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Review Article

CLIMATE RESILIENT AGRO-FORESTRY INTERVENTIONS TO REDUCE FARMING RISKS IN RAJASTHAN

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Abstract: Farming in Rajasthan is very uncertain and risky due to frequent droughts and poor production levels. However, increased levels of farm inputs has resulted in depletion of natural resources and showed socio-economic and ecological ill effects. In order to achieve the sustainability through integrated farming approaches under changing scenario of climate, various agro-forestry practices are suggested for further scaling up, acceptance and mass adoption for their multiple benefits and resilience abilities to observed risk factors. Several combinations of food crops, horticultural crops, tree crops particularly multipurpose leguminous, fast growing species as source of food and nutrition, fodder, energy, eco-friendly crops were suggested both at farm lands and non conventional land types in rural landscapes. Also emphasized their role in supporting additional income, products diversification, livelihood and employment generation opportunities through these agro-forestry practices. Ongoing government initiatives in boosting mitigation practices through various schemes, policy interventions and their potential strategies are described here.

Keywords: Agro-forestry, biodiversity, climate resilience, farming risks, livelihood, productivity, sustainability.

Introduction

The state Rajasthan in India represents its greater regions under arid and semiarid conditions where agriculture is primarily rainfed in nature. Moreover, more than 5.017 million hectare of land is cultivable wasteland. In spite of having the highest share of land area among all other Indian states, the state is not agriculturally much productive. Another life supporting occupation animal husbandry contributes to the state GDP is about 9.16%. About 35% of the income of small and marginal farmers in the state is derived from animal husbandry, with this share being as high as 50% in the arid regions (RPCB 2010). Over the period contribution of the agriculture sector to the State GDP has sunk from 64% in 1970-71 to around 60% in 1988-89 to 27% in the current time frame (RPCB 2010). To cope up the yield in such scenario, rise in agricultural production, especially with high inputs, including energy, will most likely have a negative effect on natural resources. Unfortunately, agricultural development has already led to environmental and social problems *viz,* declining groundwater

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tables, increasing salinity of groundwater, indiscriminate use of agro-chemicals, over grazing and fuelwood collection from forest area, *etc*.

Farmers in the state were found to be highly vulnerable to climatic variability due to frequent drought intervals. Crop yields have been substantially reduced, particularly for the majority of farmers who lack access to irrigation. To cope with successive years of drought, many small farmer's family members migrating to the neighboring states to support their livelihood. The current trend of biotic pressure on state's natural resources and on forests in particular for day to day needs is worth analyzing. Thus, under the given conditions of the resource base in the state, agriculture is a high risk activity. The recommended practice of integrated farming has not yet come true in practice. Also, hard pressing market forces and changing climate are other burning issues in balancing economic growth and greater ecological sustainability. Adopting strategies to safeguard these natural resources at the earliest will not only result in greater ecological services and functions, but also compliment the efficiency, productivity and prosperity of farming community and the society.

Farm productivity & risks

During the last three decades the net sown area in arid Rajasthan has increased by 36% while current and long fallows have declined by 29 and 41%, respectively. The net irrigated area has also increased by 140% (TERI, 2010). It is to be noted that the ground water in state is overexploited to the tune of 109-145% (Sharma, 2009). The estimated annual, per capita water availability in the state during 2001 was 840 m^3 and it is expected to be 439 m^3 by the year 2050, against the national average of 1,140 m^3 by 2050 (Narain *et al.*, 2005). The soil organic content stands at 70.08 tons per hectare, which is one of the lowest amongst all Indian states (RPCB, 2010). It also ranks among the states where proportion of land undergoing degradation is highest (Ajai *et al.*, 2009). Apart from that, State has 47% probability of occurrence of a meteorological drought, the highest in the country (Rathore, 2004, RPCB 2010) by which both low-income and middle-income households are vulnerable. In context of farm sizes, it is marginal and small farmers that are normally most vulnerable, whereas in desert region, even the large land holders are vulnerable due to the inferior quality of land with no irrigation facilities and greater dependency on erratic rainfall.

The fodder deficit of western Rajasthan is estimated to be as high as 60 per cent of the demand and ranges from 55 per cent in western districts to 69 per cent in central districts and 72 per cent in eastern districts (Pratap Narain and Kar, 2005). This situation is further aggravated during drought years. With respect to livestock, due to greater mobility and

voracious feeding nature small ruminants like goats and sheep as well as intensively managed buffaloes escape the risk of drought but the cows are more vulnerable made them to abandoned to starvation or put in charity centers because of acute shortage of fodder and finances (Figure 1 a and b).

Fig.1 a. Heavy lopping of fodder trees

FIg. 1b. Uncontrolled forest grazing

The number of buffalo, goat and sheep has grown significantly in the past 50 years. Steep rise in goat and sheep numbers may be attributed to the poor availability of fodder to sustain buffalo/cattle. According to 19th Livestock Census-2012 Rajasthan has livestock population of about 5,77,32,204 accounts highest in the country after Uttar Pradesh (6,87,15,147). Also, one of the highest methane emitters state contributing almost 9.1% to the total methane emissions of the country (Chhabra *et al*.,2009).

Role of Agro forestry for multiple benefits

In the context of farming risks and uncertainties as discussed above, rising agricultural production and sustainable farming is really a challenging one**.** Government of India's initiatives in this regard by National Mission for Sustainable Agriculture (NMSA) formulated for enhancing agricultural productivity that derives its mandate from Sustainable Agriculture Mission which is one of the eight Missions outlined under National Action Plan on Climate Change (NAPCC) especially in rainfed areas focusing on integrated farming, water use efficiency, soil health management and synergizing resource conservation is worth to highlight in this regard. **C**rop diversification is an important component of sustainable agriculture practices over the monoculture cropping patterns; however combination of multipurpose tree species (MPTs), animal components along with agriculture crops is also a proven scientific land use management practice which is commonly known as agro-forestry. As multifunctional agro-forestry system provides fodder, fuel, timber, fruits, seeds, pods,

livelihood support apart from soil quality enhancement and proficient restoration of soil organic matter (Pandey, 2007).

Agro-forestry practices not only provides environmental services, but also economic gains, as about 65 % of the country's timber requirement is met from the trees grown outside forests. This can also help in generating the rural employment and rural development opportunities by providing agro-forestry tree produce based economic opportunities. Beyond mitigating climate change, the other benefits of having trees on the landscape include the maintenance and improvement of soil productivity, biodiversity and ecosystem services, many of which are highly correlated with the carbon stocks in soil and biomass. Inter-annual, intra-seasonal, monthly and daily distribution of climate variables (primarily temperature, precipitation and humidity) play a fundamental role in most of the physical, physiological, chemical and biological processes that drive productivity in agriculture, livestock and forestry. Any change in climatic determinants can not only lead to adverse impacts on food security and nutrition but also essentially affect well being of the population deriving livelihood and income from the sector. Agriculture and allied sectors therefore exhibit high sensitivity to climate stresses.

Climate Change Agenda for Rajasthan - 2010 highlights the Mission on Afforestation through promotion of agro-forestry in order to buttress livelihoods of forest-dependent communities. Hence, to cope with climatic changes, agro-forestry can become an important tool to build resilience of farmers and rural people against threats of climate change and natural calamities. This provides broader scope of agro-forestry in the current context in the state that seems to be more relevant to explore greater benefits in the area of achieving higher productivity and sustainable scientific land use, risk reduction and maintaining regular flow of farm income, food and nutritional security apart from maximizing ecological services and biodiversity conservation. Thus, agro-forestry in the state boosts up the following benefits:

- Reducing pressure on natural forest
- Reducing the demand supply gap of immediate forest products
- Improving the farm productivity
- Generating diverse products in short rotation period to ensure regular income flow
- Improving the soil productivity
- Restoring and conserving the biodiversity
- Pacing towards energy fulfillment
- Supporting livelihood and ensuring food and nutritional security

- Environmental amelioration, carbon sequestration and mitigating the risks of climate change.

Climate resilient agro-forestry Interventions

Traditional agroforestry practices involving tree species such as *Prosopis cineraria, Tecomella undulata* and *Salvadora oleoides, Dalbergia sissoo and Azadirachta indica* has been an important life support system during drought. In these localities with changes in technologies, markets, etc. the use of traditional knowledge is getting reduced ultimately increasing the stress over the ecosystems and impacting the livelihoods of the local people. But even today traditional knowledge has potential to assist the disaster management strategies in a participatory and decentralized manner. The commonly found agri-silviculture practices in different parts of the Rajasthan includes *Acaia nilotica* with wheat and mustard, *Ailanthus excelsa* with wheat, *Prosopis cineraria* with *Vigna radiata* and wheat and *Hardwickia binata* with *Vigna radiata*.

Traditionally grown trees in farm lands like *Prosopis cineraria*, *Dalbergia sissoo*, *Acacia leucophloea* and *Acacia nilotica* having a canopy diameter of about 8 m contribute significantly in improvement of soil biological activities in terms of microbial biomass, C, N and P, dehydrogenase and alkaline phosphatase activity under different tree based agro-forestry systems. Amongst trees, *P. cineraria* based system is reported to bring maximum improvement in soil biological activities. It has been observed that, indigenous tree *Prosopis cineraria* - Khejri in Rajasthan effectively stabilizes sand dunes and can withstand periodic burial. It is believed to be the best suitable agro-forestry species, due to its deep taproot system, positive allelopathy effect, soil fertility improvement and yield augmentation of understorey crops (Gates and Brown, 1998).

Agriculture is a sector that requires constant adaptation in order to maintain yields. Considering the diverse agro-climatic zones recognized in the state, the following potential climate resilient agro-forestry Interventions are described here. Agri-silvicultural system involves intercropping of agricultural crops with tree crops where the shallow rooted food and fodder crops of shade loving nature were cultivated simultaneously. Along with major field crops, short rotation small/medium sized timber species like *Acacia nilotica* (babool), Dalbergia sissoo (*sissoo*), *Azadirachta indica* (neem), eucalyptus and teak can be raised. Extending the same, some of the missing agro-biodiversity crops can also be taken up both for commercial and conservation purposes.

Jhalawar region being located in South-East Rajasthan recognized as semi-arid area receives an average of 943 mm of rainfall annually. In addition to high degrees of climate sensitivity, it also ranks among the lowest of the state's districts in terms of its adaptive capacity (O'Brien *et al,* 2004). Over the past two decades, many farmers in Jhalawar have shifted from traditional crops, such as sorghum and pearl millet, to production of soybeans and oranges, which receive higher market prices. However, soybean prices much fluctuate according to market prices, the shift toward soybean production has left farmers in Jhalawar vulnerable to price shocks. In agri - silvi horticulture system greater demand has been observed for bamboo culms during setting up of fruits in citrus orchards of Jhalawar region (Figure 2). Thus, growing solid bamboo species in linear strip at 5 mX 5 m spacing or in a scattered way on farm field or boundary can be a viable option for maintaining healthy orchards along with regular flow of produce as an additional income.

Similarly, *Lawsonia inermis* (Henna) also fetches higher market demand which prompts as dense hedge crop. The major advantage apart from the market support attributes moisture conservation. In addition exploring tree combinations with other several horticultural crops like kinnow, *Phyllanthus emblica* (amla) in Ganganagar and Hanumangarh, *Psidium guajava* (Guava) in Sawai Madhopur and Bundi, *Cuminum cyminum* (cumin) in Jalore, Barmer and Jhalawar regions.

Out of the total seed spice production in Rajasthan coriander contributes about 58.51% from 40.86% area. SE Rajasthan primarily dominates in coriander production where Kota region alone contributes about 98% area in the state. The main constraints for higher yield and better grain quality are found to be the cloudy weather and rainfall during flowering and seed setting. Further, low temperature and wind affects early sown crop and harvested crop, respectively (Meena *et al.,* 2013). Thus, coriander under suitable canopy management of woody perennials may safeguard and promote the yield and quality. Thus, there is immense scope to diagnose and adopt coriander cultivation with tree combinations in these localities.

Silvi horticultural system includes raising tree crops along with horticultural crops (fruits, vegetables, flowers, plantation crops, spices etc).Under this category initiatives are suggested to harness the benefit of low cost established wild underutilized fruits cultivation like *Annona squamosa* (sitaphal), *Manilkara hexandra (Rayan)*, Salvadora sps, *Capparis* sps (kair), *Artocarpus integrifolia* (jackfruit) , *Syzygium cuminii* (jamun), *Limonia acidissimica* (kainth) and *Moringa olefera* (*Senjan*), *Sesbania grandiflora* are suggested for raising on the field in semi arid and humid regions.

Further, cultivation of indigenous vegetables which are hardy, drought resistant that have short duration, grow well and have good nutritive and medicinal values with resistance to biotic and abiotic stresses, like *kachari* (*Cucumis melo* var. agrestis), snap melon (*Cucumis melo* var. momordica), spine gourd (*Momordica dioica*), bitter melon (*M. balsamina*) and hill colocynth (*Cucumis hardwickii*). These varieties are currently grown in southern Rajasthan by tribal people for their income generation.

Unlike other popular areas of **crop combinations with plantations** in the country *viz*, coconut, coffee, rubber, areca are not possible due to climatic and edaphic limitations but a small initiatives like betel vines plantations under high density *Moringa olefera* (drum stick), *Leucaena leucocephala* (subabul) and *Sesbania grandiflora* can be taken up in parts of sub humid regions of Rajasthan. Looking into hardiness, fast growing high biomass yielding and nitrogen fixing nature of these tree species the innovative interventions may yield good results in South east part of the state in particular.

Rajasthan comes under high damage zone owing to high velocity winds. After Jammu and Kashmir, Rajasthan is the second state where maximum number of cold waves has occurred (De *et al*., 2005). Hence, protecting crops and animals against extreme environment through erecting windbreaks and shelterbelts enhances protective values. Linear or multi row **windbreaks** with fast growing species like *Dalbergia sisoo* (sissoo), *Ailanthus excels*a (Ardu), *Syzygium cumini* (jamun), *Acacia nilotica* (babool) *etc* can be erected in arid and semi arid region by keeping tall trees in the centre to reduce the impact of wind erosion, moisture conservation, safeguarding crops, animals and properties against high wind velocity.

Live hedges: On account of extensive rhizome-root system and accumulation of leaf mulch, bamboo serves as an efficient agent in preventing soil erosion, conserving moisture reinforcement of embankments and drainage channels etc. (ZHOU *et al*, 2005). Bamboo based and *Lawsonia inermis* (henna) based live hedges not only boost the regular income with least input but favors early pay back. Sharma *et al* (1992) have also reported that bamboo conserves soil moisture and mitigates the adverse drought effects on flora and fauna.

Boundary plantations: For large sized landholders both under irrigated and un irrigated conditions, block plantations with *Tectona grandis* (teak), *Dalbergia sisoo* (sisoo), *Acacia nilotica* (babool), Eucalyptus Sps, *Leucaena leucocephala* (subabul), Ailanthus sps and bamboo plantations can be advisable for greater multiple benefits from trees.

Added to that, under **energy plantations and block plantation** systems, it is advisable to raise multipurpose fast growing, energy supplementing tree species under high density

schedules. Looking into the strong prospects State Bio-Fuel Mission was constituted in 2005. There is tremendous potential of cultivating biofuel crops and tree borne oil seeds on culturable wasteland degraded forest land, farm boundary etc in the state through massive scale plantation of *Jatropa curcas* (jatropa), *Pongamia pinnata* (Karanj) and *Simaruba glauca*. Further, coordinated efforts of institutional, technical and financial support by line departments and universities to transfer the technology and supplying planting material is essential towards pacing up energy reliance. In general *Pongamia pinnata* (Karanj) and *Leucaena leucocephala* (subabul) based alley cropping may also be a good viable option for improving soil productivity in addition through its nitrogen fixing ability.

The high density energy plantations of fast growing *Leucaena leucocephala* (subabul), *Acacia nilotica* (babool) and exploration of *Acacia auriculiformis* and *Acacia mangium* under village wood lot scheme/ **agro-forestry fuel wood systems** may also be initiated as pilot projects for their suitability. Apart from this, there is a greater scope for harnessing the benefits of oil production under ongoing.The major species required attention under the agro-forestry practices involves *Madhuca indica* (Mahua), *Pongamia pinnata* (Pongamia), *Azadirachta indica* (Neem), *Schleischeria oleosa* (Kusum) *etc.*

Production of fuel wood on farm lands should be given priority in arid region. The anticipated benefit not only improves the supply level of fuel wood but promotes greater market benefits. In this regard, *Acacia auriculiformis* and *Acacia mangium* and other fast growing species can also be explored in strips, scattered, or on farm boundaries or in block plantations. Though very assertive work in the state has not carried out on these species but, initiatives may open up research and cultivation aspects for better performance in near future.

During droughts, livestock play a larger role in supporting the income and sustaining the rural population. Kalla and Goyal (1986) who estimated employment opportunities under farming and livestock farming reported that, cropping activities provided only 16 standard days/ year/ household while livestock rearing accounted for nearly 300 standard days/year/household in the arid areas. However, under conditions of declining water and fodder availability, the contribution of this sector to household incomes of farming communities declines drastically. Rajasthan ranks second highest in milk production in the country (amounting to nearly 17 lakh kg per day). Reduction in feed and fodder availability due to changes in the climate can also affect livestock productivity. Further, heat stress in dairy animals is likely to impact their productive and reproductive performance. The annual total milk loss due to thermal stress at the all-India level was 1.8 million tonnes or approximately 2% of the total milk production of

the country amounting to a whopping Rs. 2661.62 crores per year. However, current annual loss in milk production due to heat stress in Rajasthan is 98.65, 40.55 and 29.74 liters per animal per year in crossbred cows, local cows and buffaloes respectively (Upadhyay *et al.,* 2009).

Silvo-pastoral systems attempt to combine the production of protein rich trees primarily to produce fodder for livestock or for timber, fuel-wood, fruit or to improve the soil. In this system further, mixed wood lots specifically multipurpose trees are grown mixed or separately planted for various purposes such as wood, fodder, soil conservation, soil reclamation, shelter *etc*. Current annual loss in milk production due to heat stress in Rajasthan is estimated to be 98.65, 40.55 and 29.74 liters per animal per year in crossbred cows, local cows and buffaloes respectively. In order to promote the supply of fodder Silvi - pastoral practices with protein rich fodder species along with leguminous herbs/shrubs in acute fodder shortage areas and on community wastelands, *panchayat* lands, common grazing lands and ravinous areas can be promoted for supplementing fodder and fuel wood. Suitable fodder tree species under this interventions includes, *Acacia nilotica, Acacia senegal, Bauhinia purpurea, Dalbergia sissoo, Hardwickia binata, Leucaena leucocephala, Prosopis cineraria.* Also, the g**rass and legumes suitable are** *Dicantheum sps, Cenchrus sps, Panicum sps, Pennisetum sps, Chrysopogan sps, Paspalum sps, Digitaria sps, Heteropogan sps and Stylosanthus sps. etc.,*

Agroforestry for biodiversity conservation: Forest degradation has caused immense losses to the bio-diversity in the state, which can be conserved through Agroforestry by adopting a strategy of conservation through multiplication and use. On this line, conservation of medicinally important rare and endangered species can be taken up both on small and large sized farms not only for the conservation purpose but also to generates heavy demand for the unique product. National Medicinal Plant Board (NMPB) and national Mission on Medicinal Plants (NMMP) emphasize the cultivation of rare and uncommon commercially important medicinal plants in the state. Best example in this regard could be raising *Commiphora wightii* (Guggal), *Gloriosa superb* (Kalihari)*, Ocimum sanctum* (tulsi), Chlorophytum sps (safed musli), *Withania somnifera* (ashwagandha), R*auwolfia serpentina* (sarpagandha) and *Tinospora cordifolia* (Giloi*) etc*. on commercial basis.

The tree components in agro-forestry systems can be important sinks of atmospheric carbon due to their fast growth and high productivity. Thus, promoting agro-forestry can be one of the options to deal with problems related to land use and CO_2 induced global warming.

Carbon sequestration in different agro-forestry systems occurs both belowground, in the form of enhancement of soil carbon plus root biomass and aboveground as carbon stored in standing biomass.

Fig 2: Importance of bamboo in Citrus orchard

Strategies for promoting agro-forestry practices in Rajasthan

Agriculture and allied sectors therefore exhibit high sensitivity to climate stresses. Some of the earliest studies of potential carbon storage in agro-forestry systems and alternative land use systems for India had estimated a sequestration potential of 68-228 Mg C/ha (Dixon *et al.,* 1994). As per estimation of FSI-2013, Rajasthan state has reported 8373 sq km of tree green cover under agro-forestry area which is about 2.45 % tree green cover percent to its total geographical area. Further, it is found that it contributes 64.770 million cubic meter of growing stock volume with 15.18 million tons of carbon stock under agro-forestry area in the state. According to National Agroforestry Policy-2014 directives, states have to identify about 20 commonly grown trees species which can be grown on farmlands for the economic and ecological benefits of the farming community. Further, policy describes that these species have to be notified for exemption from any state regulatory regime, especially on growing, harvesting and transit. Thus recognized that agro-forestry is perhaps the only alternative to meeting the target of increasing forest or tree cover to 33 per cent from the present level as envisaged in the National Forest Policy - 1988. The Greening India mission under the National Climate Change Action Plan targets 1.5 M. ha of degraded agricultural lands and fallows to be brought under agro-forestry; about 0.8 M ha under improved agro-forestry practices on existing lands and 0.7 Mha of additional lands under agro-forestry (Puri and Nair, 2004).

One of the major hurdle for this is readily available quality planting material. The seeds, seedlings, clones, hybrids, improved varieties, etc. are generally of mixed quality and not available commonly, particularly in the resource poor regions. It is estimated that only about 10% of planting material is of high quality, the rest without any guarantee for quality standards. In addition to this survival of trees is one of the most challenging tasks in the establishment phase of the trees, and without addressing the issue of water this does not seem to be possible.

Results available on agro-forestry in the public and private domain do not regularly reach the farmers due to lack of a dedicated extension system. There is a serious lack of institutional mechanisms at all levels to promote agro-forestry. The efforts to dovetail agro-forestry programme to any other established programme which have strong institutional mechanism up to the implementation level, such as the Integrated Watershed Management Programme are non-existent. More so, the mis-notion or concepts viewing trees as long term obstruction to agriculture, incompatibility with farm operations and intercultural treatments among farmers is prevailing and need to be attended for wider adoption and scaling up of agro-forestry practices in this region. Also, lack of know how about production possibilities and opportunities of agro-forestry requires a special attention here. Thus emphasizes the following necessary **extension strategies** to promote the agro-forestry in this region for above remarked reasons.

- Selection, adoption and multiplication of suitable model on farmers field
- Human resource development: Imparting training to progressive farmers, establishment of demonstration plots, educational farm visits etc to wide spread for adoption of agro-forestry practices.
- Supplementing quality planting material is one of the major challenge in adoption of agro-forestry and social forestry practices. High yielding planting material should be made available through promoting kisan nursery, school nursery, women nursery and nurseries through SHGs to strengthen farmers interest in planting trees.
- Ongoing Government Programme like Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA), National Bamboo Mission (NBM), National Horticulture Mission (NHM), National Livestock Mission (NLM), National Biofuel mission, SHGs, watershed pogramme, *Panchayat* development plans are intended to promote tree cover on non-conventional forest area and to enhance agricultural productivity through focusing integrated farming, water use efficiency, soil health management need to be synergized.

- Strengthening institutions, coordination and networking: Efficient networking, communication and coordination between line departments in popularizing the agro-forestry practices along with establishment of necessary infrastructure, creation of market, entrepreneurship skills and setting up of cooperative units for active participation of farmers.

Conclusion

Site factors, unscientific land use practice, conversion of farm lands for non-farm purpose are majorly responsible for low productivity of farms that posed the greater risk of subsistence and future livelihood of marginal and small land holders in Rajasthan. In addition to changing climate its impacts on agriculture are anticipated in same line. In order to preserve the natural resources and to safeguard the future of farm and farm productivity on sustainable basis several agro-forestry interventions and extension strategies are proposed in the state. These interventions not only yield economic and ecological benefits both at micro and macro level, but aid to overcome the listed constraints through enhanced farm productivity, soil improvement, supplementing, food and nutrition, fodder, employment and ecosystem benefits including soil and water conservation, biodiversity conservation and carbon sequestration.

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