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Cactus as a Resilient Substitution Crop for Dryland Agricultural Systems

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The global agricultural sector is currently facing a multifaceted crisis characterized by accelerating impacts of anthropogenic climate change, the persistent degradation of arid and semi-arid landscapes, and the socio-economic pressures of land fragmentation among smallholder farmers. In these vulnerable ecosystems, conventional forage and food crops often reliant on predictable precipitation and high-input irrigation are increasingly failing to provide stable yields. Consequently, the identification of alternative, drought-resilient crops has transitioned from a localized agricultural preference to a global strategic necessity. *Opuntia ficus-indica*, widely known as the prickly pear or nopal cactus, stands at the forefront of this transition. (Pisa, 2021). This perennial succulent, characterized by its specialized Crassulacean Acid Metabolism (CAM) and unique morphological adaptations, offers a viable solution for dryland holders seeking to mitigate fodder scarcity, and diversify income streams through a multifaceted industrial model.

Cactus - Prickly pears (Opuntia spp.), a type of spiny cactus, mostly from Mexico and Texas, can survive and provide fodder for livestock in conditions of acute water scarcity. (Middleton & Beinart, 2005). The core of this resilience is Crassulacean Acid Metabolism (CAM) photosynthesis that leads to achieve a water-use efficiency (WUE) that is significantly higher than that of most terrestrial plants. It has deep taproots, develops an expansive, shallow network of roots typically concentrated in the top 15 cm to 50 cm of soil. These roots can respond rapidly to light rainfall or even heavy dew, a critical advantage in desert environments where subsoil moisture is often non-existent. The plant's ability to maintain physiological activity even at higher temperature that's shows as a strategic crop for a warming planet. The presence of spines—anatomically modified leaves—and glochids—irritating hair-like bristles—has historically limited the direct utilization of *Opuntia* as a forage crop. Spines provide essential protection against wild herbivores and can be an advantage when the cactus is used for bio-fencing to protect property lines. The development and selection of "spineless" or "thornless" varieties has been a primary goal for modern plant breeders. Modern breeding efforts led by the International Center for Agricultural Research in the Dry Areas (ICARDA) and the Indian Council of Agricultural Research (ICAR) focus on evaluating large germplasm collections to identify accessions that combine spinelessness with high biomass yield, high carbohydrate content, and rapid regeneration after harvesting. (Kumar et al., 2013).

Nutritional Importance and Biochemistry of Cactus

Forage: The nutritional profile of *Opuntia ficus-indica* is uniquely suited to the requirements of dryland livestock, primarily as a source of energy, hydration, and minerals. Chemically, the cladodes are rich in soluble carbohydrates, minerals viz., particularly calcium (2.0–3.5) and magnesium (0.3–0.8), and vitamins A and C. However, they are notably low in crude protein (CP) and crude fiber (CF). This nutritional skew requires a strategic approach to feeding. Ruminants cannot be sustained on cactus alone without developing digestive disturbances, such as diarrhea, due to the high mucilage content and rapid rate of passage. Therefore, the standard recommendation for dryland farmers is to feed cactus in a ratio of 1:3 with hay , fibrous fodder such as wheat straw, hay, or sorghum stalks. When integrated into a balanced diet, the mucilage in the cactus actually benefits the rumen by enhancing insalivation and preventing the sharp drops in pH that lead to acidosis, a common problem when feeding high-energy concentrates like barley or maize. (BAIF, 2024)

Nutritional Component	Average Value (DM Basis)	Nutritional Significance
Total Carbohydrates	60-72 %	Primary energy source
Crude Protein (CP)	3-5 %	Requires supplementation
Mineral Matter (Ash)	15-20 %	High Calcium/Magnesium
Crude Fiber	8-12%	Requires dry fodder mix
Vitamin C	15-26 mg/100g	Antioxidant/Health boost

Research has also identified significant medicinal and functional food properties within the *Opuntia* genus. The fruits and cladodes contain various phenolic compounds and antioxidants that can lower cholesterol and triglyceride levels in both humans and livestock. In lactating animals, the inclusion of cactus in the diet has been shown to increase milk yield by up to 30 %, while also improving the quality of the meat by increasing the proportion of beneficial fatty acids, such as conjugated linoleic acid. (ICARDA, 2026).

Fodder Provision and Management Strategies for Dryland Holders

For the smallholder farmer, the introduction of *Opuntia ficus-indica* as a substitute crop requires a shift in traditional land management. Unlike seasonal cereals, the cactus is a long-duration crop that can remain productive for 25 to 50 years with proper management. It is "easy to establish, maintain, and utilize," requiring minimal inputs once the initial root system is developed. The most common propagation method is vegetative, using mature cladodes (at least six months old) that are allowed to callus for one to two weeks before being planted upright in the soil. Management for fodder yield typically involves higher planting densities and regular harvesting cycles. One of the most valuable roles of the cactus for a dryland holder is its function as a "fodder bank." Because the pads store water and nutrients for long periods, they can be harvested on an "as-needed" basis, providing a fresh, green alternative during the peak of summer when all other vegetation has turned brown and unpalatable. This "on-demand" harvesting eliminates the need for expensive storage infrastructure like silos or hay barns, which are often beyond the financial reach of marginal farmers.

Adaptability to Land Fragmentation and Marginal Environments

Land fragmentation—the subdivision of ancestral farms into increasingly smaller, non-contiguous plots—is a significant constraint on agricultural productivity in developing nations. Traditional mechanization and large-scale irrigation are often unfeasible on these small patches. However, *Opuntia ficus-indica* is uniquely suited to fragmented landholdings. It can be cultivated as a "boundary crop" along the edges of small plots, serving as both a protective hedge and a source of fodder without occupying the primary space reserved for food crops. Furthermore, the cactus thrives on "marginal" land—areas with rocky soil, steep slopes, or degraded fertility where cereals like wheat or sorghum would fail. Its shallow root system and ability to trap soil and moisture at its base make it an excellent tool for erosion control and land reclamation. In Tunisia, cactus rows are planted on the inner side of terraces

to stabilize the earth and prevent runoff, effectively turning a soil conservation measure into a productive fodder source. The socio-economic challenges of fragmentation can be further mitigated through "group farming" and the formation of Farmer Producer Organizations (FPOs). By pooling contiguous patches of land, smallholders can share the costs of establishing nurseries or purchasing communal processing equipment like forage choppers. In India, organizations like BAIF have successfully demonstrated this collective model by establishing over 800 field demonstrations and decentralized nurseries, allowing farmers to bypass the "economies of scale" barrier.

Climate Change Integration and the 5F Industrial Model

The perception of *Opuntia* is currently undergoing a radical shift from a "plant of the poor" to a high-value industrial crop. Under the 5F framework, *Opuntia* serves as a source of:

- **Fashion** – fibers, dyes, cosmetics, and bio-based materials
- **Food** – cladodes and fruits for human consumption
- **Fuel** – biomass and bioenergy production
- **Fertilizer** – organic manure, compost, and soil conditioners
- **Fodder** – nutritious feed for livestock, particularly in dryland systems

This diversification is crucial for climate change adaptation, as it allows farmers to generate income even if one sector of their enterprise—such as livestock—is temporarily underperforming. In the realm of "Fashion," the development of cactus-based "vegan leather" has opened up lucrative global markets. In "Fuel," the high biomass productivity and high sugar content of the pads make them an ideal feedstock for biogas production, with a methane concentration of 60-65 %. The byproduct of this energy generation is a high-quality "Fertilizer," which can be returned to the soil to complete the nutrient loop. For Food, the growing demand for cactus juice and functional food supplements—valued for their ability to increase hemoglobin and manage blood glucose—provides another high-margin opportunity for rural entrepreneurs.

Strategic Implementation and Policy Recommendations

The successful integration of *Opuntia ficus-indica* as a substitution crop for dryland holders requires a coordinated approach involving research, policy, and market linkages. The current research highlights several critical success factors:

1. **Varietal Selection:** It is imperative to promote only the high-performing, spineless accessions identified by institutions like CAZRI and ICARDA to ensure farmer acceptance and livestock safety.
2. **Decentralized Nurseries:** To overcome the logistical hurdle of transporting bulky cladodes, decentralized nurseries must be established within 20-30 km of the target farms, ideally managed by local FPOs.
3. **Balanced Feeding Education:** Farmers must be trained in the 1:3 feeding ratio to prevent digestive issues in their livestock and maximize the nutritional benefits of the cactus.
4. **Value-Chain Integration:** Direct linkages between farmers and the budding vegan leather and biogas industries are necessary to ensure that the increased biomass production translates into higher household income.

As climate change continues to redraft the boundaries of viable agriculture, the "green gold" of the arid zones—*Opuntia ficus-indica*—offers a rare combination of ecological restoration and economic viability. For the dryland smallholder, it is no longer merely an emergency fallback but a central pillar of a resilient and diversified agricultural future.

References

1. BAIF. (2024). *Unconventional fodder resources: A boon for smallholders*. BAIF Development Research Foundation. https://baif.org.in/fodder-resources.

2. ICARDA. (2026). *Cactus pear for better nutrition and income*. International Center for Agricultural Research in the Dry Areas. https://icarda.org/research/innovations/cactus-pear-better-nutrition-and-income
3. Kumar, S., Kumar, K. T., Mishra, A. K., Ahmed, S., & Ghosh, P. K. (2013). Evaluation of cactus as an alternate fodder resource in semi-arid region of India. *Indian Journal of Animal Nutrition*. https://files01.core.ac.uk
4. Middleton, K., & Beinart, W. (2005). Cactus pear as dryland fodder: Ambovombe Farm, Madagascar and Wellwood Farm, South Africa compared, c. 1920–1950 (Part II). *Journal of Agrarian Change, 5*(2), 251–280.
5. Prisa, D. (2021). *Opuntia ficus-indica*: The key plant in climate change—Characteristics, cultivation and uses. *GSC Biological and Pharmaceutical Sciences, 17*(2), 94–105.