Enhancing farmers' income through pulses in millets-based cropping in rainfed areas

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Introduction

Majority of the Indian population (70%) is dependent on agriculture which governs national economy, also food and nutritional security of the country and accounts for approximately one-fifth of the total gross domestic product (GDP). With increasing population, agriculture has prolonged scope for sustainable development to feed the mouth of vast population and livelihood support for rural population. Rainfed agriculture, which is totally rain dependent, accounts for 55.3% (about 78 m ha) of the net cultivated area in India and supports 40% of the human and 60% of the livestock population. Millets and pulses have potential to grow in harsh environment and minimize risks of entire crop failure unlike other cereals namely, wheat, rice and maize.

Millets and pulses, in India, bear significant relevance in promoting food and nutritional security for a number of reasons. These are the staple source of protein to a significant share of the Indian population and in particular the vegetarian population. Certain estimates reveal that India is estimated to have around 30 percent of the vegetarian population, who depend on pulses and millets for protein and minerals. They are also a rich source of proteins, fibre, vitamins and minerals, such as iron, zinc, folate, and magnesium (APEDA, 2015). Just as pulses provide nutritional benefits to humans, they also produce a number of different compounds that feed soil microbes thus benefitting soil health. One of the most popular benefits is the ability of pulses to fix atmospheric nitrogen (N) thereby, improving soil fertility. Not only do pulses discharge greater and different types of amino acids, the plant residues left after harvesting pulse crops also improve biochemical composition of the soil. Hence, pulses production can be provided compatibility with cereal crops to promote sustainability of the farming systems (Gowda et al, 2013). India is world's largest consumer of pulses (APEDA, 2015), domestic production has not been able to match demand thereby making India a net importer of pulses in recent times. In the last three decades, the total production of pulses only increased from 12 to 13 million tonnes and eventually resorted to imports to meet the demand. Pulses are usually cultivated as mixed crops along with crops such as cotton, mustard, or as catch crops between two cereal crops. A comparison of the economics of pulse-based cropping systems with non-pulse-based cropping systems was done by Materne and Reddy (2007) and stated that the input utilization (fertilizers, pesticides, labor and water) was less for the pulse-based cropping systems. The benefit-cost ratio was almost the same (1.8) for both the cropping systems. Overall, pulse-based cropping systems are more suitable for resource-poor farmers and water deficit regions (Ali and Gupta, 2012). Millets and pulses are the most important dryland crops grown in both kharif and rabi seasons in the semi-arid regions of the country for food, feed and animal fodder. These crops also show considerable resilience to changing climate (drought, heat and nutrient stresses). Sorghum productivity can be sustained during drought by adopting following advanced production technologies.

Growing import dependency and rising prices of pulses and millets are the prime challenges. This is primarily due to more money earning orientation and other infrastructural facilities that may have favoured other crops over millets and pulses, as well as farmers shifting to cash crops because they are more remunerative. These challenges of low productivity, growing water scarcity, land degradation and climate change effects need to be addressed with suitable technological interventions, promotion of value-addition, marketing and policy support in order to ensure nutritional and livelihood security of resource-poor farmers in rainfed areas.

Agro-ecological scenario of rainfed agriculture in India

India is home to 18% of world's population, 15% of the world livestock, 4.2% of fresh water resources, 1% of forests, and 0.5% of pasture land, but only has 2.3% of the geographical area. India is home to 25% of the world's hungry population of ∼1 billion along with an estimated 43% of children malnourished under the age of five. The net sown area in India has remained constant for several years at 141 M ha, but the human and livestock populations have been steadily increasing. Though the Indian population increased from 361 million in 1951 to 1140 million in 2011, tripling over 60 years, the food-grain production has more than quadrupled, but the yield gains are largely from the irrigated agroecosystems. Notwithstanding the increase in average productivity from 0.6 Mg ha^{-1} in the 1980s to 1.1 Mg ha^{-1} at the present time, large yield gaps exist for rainfed crops in the semiarid regions. Overall, the rainfed areas produce 40% of the food grains, support two-thirds of the livestock population, and are critical to food security, equity, and sustainability (Srinivasarao et al. 2015).

Rain fed agriculture is defined as “areas with less than 25% of assured irrigation and with annual rainfall of 500-1500mm. India ranks first in rainfed agriculture globally in both area (86 Mha) and the value of produce. Rainfed regions in India contribute substantially toward food grain production including 44% of rice, 87% of coarse cereals (sorghum (Sorghum bicolor), pearl millet (Pennisetum glaucum), maize (Zea mays)), and 85% of food legumes, 72% of oilseeds, 65% of cotton, and 90% of minor millets. Overall, the rainfed areas produce 40% of the food grains, support two-thirds of the livestock population, and are critical to food security, equity, and sustainability (Srinivasarao et al. 2015).

India is also facing the biggest challenge of meeting the food demands by increasing the production (per unit land) simultaneously without degrading the soil and water resources and maintaining a favorable ecological balance. In recent years, there is a general trend of reduction in per capita consumption of food grains and increase in the consumption of livestock products and vegetables. Despite decline in the food grain consumption because of the dietary shift, there is no substitute for cereals and pulses which are the staple foods, and the most economic sources of energy and protein and vital for nutrition of poor people. Hence, greater production of food grains is essential to meet the dietary needs in the near future. The demand for cereals is projected to grow from 185 million metric ton (Mt) in 1944-1995 to 270 (Mt) in 2024-2025. Domestic production of all these food commodities must be increased at the rate of (% $year^{-1}$) 2 for cereals and pulses, 6 for oilseeds, 0.9 for vegetables, 2.4 for milk, and around 3.5 for fish and egg. Growth rates required for cereals, pulses, and oilseeds exceed those achieved during the last decade. Thus, new and innovative strategies must be identified and implemented for increasing the production of cereals, pulses, oilseeds, and the projected food demand must come from increasing production of the rainfed agriculture, because there is little potential of expansion in irrigated area (Srinivasarao et al. 2014).

Cropping patterns in rainfed areas

Predominant rainfed crops grown in India include: coarse cereals (85%), pulses (83%), oilseeds (70%), and cotton (65%). In arid regions, single crop system involving a long fallow period (October to June) is a rule rather than an exception. Mixed or intercropping is common as a means of insurance and risk minimization. A large proportion of Vertisols in the semiarid region are left fallow during the rainy season due to water logging and drainage problem. A postrainy season crop is raised on the moisture stored in the soil profile. Sorghum (Sorghum bicolor), chickpea (Cicer arietinum), and to a lesser extent, safflower (Carthamus tinctorius) are commonly grown in Central India. These crops are grown either as sole crops or in intercropping combinations. In the North Central Plains, the main crop wheat is mostly grown as a sole crop, but is occasionally intercropped with chickpea. Common cropping systems in Vertisols are based on cotton. The cotton-based systems are cultivated on soils on the plateau or upper parts of the landscape as these soils are better drained than those at the lower part of the slope. On Alfisols, rainy season cropping is common, except on deeper soils where double cropping is practiced in years with good rainfall (Srinivasarao et al. 2015).

The changes in cropping pattern also have implications on resource use. Continuous monocropping increases vulnerability of farmers to weather risks, degrades soil fertility, depletes groundwater, and increases build-up of pests and diseases. These issues have to be addressed through both technological and policy interventions. There is a need to evolve management practices for farmer’s preferred crops without degradation of the natural resource base; and also there is need to define agroecological zones where such cropping patterns can be adopted sustainably. Simultaneously, need-based policy incentives are required to encourage farmers to adopt agroecology-compatible cropping patterns so that the farmers’ income is enhanced and the resource base is also restored and sustained.

Problems of Rain fed agriculture

1. **Low gross cropped area:** Due to inadequate irrigation facilities and low rainfall, most of the area under rain fed cultivation kept fallow. Only 66% of the area is cultivated every year.
2. **Risk:** As the agriculture is depended heavily on rains, risk is increasing. Amount rainfall, frequency of rainfall and untimely rains increases risk in rain fed areas

3. **Crust formation:** One of the biggest challenges in rain fed agriculture is crust formation. As there is little or no moisture in the soil coupled with low organic carbon make the top soil become hard for cultivation

4. **Soil erosion:** Wind and water are the common factors contributing for soil erosion. Lack of proper erosion control measures leads to loss of top soil. A study in Ananthapur reveals that on average every year 4tons of top soil is eroded due to wind erosion.

5. **Low organic carbon content:** All most all rain fed soils are poor in organic carbon content, which is the important factor minimizing the productivity.

6**. Depletion of ground water:** Over exploitation of ground water to irrigate crops particularly Paddy is another problem. Absence of ground water recharging aggravates the problem.

7. **Salinity and alkalinity:** Salinity and alkalinity due to accumulation of slats is another factor limiting the productivity levels.

Importance of millets

Millets are one of the cheapest sources of energy, higher content of digestive fibres, protein, vitamins and minerals (Ashok Kumar et al., 2012 and 2013). In terms of nutrient intake, sorghum accounts for about 35% of the total intake of calories, protein, iron and zinc in the dominant production/consumption areas (Parthasarathy Rao et al., 2006). Besides, being a major source of staple food for human beings, it also serves as an important source of fodder, feed and industrial raw material. It is grown in semi-arid climate where other cereal crops don’t stand well (Paterson et al., 2009). The threat of climate change is looming large on the crop productivity of millets. The area under cultivation millets and consumption is declining due to, low remunerative price, limited productivity, high drudgery involved in their processing, negative perceptions as a food of the poors and policy neglect when compared to other crops (Karthikeyan, 2016). However, the millets including sorghum are emerging as a potential alternative food, feed, and fodder crop because of its resilience to high temperature and drought makes it a climate-ready crop.

Though, we have potential sorghum and other millets technologies developed by the research organizations, there is a wide gap between the potential yield of the scientific technologies and that of the farmers obtain in their fields due to the several reasons like, lack of knowledge and skill and input support at grass-root level, etc. Marketed surplus ratio (MSR) of sorghum has increased significantly over the years from a mere 24 in 1950-51 to 64.14 in 2012-13 which implies that sorghum farmers have started selling off their products after meeting the consumption needs. Similarly, MSR of bajra has also increased over the years. The marketed surplus ratio of *ragi* has become almost half as compared to the early 2000's (ASG, 2014). It means that there is lot of scope for value-addition and processing to earn more than the routine business. Therefore, promotion of pulse crops with the millets and allied framings is also a viable option towards nutritional and economical security in sustainable way.

Challenges related to millets and pulses in rainfed agriculture

Since, rainfed agriculture has wide variability in rainfall, soils, temperature, terminal droughts, and vulnerable to climate change impacts, there are following crucial challenges which need to be addressed with science-based solutions.

- **Low productivity:** Due to dependent on natural rainfall, most of the area under rain fed cultivation, no use of soil type-based high yielding cultivars, non-adoption of soil moisture conservation practices and improved production technologies led to the low productivity.
- **Biotic stress:** Difficulties in timely sowing and non-adoption of disease resistant cultivars resulted into severe infestation of shoot fly and grain mold disease, respectively in *kharif* sorghum. Due to less and isolated cultivation of sorghum is prone to severe birds' and wild boar damage.
- **Competition with cash/vegetable crops:** The millets are not treated as cash crops and therefore, growers cultivates them on medium to poor soils with low or no inputs, like fertilizers, irrigation, etc.
- **Low remunerative:** Due to low productivity, lack of standardized market, buy back arrangements based-on minimum support price (MSP) and non-inclusion in mid day meal (MDM) or public distribution system (PDS), farmers could not get remunerative price.
- **Fluctuating market prices:** Since, there are no standardized market facilities and intelligence and procurement by the governments, market prices of the millets and pulses are sometimes less than cultivation cost.
- **Unawareness about health and nutritional benefits:** Though, the millets are good for human health and overcome several diseases, their consumption is reducing drastically due to unawareness, lack of commercial ventures and policy ignorance.
- **Lack of irrigation facilities:** Since, irrigation facilities are scanty and these crops are low/no remunerative, the farmers grow other cash crop or vegetable with available irrigations. Lack of availability of assured water supply and protective irrigation is a major reason for low yields.
- **Soil salinity:** Continuous rainfall and irrigation leads to accumulation of salts and drainage problems in black cotton soils. Therefore, the irrigation has to be used very judiciously to avoid salinization of soils as well as water-logging.
- **Low organic carbon content:** All most all rain fed soils are poor in organic carbon content, which is the important factor minimizing the productivity. Unavailability of organic fertilizers and continuous use of chemical fertilizers for cash crops led towards poor soil status.

Technology interventions

There is a large scope for increasing productivity and profitability for farmers through scaling-up of climate resilient agriculture; however, it calls for concerted efforts, adoption of location-specific and cost-effective technologies in diversified farming. The new technologies should also be less input intensive, cost-effective, less labour intensive and economically viable. Based-on experience of millets cultivation, some promising interventions are enlisted.

Millets-based pulses crop systems

The pulse-based cropping systems are environmentally sustainable also, as they require lower use of fertilizers, pesticides and irrigation in addition to enhancing the productivity of cropping systems by increasing yield of subsequent crops (Reddy 2004, Reddy 2009). To achieve appropriate land use, efficient inter- and sequence-crop systems were recommended based-on soil type, rainfall and length of growing seasons. Intercropping sorghum with legumes not only produces higher yields per unit area and time, but also provides nutritional security, economic benefits and improves soil health. Sorghum+pigeonpea (2:1/3:1/6:2) and sorghum+ soybean (3:6/2:4) are the two most common intercropping systems. Medium duration sorghum genotypes are most suitable for intercropping. Soybean - rabi sorghum has been found more productive and economically viable system in areas receiving annual rainfall above 700 mm and medium to deep soils having high water retention capacity, and sorghum (kharif)-chickpea, safflower and mustard (rabi) under limited irrigation conditions. Many other millets-based intercrop and sequence cropping are found to be more profitable namely, intercropping of sorghum (CSH 16) with pigeon pea in 2:1/2:2 row ratio and sorghum+soybean in 3:6 row ratio. Medium duration sorghum cultivars like CSH 16, CSH 18, CSH 25, CSV 15 and CSV 20 were most suitable for intercropping with greengram and blackgram. Crop sequence with black gram / green gram / soybean / cowpea (fodder) in kharif followed by rabi sorghum, and soybean-rabi sorghum sequential cropping was found more feasible and profitable. Also mix-cropping of sorghum and chickpea is well established and prominent in most of the rainfed areas of the Maharashtra and Karnataka. Promising intercropping with other minor millets were like, Pearl millets+Greengram, Pearl millets+Groundnut, Finger millets+Pigenpea, FM+Blackgram, FM+Fieldbean, Barnyard millets+Ricebean, Foxtail millets+Pigenpea, Foxtail millets+Fieldbean, Kodo millets+Pigeonpea, oilseeds, Little millets+Pigenpea, Greengram, Soybean, and Proso millets+Greengram. Crop sequence with Pearl millets-Chickpea and Finger millets-Blackgram, Greengram is also recommended.

Location-specific technology suitable for millets-based pulses crop systems

Soils in rainfed areas can be classified into three major categories based on soil depths, viz., shallow (<45 cm depth), medium (45-60 cm depth) and deep (>60 cm depth) with low-medium in water holding capacity. The moisture retention capacity varies therefore; soil-types based varietal selection is more suitable. Several millets especially sorghum cultivars were introduced in millets growing states which were found to be suitable in millets-based pulse crop systems. The crop production technology namely chemical weed control measures useful for the above cropping patterns were also available to use as mentioned in the following Table. Impact of the demonstrated technologies under FLDs proved that even small changes in use of low-cost recommended practices and timely management can have large effects on yields and monetary benefits (Chapke *et al*., 2011).

Intercropping systems	Recommendation	Time of application	References
Sorghum + pigeonpea	Metolachlor 0.75-1.5 kg/Fluchloralin 0.50/Pendimethalin 1.0 /Alachlor at 1.0 kg/ha + 1 inter-row cultivation/hand weeding	Pre-em. 30-35 DAS	Arya and Niranjan (1993); Billore et al. (1990); Kandasamy et al. (1999); Singh and Singh (1999).
Sorghum + cowpea/greengram/blackgram	isoproturon at 0.50 kg/ha or butachlor at 0.75-1.0 kg/ha or metolachlor 1.0 kg + 1 HW	Pre-em. 35-40 DAS	Kempuchetty and Sankaran (1990) ; Krishnasamy and Krishnasamy , (1996); Ponnuswami et al. (2003), Sundari and Kathiresan (2002)
Cropping systems			
Sorghum-cotton	Pre-emergence application of atrazine 0.25 kg/ha in sorghum and pendimethalin 1.0 kg/ha in cotton; Poor establishment of greengram and groundnut after atrazine treated sorghum.		Palaniappan and Ramaswamy, 1976
Sorghum-safflower	Pre-emergence application of atrazine at 0.75 kg/ha in sorghum		Giri and Bhosle (1997)

Water conservation practices

Dependent on rainfall for *kharif* and residual moisture for *rabi* crops is a major concern. Cultivation of *rabi* sorghum and chickpea on residual soil moisture and occurrence of terminal drought are the major reasons of low productivity. In-situ moisture conservation practices like compartmental bunding and ridges and furrows, adoption of soil-based improved cultivars, nutrient management and irrigation scheduling based-on water availability whereas, organic mulching in *kharif* are the important management options for improving sorghum productivity (Patil *et al*., 2013). Results revealed that compartmental bunding during *kharif* season conserved 12.6% more soil moisture and produced 20.6% higher grain yield over farmers' practice.

New niches of millets and pulses cultivation (in rice fallows)

Although millets are known to be climate resilient crops, their cultivation in traditional areas is reducing. New niches like rice fallows sorghum and pulses cultivation plays significant role in economical security of the farmers. Sorghum hybrid; CSH 16 (7.50 t ha^{-1}) yielded significantly better than the locally popular hybrid Mahalaxmi 296 (5.86 t ha^{-1}) in rice fallows in Guntur district of Andhra Pradesh, during four years from 2012 to 2016. The significant increase of 27% was observed in grain and ultimately it was resulted into 73% higher monetary benefit to the farmers (Chapke *et al*., 2011a). The district yield average of sorghum is 6.80 t ha^{-1} during 2014-15 which is around seven times more than the national yield average (0.90 t ha^{-1}), Such success story can be replicated to introduce other millets and pulses like, blackgram and green gram in rice fallows which, assures additional income to the farmers.

Value-addition and post-harvest processing

The increasing MSR indicated that there is lot of scope for value-addition and processing to earn more than the routine business. Creation of demand for millets and pulses value-added products as healthy food will boost the production and consumption scenario of millets which will have a long-term impact on the sector. Increase in demand for the millets and value-added products will boost the farmers' morale towards millets cultivation and will also help in realising better prices for their produce. In addition, there is increasing scope for fadder value-addition.

Mechanization

As the millets cultivation especially sorghum is more labour-intensive and more than 55% cost goes towards labourer and labor problem is common for all the crops. Harvesting operations needs more labourer and takes major share. Hence, suitable harvesting–cum-threshing like combine machine is much essential. Moreover, 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. The above mechanization can help to reduce cost and labour requirements which will encourage the farmers.

Sustainable millets production and value chain through FPOs

Most important factor that accelerates the competitiveness of the millets and pulses in the international as well as domestic markets is the grain quality and organic produce. Use of pest and disease resistant, nutritional rich varieties and organic production could create more opportunities. Enhancement of export competitiveness of these crops in the international as well as targeted domestic markets will help the farmers to fetch good returns for their produces in long term. For this and in view of small and marginal farmers' background, their collectivization into farmer's producer organizations (FPOs), may be an effective pathway to harness collective synergy.

Promotion of allied enterprises as integrated farming system

Since, the mono-cropping and traditional farming are not viable, 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 soil, plant, animal cycle is the basis for all feed used by the animals. The livestock in the rainfed regions are weak. Farmers in this area often sell their cattle due to the scarcity of fodder. The land holdings are being reduced with increased population pressure. There is large unexploited scope to harness system level productivity and value chains, wherein women have income-generating opportunities through women-focused activities. Therefore, the millets and pulses-based integrated farming system approach with introduction of poultry, dairy, goat farming, piggery and apiculture at each household will help to supplement the farmers' income and women empowerment.

Drivers to strengthen value chain

The farmers have limited resources and diversified needs under several socio-economic and farming constraints which had become their primary concern in motivational perspectives before they decided for any changes and adoption of the new practices. Millets and pulses are less remunerative which requires the following necessary supports as drivers in value chain mode to make them more profitable in order to enhance farmers' income.

- **Institutional support:** There is a large scope for increasing productivity and profitability for farmers through promising production technologies developed by research and development (R&D) organizations and scaling-up of climate resilient crops *viz*., millets along with pulses. Weather forecasting- and resource-based crop selection coupled with soil test-based recommendation have crucial role in bridging out the wide yield gap. For adoption of new technologies and farm practices requires a wide array of human skill which is equally important component.
- **Input support:** Availability of quality inputs like, seeds of HVYs, disease resistant varieties, fertilizers, agro-chemicals, in time and place are the keys for adoption of new technologies for increasing productivity and profitability. Varietal replacement with high-yielding and climate smart crop backed with developing de-centralized seed systems group approach (farmers' cooperatives, SHGs, FPO, etc.) needs to be operationalized.
- **Financial support:** Hassle free and timely financial support for mechanization labour intensive operations is a stepping stone for encouraging farmers to overcome labour problems and to avoid losses for failing in timely operations. Promoting on-farm mechanization through PPP mode, incentives to entrepreneurs to set-up village level one-stop-center for agricultural mechanization and other ways are viable options.
- **Market support:** Standardized market facilities, intelligence development, get rid off from middlemen and buy back arrangements at grass root levels would enhance confidence of the farmers. These are the important burning issues to be addressed on priority.
- **Infrastructure support:** Millets and pulses are known to be healthy food, even primary processing can double the income of farmers as it is main bottleneck. To overcome short self-life problems of millets; storage, road, transport facilities and adequate electricity supply are essential.
- **Policy support**: There is lot of scope for value-addition and processing to earn more than the routine business. It can be promoted through entrepreneurship development in collective action mode through SHGs and FPOs. These apart, policy support for farm-gate processing, control of wild animals, buy back assurance; implementation MSP for all millets, their inclusion in MDM and PDS system will boost-up the economy of the farmers in rainfed areas. Farmers should be covered under insurance schemes to avoid any loss due to crop failure and other natural calamities.

Strategy

Millets and pulses have huge potential to enhance the income of the resource poor farmers in dryland conditions which needs such strategy that should be matched these challenges. The following key steps constitute the strategy emphasizing plough to plate transition in order to enhance the farmers' income at substantial level.

- Enhancing productivity introducing location-specific millets-based pulses and suitable promising production technologies from R&D organizations
- Emphasis on moisture conservation practices and also link with watershed development programme
- Introduction of millets-based pulses in new niches and allied farming involving women like, poultry, dairy, goat farming, piggery and apiculture
- Introduction of mechanization and hassle free financial support
- Marketing facilities and inputs support in convergence mode (single window system) and collective action through FPOs
- Creating awareness about health and nutritional benefits of millets and pulses through effective mass and local media to bring change in the consumer preferences
- Promotion of value-addition through entrepreneurship development through group approach (SHGs, NGOs)
- Policy support for buy back arrangements with MSP, crop insurance, inclusion in MDM and PDS system, infrastructure for farm gate processing and warehouses

Conclusion

One of the most important ways to address India's developmental challenges is through achieving self-sufficiency in food production and ensuring nutritional security for all. India's substantial vegetarian population, food access challenges faced by people across states, and growing sustainability challenges in the Indian agriculture, makes it important not only to have policies that can promote production of pulses and millets as they are highly compatible, but also ensure better access and delivery at affordable prices. One of the most of the important issues with regard to retail availability and price has been the government's inaction in procuring and distribution millets and pulses particularly through the public distribution system. Procurement of pulses and millets has remained very weak. Pulses and millets procurement remained a deficit area which has deprived the growers of enjoying the full advantage of MSP.

In order to achieve the goal of enhancing farmers' income through millets-based pulses cultivation, there is need of viable strategy comprising of major elements viz., introduction of millets-based pulses cultivation to minimize the risks and capacity building with support of R&D organizations coupled with inputs supply in single window mode, (ii) promotion of value-addition and creating market demands through collective action like, formation of FPOs and SHGs, and (iii) policy support for buy back arrangements with MSP, crop insurance, inclusion in MDM and PDS system, infrastructure for farm-gate processing and warehouses.

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