appropriate cropping system is central to stabilising production, since it determines how effectively the limited and uncertain rainfall is captured, conserved and converted into economic yield. The overriding objectives of a dryland cropping system are efficient utilisation of available moisture, minimisation of the risk of total crop failure, maintenance of soil fertility and stability of net returns across seasons of varying rainfall (Wani et al., 2012; Singh & Bhushan, 2021).

Principles Governing Cropping Systems in Drylands

- Matching crop and variety duration with the length of the available growing period and the probable date of onset and withdrawal of rainfall (Rao, 2010).
- Diversification of crops and inclusion of legumes to spread risk, improve soil fertility through biological nitrogen fixation and provide a fodder or food buffer in poor rainfall years (Hegde, 2011).
- Efficient capture and conservation of rainfall through appropriate land configuration, mulching and in-situ moisture conservation practices integrated with the cropping system (Wani et al., 2012).
- Selection of crop combinations with complementary rooting depth, canopy architecture and water-use patterns to reduce inter-crop competition (Reddy, 2017).
- Inclusion of contingency crop options to permit adjustment of the cropping plan in response to delayed onset, mid-season or terminal drought (Venkateswarlu & Shanker, 2009).

Major Types of Cropping Systems Practised in Drylands

Mono-cropping / Sole cropping: Growing a single crop on a piece of land during a season, generally practised in low rainfall (dry farming) tracts where moisture is insufficient to support more than one crop, e.g., sole pearl millet or sole sorghum (Rao, 2010).

Intercropping: Growing two or more crops simultaneously on the same piece of land in a definite row arrangement, the most widely recommended system for dryland areas because it improves resource-use efficiency and provides insurance against failure of any one component crop, e.g., sorghum + pigeonpea (2:1), pearl millet + green gram, groundnut + pigeonpea (Hegde, 2011; Wani et al., 2012).

Mixed cropping: Growing two or more crops simultaneously with no distinct row arrangement, practised traditionally by dryland farmers as a means of minimising total crop failure under highly uncertain rainfall, e.g., mixtures of sorghum, pigeonpea, greengram and sesame broadcast together (Reddy, 2017).

Sequential cropping: Growing two crops in succession on the same field within an agricultural year, feasible in dryland areas with relatively assured rainfall and a longer growing period, e.g., a short-duration kharif legume followed by a rabi crop on conserved soil moisture (Singh & Bhushan, 2021).

Relay cropping: Sowing the succeeding crop before the standing crop is harvested, thereby making efficient use of residual soil moisture and minimising the turnaround time between crops, e.g., relaying of a short-duration pulse into standing sorghum near maturity (Rao et al., 2019).

Strip cropping: Growing different crops in alternate strips across the slope, primarily to reduce soil erosion and runoff while maintaining crop diversity, commonly used on undulating dryland terrain (Venkateswarlu & Shanker, 2009).

Alley cropping / Agroforestry-based systems: Integration of perennial trees or shrubs with arable crops grown in the alleys between tree rows, providing fuel, fodder and soil-conservation benefits while buffering crop income against seasonal rainfall failure, e.g., Leucaena- or Glyricidia-based alley cropping with pulses or millets (Wani et al., 2012).

Cropping Pattern for Dryland Farming

Cropping pattern denotes the proportion of area under, and temporal and spatial arrangement of, different crops grown in a particular region during a given agricultural year, as determined by the prevailing rainfall regime, soil type, length of growing period and socio-economic considerations of the farming community (Reddy, 2017; Rao, 2010). While cropping system describes the components and management of crop combinations on a given field, cropping pattern reflects the broader, region-level distribution of crops and their sequence, shaped largely by the dependable rainfall and the length of the growing season available in a tract (Hegde, 2011).

Factors Determining Cropping Pattern

- Quantum, onset, distribution and withdrawal pattern of seasonal rainfall, which determine the length of the assured growing period (Wani et al., 2012).
- Soil depth and water-holding capacity, which influence the moisture available to the crop beyond the rainy period (Rao et al., 2019).
- Probability of dry spells at critical crop growth stages, assessed through rainfall probability analysis for the region (Venkateswarlu & Shanker, 2009).
- Market demand, food and fodder requirements of the farm household, and the relative profitability of alternative crops (Singh & Bhushan, 2021).
- Availability of drought-tolerant, short-duration cultivars suited to the dependable rainy period (Reddy, 2017).

Representative Cropping Patterns in Dryland Tracts

Rainfall Zone (approx.)	Length of Growing Period	Representative Cropping Pattern	Major Crops
< 500 mm (arid)	< 90 days	Sole cropping, single short-duration crop	Pearl millet, minor millets, sole moth bean
500–750 mm (dry farming)	90–120 days	Sole cropping / simple intercropping	Sorghum, pearl millet, pigeonpea-based intercrops
750–1150 mm (dryland)	120–150 days	Intercropping; sequential cropping in good years	Sorghum + pigeonpea, groundnut + pigeonpea, soybean–chickpea
> 1150 mm (rainfed, sub-humid)	> 150 days	Sequential / relay double cropping	Rice–pulse, maize–chickpea, soybean–wheat (residual moisture)

In medium and deep black soil (Vertisol) tracts of peninsular India receiving 750–1000 mm rainfall, intercropping systems such as sorghum + pigeonpea or soybean + pigeonpea are widely practised, taking advantage of the differing maturity periods and rooting patterns of the component crops to ensure that at least the longer-duration legume survives terminal moisture stress (Hegde, 2011; Wani et al., 2012). In contrast, in the shallower red and lateritic soils of low rainfall tracts, the cropping pattern is generally restricted to short-duration sole crops or simple two-crop intercrops of pearl millet and pulses, designed to complete the life cycle within the limited assured rainy period (Rao, 2010; Reddy, 2017).

Constraints in Dryland Farming

- Recurrent and unpredictable moisture stress, including delayed onset, intermittent dry spells and early withdrawal of the monsoon (Venkateswarlu & Shanker, 2009).
- Low and unstable productivity arising from shallow, low-fertility soils with poor moisture retention (Rao et al., 2019).
- Limited access to inputs, credit and risk-mitigation instruments such as crop insurance among small and marginal dryland farmers (Reddy, 2017).
- High soil erosion hazard due to intense, erratic rainfall events striking sparsely vegetated land (Wani et al., 2012).
- Inadequate adoption of moisture-conservation and contingency crop-planning technologies at the farm level (Singh & Bhushan, 2021).

Strategies for Sustainable Dryland Cropping

- In-situ moisture conservation through appropriate land configuration (broad-bed and furrow, contour bunding, ridge and furrow), residue retention and mulching (Wani et al., 2012).

- Adoption of drought-tolerant, short-duration and input-responsive cultivars suited to the dependable length of the growing period (Hegde, 2011).
- Diversification through legume-based intercropping and mixed cropping systems to reduce the risk of total crop failure and improve soil fertility (Rao, 2010).
- Contingency crop planning based on rainfall onset, including provision for re-sowing, gap-filling or alternate crop options under delayed or deficient rainfall (Venkateswarlu & Shanker, 2009).
- Integration of crop production with livestock, agroforestry and water-harvesting structures for supplemental life-saving irrigation, where feasible (Reddy, 2017).

Conclusion

Dryland farming, distinguished from dry and rainfed farming primarily on the basis of annual rainfall quantum and its distribution, supports a substantial proportion of global and Indian agriculture under conditions of recurring moisture stress, fragile soils and high production risk. The defining climatic, edaphic and socio-economic characteristics of dryland regions necessitate cropping systems and cropping patterns that are specifically designed to capture and conserve scarce rainfall, spread production risk across crops of differing duration and water requirement, and sustain soil fertility over time. Diversified systems such as intercropping, mixed cropping, sequential and relay cropping, matched to the locally dependable length of the growing period, remain central to stabilising yields and farm income in dryland tracts. Continued refinement of cropping patterns, supported by moisture-conservation technologies, drought-tolerant cultivars and contingency crop planning, is essential for enhancing the resilience and sustainability of dryland farming under increasingly variable rainfall conditions.

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