Sustainable Technologies for Rain fed Agriculture in India

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Abstract— *India's agrarian economy contributes 21% to the country's GDP and provides employment to 60% of the population. Rainfed agriculture constitutes 67% of the net sown area, contributing 44% of food grains and supporting 40% of the population. To meet the increasing demand for food grains, it is crucial to enhance the productivity of rainfed areas from the current 1 t/ha to 2 t/ha over the next two decades. However, the quality of natural resources in these regions is deteriorating due to overexploitation, and rainfed areas face biophysical and socio-economic constraints affecting crop and livestock productivity.*

This paper critically examines economically viable technologies for rainfed agriculture, including soil and rainwater conservation, efficient crops and cropping systems tailored to the growing season, and suitable implements for timely sowing and labor-saving. Sustainable practices such as integrated nutrient and pest management (INM and IPM) are emphasized. Additionally, the paper highlights interventions in dryland technologies to utilize marginal lands through alternative land-use systems like silvopasture, rainfed horticulture, and tree farming, demonstrated on a watershed basis. The integration of livestock with arable farming systems and the incorporation of indigenous knowledge are also discussed. Finally, the paper advocates for the formation of self-help groups, innovative extension tools such as portable rainfall simulators, and focus group discussions to facilitate the adoption of rainfed technologies by farmers. A farming systems approach in rainfed agriculture not only addresses income and employment challenges but also ensures food security.

Keywords— Rainfed agriculture technologies, sustainable, indigenous knowledge.

I. INTRODUCTION

India's economy heavily relies on agriculture, which contributes 21% of GDP and provides employment for 60% of the workforce. Over the past three decades, the country has achieved self-sufficiency and surplus food production. However, feeding the growing population remains a formidable challenge, with projections indicating the need to support 1.3 billion people by 2020, requiring an annual increase of 5-6 million tons of food grains. Despite advancements, issues like poverty and malnutrition continue to hinder national food security, particularly in rural areas where over 70% of the population resides. Rainfed agriculture accounts for 67% of the net sown area, producing 44% of food grains and supporting 40% of the population. Even after realizing the full irrigation potential, 50% of the net sown area will remain rainfed.

Currently, rainfed agriculture constitutes 95% of the area under coarse cereals, 91% under pulses, 80% under oilseeds, 65% under cotton, and 53% under rice. Livestock forms an integral component, with two-thirds of animals thriving in rainfed regions. These areas encompass diverse environments, including semi-arid to sub-humid climates, shallow to deep soils, and varying crop-growing periods of 90-180 days.

II. METHODS AND MATERIALS

This study employs a descriptive and explorative methodology, utilizing secondary data from government reports, research institutions, and published sources such as websites, periodicals, and reports.

2.1 Scenario of Food Demand and Resources:

India’s food grain demand is projected to reach 243 million tons by 2007-08 and 308 million tons by 2025 under a low population growth scenario. For a higher growth scenario, the requirement is 320 million tons. Ensuring protein security is becoming increasingly critical due to the predominantly vegetarian diet and limited availability of pulses, with current consumption at 25 g/person/day against the dietary requirement of 70 g.

Agricultural production increased significantly from 50 million tons in 1950 to over 200 million tons by 2000, driven by the Green Revolution. However, this progress came at the cost of land and water degradation, biodiversity loss, and environmental pollution. Moving forward, ecological sustainability and economic access to food will be major concerns.

2.2 Shrinking Natural Resources:

Per capita agricultural land in India decreased from 0.46 hectares in 1951 to 0.15 hectares in 2000, compared to the global average of 0.6 hectares. The population density on net-cropped land rose from 3 persons/hectare in 1951 to 6.5 in 2000 and is projected to reach 8 by 2025. Competing demands for food, fiber, fuel, and urbanization exacerbate the pressure on shrinking natural resources.

2.3 Constraints of Production in Rainfed Areas:

Rainfed regions face numerous challenges, including:

- Low and erratic rainfall
- Land degradation
- Poor productivity
- Limited input use and technology adoption
- Inadequate draft power
- Insufficient fodder and low-productivity livestock
- Resource-poor farmers and limited credit availability

2.4 Strategies for Sustained Food Production in Rainfed Regions:

A number of economically viable rainfed technologies have been developed over the years in the country to address the challenges of food production in rainfed agriculture. Through CRIDA (Central Research Institute for Dryland Agriculture) and its network centers over the last three decades, these technologies have been refined and validated in farmers' fields using approaches like Operational Research Projects (ORPs), Institute Village Linkage Program (IVLP), and farm science centers.

Key innovations include simple yet effective practices such as off-season tillage in rainfed Alfisols and related soils, aimed at improving moisture conservation and weed control. Farmers in Operational Research Project areas of Hyderabad, for example, adopted this practice for crops like sorghum and castor, achieving yield increases of up to 40% compared to traditional methods.

However, a significant barrier to the widespread adoption of these practices is the lack of adequate draft power among small-scale farmers. Custom hiring of tractors has emerged as an effective solution, enabling farm mechanization on these rainfed lands and helping farmers adopt these sustainable practices.

2.5 Soil and Rainwater Conservation Techniques:

Efficient conservation of rainwater is the central issue in successful dryland farming. Extensive trials conducted by the soil conservation and dryland research centers have led to the identification of a number of inter-terrace land treatments besides contour and graded bunds (Sharma et al., 1982). These techniques are location specific, and the benefits from their adoption are highly variable depending on the rainfall intensity, slope, and texture of the soil, besides the prevailing crop/cropping system (Katyal and Das, 1993).

Farmers have not widely adopted mechanical measures like contour bunds, graded bunds, grassing of waterways, and construction of farm ponds without government support due to financial constraints. However, studies at Hyderabad, Bangalore, and Anantapur revealed that more than 80 percent of farmers follow simple conservation measures like sowing across the slope, opening of dead furrows, and keyline cultivation. The yield improvement by adopting soil and water conservation measures varies between 12 and 20 percent, which are at times not convincing enough to farmers. However, cumulative effects are significantly visible at some locations. Since such measures help in the long-term conservation of resources, these are implemented through the Government of India or the respective State Government-sponsored watershed management programs.

2.5.1 Timely Planting of Crops:

Timely sowing ensures better plant stand, higher yields, and optimal rainfall use. Demonstrations in farmers' fields through programs like ORPs and KVKs have shown significant yield reductions when sowing is delayed by 15 days. Availability of farm implements is critical to overcoming these constraints.

2.5.2 Adoption of Improved Crop Varieties:

Improved varieties tailored to rainfed conditions have increased farmers' benefits by Rs. 2,000-4,000/ha. Examples include improved sorghum, castor, and sunflower varieties.

2.5.3 Efficient Crops and Cropping Systems:

Efficient intercropping and sequential cropping systems have been recommended based on soil type, rainfall, and growing season. For example, the sorghum-pigeonpea (2:1) system and finger millet-pigeonpea (8:1) system have been successful in different regions. However, adoption challenges include preferences for fodder genotypes, lack of suitable farm implements, and delayed planting.

2.5.4 Farm implements:

Proper tillage and precise placement of seed and fertilizers in the moist zone are most critical to for successful crop establishment in drylands. Since the sowing of crops must be completed in a short span of time, use of appropriate implements is necessary to cover large area before the seed zone dries out. Suitable implements have been recommended for various locations to meet this requirement. These are designed to suit the soil type, crop and the draught power availability. In many cases, the existing local implement used by the farmers have been improved to increase their working efficiency (Gupta and Sriram, 1987).

Studies at CRIDA in farmers' fields of Telangana indicated that use of the drill plough for sowing of castor and sorghum crops showed no variation in yields of the crops and plant as compared to farmers practice resulted 1 ½ times more coverage compared to farmers' method of seeding. Two labourers who are required for placement of seed and fertilizer in farmers method can be saved with the drill plough. Thus a saving of Rs. 187/ha is possible with a drill plough compared to the traditional plough and plant system.

2.5.5 Nutrient management:

Fertilizer recommendations in rainfed crop production have been made primarily for NPK along with the conjunctive use of chemical, organic and bio-fertilizer (Rao and Das, 1982). Inclusion of legumes in cropping systems can supplement fertilizer N to the extent of about 20 kg N per ha. Conjunctive use of fertilizer N with FYM, croppings of luecaena and gliricidia help in reducing the requirement of fertilizer by 50 percent (Reddy et al., 1996).

2.5.6 Integrated pest management (IPM):

Pests and deceases constitutes a major constraint to increased food production. Crop losses due to pest attack range from 10-30 percent depending on the crop and environment. Complete crop failure may occur in case of serious attack. Indiscriminate use of the pesticides in rainfed crops will lead to harmful side effects such as direct toxically to the applicator or consumer, development of strains or pests resistant to pesticides, resurgence of pest species, outbreak of secondary pesticides, destruction of non-target organisms such as parasites and predators and accumulation of harmful residues of food products. Integrated pest management is one of the alternatives for the chemicals used for pest management. IPM encourages the most comfortable and ecologically sound combination of available pest suppression techniques and to keep the pest population below economic threshold. Easily adaptable and economically viable integrated pest management strategies have been developed for the control of major pest in rainfed crops like cotton and pulses.

2.5.7 Alternate Land use Systems:

Despite evolving a number of production technologies, arable cropping in dry lands continues to suffer from instability due to aberrant weather. To provide stability to farm income and also utilize the marginal lands for production of fodder, fuel wood and fibre, a number of alternative land use systems were evolved based on location specific experimentation and cafeteria studies (Singh, 1988). In addition to the above general guidelines, specific experiments have been carried out to develop land use practices for different categories of soils across the centres integrating annual crops with the perennial component in order

to utilize the off-season rainfall (Katyal et al., 1994). Different alternate land use systems include agri-silviculture, silvi-pasture, agri-horticulture, alley cropping etc.

2.5.8 Integration of live stock with rain fed farming systems:

Live stock is treated as a part of farming system in rainfed agriculture in India. The soil, plant, animal cycle is the basis for all feed used by the animals. The livestock in the rain fed regions are weak. Farmers in this area often sell their cattle due to the scarcity of fodder. In India the land holdings are being reduced with increased population pressure. Hence, land not suitable for agriculture has to be diverted for raising fodder need of animals through the appropriate alternate land use system such as improved pasture, silvipasture, hortipasture and tree techniques.

2.5.9 Integration of the technologies through watershed approaches:

The concept of watershed is important in efficient management of water resources. As the entire process of agricultural development depends upon the status of water resources, the watershed with distinct hydrological boundary is considered ideal for taking up a development programme. In brief, planning and designing of all soil conservation structures are carried out considering the peak runoff. In this context, the watershed concept is of practical significance. Also, the entire development needs are to be taken up on topographic considerations from ridge to valley.

2.6 Resource conservation measures:

Details about conservation measures adopted in cultivated lands have been delineated by Katyal et al., (1995) and Sharma and Mishra (1995). Based on the nature and type of barriers and their cost, the conservation measures in arable lands can be divided into three categories: (i) Hardware treatments (ii) Medium software treatments and (iii) Software treatments.

2.7 Farming system approach:

Of late, it has been increasingly recognized that unlike irrigated areas, it is difficult to develop profitable technologies for heterogeneous agro-ecological and socio-economic conditions of small holders in arid and semi-arid regions (Osten et al., 1989). Since, the problems are complex, addressing only a component of the farming system, e.g crop variety, fertilizer use or even crop husbandry per se is not expected to bring about a significant increase in the productivity as witnessed in irrigated areas. The extension strategy should be such as to match this challenge. The farming systems perspective, dovetailed on watershed approach therefore can be the appropriate management strategy for such regions (Chambers, 1991).

III. CONCLUSION

The following steps constitute the farming systems mode for research, both on-station and on-farm (Watershed):

- PRA and assessment of socio-economic conditions of people.
- Identification of ITK (indigenous technical knowledge)
- Collection of available technological knowledge on various components of the farming system – arable farming, animal husbandry, water harvesting, management of wastelands and alternate land use systems etc.
- Focus group (farmers) interaction to identify appropriate technology for different categories of farmers.
- Identification of lead farmers to function as facilitator in technology application and adoption.
- Identification of points of synergy among systems components.
- Structuring of technological components with maximum synergy.
- Phasing of program over the project period.

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