NJAS - Wageningen Journal of Life Sciences xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

NJAS - Wageningen Journal of Life Sciences

journal homepage: www.elsevier.com/locate/njas

Sustainable use of natural resources for crop intensification and better livelihoods in the rainfed semi-arid tropics of Central India

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ARTICLE INFO

Article history:
Received 4 July 2013
Received in revised form 13 January 2014
Accepted 22 December 2015
Available online xxx

Keywords:
Balanced nutrition
micronutrients
productivity
production system resilience
soil degradation

ABSTRACT

In Indian semi-arid tropics (SAT) in general and central part i.e. Madhya Pradesh state specifically; there are large yield gaps in most of the rainfed crops between current farmers' yields and achievable ones. Soil fertility related degradation due to deficiencies of secondary and micronutrients mainly sulphur, boron and zinc in addition to macronutrients is mainly responsible for poor crop productivity, and along with poor hydraulic properties of Vertisols is responsible for about 2 million ha rainy season fallows. Soil health assessment of 11 districts in Madhya Pradesh, India has revealed that in most of the districts only few fields with adequate levels of sulphur, boron, zinc and phosphorus indicating their widespread low levels. Potassium was in general adequate. Farmers' current blanket fertilization practices focused at macronutrients viz. nitrogen, phosphorus and potassium only, thus does not meet the variable soil fertility needs. Through participatory action research on soil test based fertilizer application, farmers realized benefits in crop productivity to the tune of 5 to 45% in the season of application and additional yield by 5 to 27% due to residual effects of S, B and Zn in succeeding three seasons. An economic assessment showed the balanced nutrition a profitable option in the 1st season itself. In current rainy fallow regions, the landform management as broadbed and furrow or conservation furrow along with balanced nutrition has shown that fallow lands in black soil regions in Madhya Pradesh can be successfully cultivated to grow soybean crop. In succeeding post-rainy season, the rainy season cultivated plots also yielded more as compared to adjoining plots having one crop only in post-rainy season. This study thus found that soil test based fertilization and landform management are the twin technologies for sustainable crop intensification in black soils of Central Indian region.

1. Indian rainfed semi-arid tropics (SAT) – importance and issues

Eighty per cent of the cultivated area worldwide is rainfed and contributes nearly 60% of the world's food [1]. These are the homes to world's poor and malnourished people, and maximum population growth (95%) is taking place in these developing regions [1]. In India also, the rainfed cropped areas comprise about 60% i.e. 89 million ha [2]. The 40% of irrigated area in India has reached a plateau in terms of productivity and today there is a big issue of concern to feed the burgeoning population. Irrigation expansion, a major thrust of growth in crop area in the past decade, is likely to continue and irrigation coverage is expected to increase from 40% to 55% over the period 2000–2050, thus still around 45% of the area in the year 2050 will continue to remain rainfed [3,4]. The option of increasing arable land is exhausted and rather per capita arable land availability in India has decreased from 0.39 ha in 1951 to 0.12 ha in 2011 due to increased population from 359 million in 1951 to 1.21 billion in 2011 [5], which is further expected to rise to 1.69 billion by 2050 [6] with associated decrease in per capita land availability (0.09 ha). Within existing land and water constraints, India must sustainably increase the current food production to around 380 million t in 2050 [4], to meet the growing food demand. So, in current context, it is very necessary to increase the productivity levels of the major rainfed crops to meet the ever-increasing demand of food, which emphasize the critical importance of rainfed agriculture in Indian economy and food security. Moreover it is a well-established fact that agriculture plays a key role in economic development [7] and poverty reduction [8] which is a rampant problem in Indian

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http://dx.doi.org/10.1016/j.njas.2015.12.002
1573-5214/

rainfed SAT regions. There is evidence indicating that every 1% increase in agricultural yields translates to a 0.6% to 1.2% decrease in the percentage of absolute poor [9], and so the issue of agriculture development in neglected rainfed regions assumes much more importance today than ever before.

Madhya Pradesh in India is a typical semi-arid tropical region. Agriculture is the predominant occupation and source of livelihood for rural people, and therefore natural resource base is the lifeline of the millions of rural poor. Depletion of the resource base is diminishing the capabilities of poor farmers to earn more and making them vulnerable to drought and other climate related disasters. The present scenario so clearly points to the need for adoption of science-led interventions leading to efficient and sustainable use of natural resources to improve agricultural productivity and livelihoods to alleviate poverty, hunger and malnutrition in SAT regions of Madhya Pradesh and India.

2. Important rainfed crops in SAT regions in Madhya Pradesh, India

In cropping pattern of Madhya Pradesh, soybean (*Glycine max* (L.), groundnut (*Arachis hypogaea* L.) and mustard (*Brassica compestris*) are the major oilseed crops (Table 1). For the country as such, soybean and groundnut together contributing about 64% of total oilseed production [5]. As regards to soybean, Madhya Pradesh is the state contributing largest acreage (56%) and production (51%) at national level (Table 1). Being the cheapest source of high quality protein (40%) [3], soybean has potential to play an important role in mitigating the large-scale problem of protein malnutrition particularly in children and women in the rural areas of the country. Its oil content (18%) is second only to groundnut among food legumes [3]. Low soybean productivity in the state in comparison to even at national level in spite of suitable agro-climatic conditions is a matter of concern. Groundnut is important oilseed crop in India (5.31 million ha area, 6.93 million tonnes production) and Madhya Pradesh state contributes significantly about 4% of national acreage and about 5% of national production (Table 1). Groundnut seeds contain high quality edible oil (50%), easily digestible protein (25%) and carbohydrates (20%) [3]. Both soybean and groundnut are legume crops which help in improving soil health, and hence have an important role in fitting in the cropping system mainly during the rainy season and sustaining soil fertility in the drylands.

Among pulse crops, chickpea (*Cicer arietinum* L.) is one of the most important crops of India contributing about 44% of total pulse production, and Madhya Pradesh state contributes highest (37%) to nation chickpea acreage and national chickpea production (43%) (Table 1). In low input traditional production systems, chickpea has been a preferred crop because of its minimal dependence on monetary inputs of N and P-containing fertilizers, irrigation and agrochemicals in general. It is a valuable source of protein for poor population and a source of livelihood for the small and marginal farmers in India and other developing countries. Chickpea is a suitable legume crop to fit in the cropping system during post-rainy season and thus contribute soil health improvement and sustaining soil fertility particularly in drylands.

As regards cereals, wheat (*Triticum aestivum*), maize (Zea mays), rice (Oryza sativa) and coarse cereals fit in the cropping system in Madhya Pradesh, and their lower productivity (Table 1) mainly due to poor management is an issue of concern. Wheat is cultivated during post-rainy season and Madhya Pradesh is next to Uttar Pradesh in acreage and Uttar Pradesh, Punjab and Haryana in production [5]; and contributes to about 16% of national acreage and 11% of national production (Table 1). Wheat yields in different states vary tremendously due to different technologies adopted by the farmers and the agro-climatic characteristics of the region.

3. Large yield gaps and existing potential to tap in the rainfed SAT regions in India

Despite long history of cultivation along with being important source of livelihood and nutrition for the small and marginal farmers in Madhya Pradesh, and SAT regions in India, the actual yields from rainfed agriculture have remained quite low as compared to achievable ones[10–15]. Historic trends present a growing yield gap between farmers' practice (FP) and farming systems that benefit from management advances. Various studies [3,16,17] in India have shown that current farmers' yields are quite low and there are large yield gaps between current farmers' yields and potentially achievable yields to the tune of 850 to 1320 kg ha^{-1} in soybean, 1180 to 2010 kg ha^{-1} in groundnut, 610 to 1150 kg ha^{-1} in chickpea, 680 to 1040 kg ha^{-1} in pearl millet, 2560 kg ha^{-1} in rice, and 70 kg ha^{-1} in wheat. A long term experiment (since 1976) at ICRISAT center based at Patancheru, India has demonstrated a virtuous cycle of persistent yield increases up to 5 times through improved land, water and nutrient management in rainfed agriculture [1,12,18]. So there is clear evidence of large gaps between actual and attainable yields, which suggest an urgent need for boosting financial and technical investments to sustainably intensify SAT regions and address the issues of poverty, food security and nutrition.

4. Soil degradation holding back the achievable yields in the Indian SAT

In the semi-arid tropics (SAT), soil fertility related degradation (19, 20, 21] in addition to water scarcity has been identified as the main cause for low crop yields and inefficient utilization of even existing water resources. Rainfed soils are multi nutrient deficient and need proper nutrient management strategies to bridge the existing gap between farmers' current yields and achievable potential yields (19, 20, 21). In view of observed deficiencies of major nutrients nitrogen (N), phosphorus (P) and potassium (K), their application as currently practiced is important for the SAT soils [22–24], but very little attention has been paid to diagnose and take corrective measures for emerging widespread deficiencies of secondary and micro nutrients in various crop production systems [20,21,25–27] followed in millions of small and marginal farmers' fields in the SAT. This corrective fertilizer management strategy to address soil fertility related degradation apparently is the key to realize achievable yields.

5. Rainy season fallows: opportunities to boost production in Central Indian SAT

There are regions in Madhya Pradesh where no crop is grown during rainy season called as rainy season fallows or rainy fallows. Three fundamental barriers to cropping in black soil region are; (1) threat of flooding of the rainy season crop due to heavy rains, (2) difficulty of soil preparation prior to the monsoon for timely sowing of a rainy season crop, and (3) reduction in available soil moisture for the post-rainy season crop if a rainy season crop is taken. Traditionally farmers grow a timely secured post-rainy season crop on stored soil moisture and keep the fields fallow during rainy season. It is estimated that 2.02 million ha accounting for 6.57% of the total area of the state remains under rainy season fallows [28,29]. Madhya Pradesh in Central India is endowed with Vertisols (black soils) and associated soils along with assured rainfall (700 to 1200 mm). These soils have poor hydraulic conductivity, and consequently are frequently poorly drained. Studies have proved that Vertisols which have good moisture holding capacity can be used to grow short duration soybean by adopting sound land management practices [12,30]. This will help increase income to farmers besides

Please cite this article in press as: S.P. Wani, et al., Sustainable use of natural resources for crop intensification and better livelihoods in the rainfed semi-arid tropics of Central India, NJAS - Wageningen J. Life Sci. (2015), http://dx.doi.org/10.1016/j.njas.2015.12.002