Assessing different systems for enhancing farm income and resilience in extreme dry region of India

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Contributed paper prepared for presentation at the 58th AARES Annual Conference, Port Macquarie, New South Wales, 4-7 February 2014.

Assessing different systems for enhancing farm income and resilience in extreme dry region of India

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Abstract

Enhancing resilience among small farm households in dry regions is important to cope with extreme weather conditions and changing climate. This study presents the results of assessment made in Western Rajasthan (Thar) covering 19 million ha area which is the most densely populated desert region in the world. Agriculture which is the important source of livelihood for large number of poor small farm holders in India is very risk prone although, agriculture's contribution to the GDP is decreasing over time. Besides livestock, farmers traditionally diversify their activity mix with forestry and horticulture. It has been well proved by many studies that the introduction of suitable perennial component in arid farming systems not only enhances farm income and family nutrition but also its resilience under water scarcity. But it has not been promoted and adopted in systems perspective as a commercially viable model. Using this case study we analyze the potential economic benefits and suitability of such models under different resource situations. The examined models are integrated horticulture and agro-forestry with suitable species together with rainwater harvesting structures that significantly enhances farm income and resilience. The annual net returns on different farm types in arid region would increase in multiple folds. The results suggest the need for reorientation of the agricultural research for development agenda taking into consideration the existing and emerging abiotic stresses, and the development and dissemination of new impact pathway through integration and convergence to intertwine the technologies with enabling institutions, policies and financial instruments as a win-win proposition through business model.

Keywords: Drylands, Farm typology, Potential benefits, Technology targeting, Resilience

1. Introduction

Dryland (arid and semi-arid) is one of the important eco-regions of our planet. It occupies more than 6.09 billion ha and supports the livelihood of 35% world population (van Ginkel et al., 2013). In view of the rapidly growing population it is generally argued that this contribution of dryland eco-regions will intensify (van Ginkel et al., 2013). The major concerns, however, are as to how the dryland eco-regions and associated agricultural production systems can meet these expectations (CRP 2012).

Agricultural production systems in dry areas are over-stretched and in states of changes both in terms of structure and functions (Haileslassie et al., 2013). Endogenic (e.g. land size and quality, water shortage, cultural and demographic) and exogenic (e.g. climate change, international market, migration) factors are most often cited as drivers of these changes (van Ginkel et al., 2013). In addition to the question on the future carrying capacity of the dryland production system in the dryland the trajectories of system changes increasingly became issues of concern.

Drought has been considered as one of the most adversely affecting extreme weather events as a threat to agriculture especially in dryland regions. The resource poor regions/ development countries are affected most severely. For example, average annual production losses in tropical areas due to drought are estimated at 25 million metric tons of rice and 20 million metric tons of maize, equivalent to around US$ 7 billion per year (Doering, 2005). Over two- thirds of India's agricultural land is vulnerable to droughts of various intensities, and the probability of occurrence of a drought is over 35 per cent (Bhandari et al., 2007). The threat is more pronounced in arid regions. The drought affects household economy directly by reducing crop and livestock production, and wage opportunities; and indirectly through a rise in food prices. The hot arid region experiences an annual rainfall between 100 and 450 mm. It comes under the influence of subtropical high pressure belt extending from northwest Africa to Asia. The Indian hot arid zone occupies an area of 0.32 million km^2 forming a continuous stretch in the north western states of Rajasthan, Gujarat, Punjab, Haryana and scattered land masses in the states of Maharashtra, Karnataka and Andhra Pradesh, 70 per cent of it falls in western Rajasthan. Low and erratic rainfall, extreme temperatures, long sunshine duration (6.6-10 hours), low relative humidity (30-80 per cent), high wind velocity (9-13 km/h) and high evapotranspiration (1600-1800 mm) and characteristic features of the region. Moreover the soils are poor in nutrients and scarcity of water and recurring droughts are perennial constraints. Despite hostile conditions, the western arid Rajasthan supports a large human and livestock population and a variety of flora and fauna. However, the ever increasing human and livestock population and development activities exert enormous pressure on the slander natural resource in the region.

Some commonly used ex-post strategies are: borrowing, change in production portfolio in favour of short-duration and water-efficient crops, diversification towards non-farm activities, and mortgaging or selling of productive assets (Walker and Jodha, 1986). Farmers also follow ex-ante agronomic and management practices, such as crop diversification, mixed cropping, cultivation of short- duration crops, conservation and judicious use of irrigation water and adoption of crop insurance. Most of these measures provide only short-term solutions, and may not help the farmers regain their previous level of livelihood and replenish the loss of productive assets in the years following a drought (Bhandari et al., 2007). Mitigating post-drought effects requires financial resources for drought relief, safety nets and other development programmes. The traditional method of restoring the health of the poor dryland soils by giving a cultivation break of 2-3 years has been discontinued by majority of the farmers due to increased population pressure and farmers preference to short term gains over systems resilience. Due to high risk involved in crop production farmers generally do not invest on fertilizers, new seeds and improved natural management practices and that results in further land degradation and poor soil health and decreased farm income (Jodha et al, 2012). Under such situation, perennials based production system: agri-horticulture and agro-forestry is considered effective strategy for improving productivity, employment opportunities, economic condition and nutritional security (Chundawat, 1993; Pareek, 1999; Chadha, 2002). Several drought hardy fruit crops like *Zizyphus mauritiana (Ber) Z. rotundifolia and Cordia myxa (Gunda)* are suitable for the area receiving annual rainfall 200 - 400 mm. Besides providing fruit these plant produce moisture laded nutritious leaves for animal. Other fruits such as pomegranate and lemon could be grown in this extreme dry region having irrigation facilities (Pareek and Awasthi, 2008). Integration of forestry tree- *Acacia Senegal (kummat*) on the field bunds together with gum enhancing technology would not only enhance the resilience of the production system but also the income and employment (CAZRI, 2010 & 2011).

Types and severities of these problems across drylands vary substantially and many literatures argue that the arid eco-region is the most affected region (van Ginkel et al., 2013). To ensure the future livelihoods of farming communities and enhance productivity and manage risk more effectively, in these areas, future trajectory of resilience building or intensification needs to acknowledge this diversity (Tittonell et al., 2010). It is also critical to target socially diverse and spatially heterogeneous farms and farming systems.

In this line efforts to target technologies most often focus to farming system approaches: which a geographical exercise, usually done on the basis of natural capital (e.g. land types and climate) and sometimes on physical infrastructure or social factors presence of roads, population density *(*Riveiro et al., 2013; Milán et al., 2006 Giller 2013). Farm level interventions implemented by public agencies are generally planned according to land holding size. However association of yield of dryland crops and livestock does not show any trend. The crop and animal yields on the farms with similar land holding size vary significantly (ICRISAT, 2013). There are major livelihood assets other than land that shapes the response of a household to the proposed interventions. Such zoning is usually helpful as first step in drawing up a farm at production system scale. Tittonell et al., (2010) illustrated that differences in level of resource endowment lead to differences in the farms of one zone compared to another. Here we are arguing that farming-system zoning is not sufficient by itself to target technologies as there are still significant differences within zones because of differences in livelihood assets: so to say different farm-system within a single farming systems. When these assets are taken into account in farm typology building there are farm-systems[1] in different zones (farming systems[2]) that may belong to the same typology. Farm-system typologies built based on key livelihood assets help to explicitly understand the potential, expectation and the limitations of farms and thus will help in developing a "recommendation domain", which can be defined as: "a group of farm-system, relatively homogenous, with similar circumstances, and for which we can make more or less the same recommendation (www.icra.edu.org; Giller 2013). Recognizing variability within and among farms and across localities is the first step in the design of policies to help poor farmers (Ruben and Pender, 2004), and a key one with regard to the adoptability and performance of new technological options proposed to improve agricultural production. Improved understanding of the main drivers of household diversity, and ability to categorize patterns of diversity that bear a relationship with livelihood strategies and farming objectives should help to better target agricultural innovations.

The overarching objectives of this study were to build relatively homogeneous group (farm typology) among dryland farmers in most extensive to considerably intensive agricultural systems of Indian *Thar* desert so that targeting of context specific technologies will be possible. Secondly the ex- ante evaluation of systems productivity enhancing and risk-reducing benefits of most promising options- perennials based integrated farming system across farm typologies and Thirdly to highlight policy implications of such approaches

1. a '**farm system**': referring to the conceptualisation of an individual farm as a system, a set of inter-related, interacting components or sub-systems and a '**farming system**': referring to a single category within a broader typology, where the category groups together farms that are 'similarly structured (Giller 2013)

towards stabilizing farm incomes and smoothening livelihood of resource poor farmers in vulnerable regions.

2. Material and methods

2.1. The study areas: location and biophysical setting

2.1.1. Location of the study areas

Our study focuses on eight villages in Jaisalmer, Barmer and Jodhpur districts in arid eco-regions of west Rajasthan (Figure 1). These districts were selected, by the CGIAR-Consortium Research Program, to serve as agricultural production systems research action sites and to represent the arid and vulnerable eco-regions in south Asia ICARDA (2012). Layers of spatially explicit data sets including soil types, rain fall, and population density were indexed and used to select these sites (ICARDA 2012). On the second step local experts and community representatives were consulted on the diversity of livelihood and production system in these districts and to narrow down the areas of interest to the next lower administrative units (Blocks). Accordingly Osien (in Jodhpur district); Chohtan (in Barmer) and Jaisalmer (in Jaisalmer) were selected. At block level similar consultations were held to select eight villages representing the different farming system in the arid eco-regions Table 1 shows silent features of the sample villages.

2.1.2. Biophysical settings

District scale data shows that generally the study areas are characterized by limited seasonal precipitation with erratic distribution, high atmospheric temperature that has large diurnal and season variation (CAZRI 2009). Although all the villages are in arid eco-region mean annual rainfall generally shows an increasing trends along West-East gradient and so does the inter-annual variation and as a result the CV. In a relative term villages in Jaisalmer are driest with mean annual rain fall of 150-170mm (Table 1). Villages in Barmer and Jodhpur receive mean annual rain fall of about 235 and 280 mm respectively. Based on large scale course maps physiographic map by the sates remote sensing and application centre (SRSAC 2010) villages in Barmer and Jaisalmer areas have arid north western sandy plain while those in Jodhpur are Alluvial plain of Luni Basin physiographic regions.

Table 1 Key features of the study villages

Key features	Study Districts, Taluks and Villages							
	Jodhpur (Osien)		Barmer (Chotan)		Jaisalmer (Jaisalmer)			
	Mansagar	Govindpura	Dhok	Dihrasar	Dedha	Damodra	Sakariya	Didhu
Rain fall (mean mm yr^{-1})	280	280	235	235	170	170	150	150
Altitude (meters)	233	241	163	128	221	162	106	157
Total household (Nr)	341	150	355	157	130	76	275	189
Total area (ha)	2443	1280	5063	1536	4041	4625	5093	13020
Total population (Nr)	2412		2174	1037	823	516	1688	1216
Irrigated area(ha)	566.56	NA	NA	NA	NA	NA	917	NA
Agricultural land holding (ha hh^{-1})	5.2	5.4	4.9	9.7	15.6	6.7	1.0	1.9
Land holding (ha $head^{-1}$	0.72		0.79	1.446	2.446	1	0.12	0.29
Rain fed farming (ha)	1756	813	1739	1521	2030	516	215	359
Livestock population (TLU)								
LSI*	1.87	1.46	4.47	9.16	10.52	2.07	3.73	7.43

LSI is livestock species index estimated as the ratio of small ruminants to large ruminants; NA is for data not available; hh is for households

Aeolian and alluvium are two major soil formations in the study areas. Entisols and Aridiols dominate in all study sites. With few exceptions soils are generally shallow and poor in organic sources nutrient such as N and C. Because the dominantly sandy texture important part of N applied loss through leaching. But depending on the micro-topography there are soils with rich clay. For example soils at the downstream of Khadin water harvesting systems have usually higher clay content (SRSAC 2010).
Because of low rainfall efforts are exerted to exploit ground water. But there are reports indicating that the ground water in some of the districts are over exploited (e.g. Jodhpur) and ground water is declining at the rate of 0.44-0.48 m per year, while in Barmer and Jaisalmer the rate estimated at less than 0.2 m per year.

2.2. Farming systems characterization

Crop or livestock based mixed crop-livestock production systems are major sources of livelihood in arid ecosystems of west Rajasthan. Multipurpose trees are part of the farming systems throughout the region. Practically the farming is an agro-forestry system. Trees play a great role in enhancing the resilience of the arid farming system. Drought hardy leguminous *Prosopis cineraria (khejri)*, traditionally protected and preferred by farmers, is the most important tree which gives leaves as fodder (*loong*), pods (*sangari*) a local delicacy and twigs as fuel or fencing material. Moreover it also has environmental benefits, enhances soil fertility, carbon sequestration, stabilizes income during drought and enhances quality of landscape; however the density of these trees has been declining due to tractorization, weakening of local institutions and policy (Jodha et al, 2012). Jodha (1986) described the agricultural systems in western Rajasthan in general as crop and livestock based and emphasized the comparative advantage livestock farming enjoys over crop farming. Discussions with farmers in the study villages indicate that small ruminants [sheep (*Ovis Aries*), goat (*Capra hircus*)] based crop-livestock production system is the main traditional system for the villages in Jaisalmer and Barmer. Depending on the level of livelihood assets off-farm income also makes important contribution to livelihood. Along the West-East rainfall gradient, crop [pearl millet (*Pennisetum glaucum (L.) R. Br*., Cumin *(Cuminum cyminum (L.)* and mustard (*Brassica juncea (L.)*] based large ruminant [cattle (*Bos indicus)* and *(Bos taurus*, buffalo (*Bubalus bubalis*)] production system are also common: i.e. villages in Jodhpur are on upstream side in terms of intensification. Traditionally trees on permanent pasture lands in these systems are major ingredient of system structure and sources of browse for small ruminants: but their role is increasingly declining due to major conversion of range lands to crop land (Jodha 1986; Haileslassie et al., 2013).
One of the major defining factors of the structure for agricultural production systems in *small ruminants based crop-livestock* (in Barmer and Jaisalmer) and *millet base crop-livestock system* (in Jodhpur) is availability of sufficient water. For example with increasing extraction of ground water there is a tendency for change in the traditional livestock herd composition in Mansagar. Experts also ascribe this change to increasing local and global demands for livestock products. District level census data over the last decades shows an increase in total livestock population. Buffalo became an important herd constituent along West-East rainfall gradient while a tendency to shift in composition of small ruminants was observed for the drier, more western part *(i.e. small ruminants based crop-livestock systems)*. An important research issue here could be to understand as to how existing feed resources complement these evolving interests in livestock enterprises. How these farm-system dynamics in their structure and function relates to farm typology approaches for targeting interventions over longer period? How the decrease in density of fodder trees and increase in density of livestock/small ruminants affects the stability of livestock production in the region?

Very often it is reported that in crop livestock system crop provide feed to livestock and livestock manure to crop. Here crop residues contribute a significant proportion of feed, but application of manure to replenish soil fertility is limited mainly to these farms having access to irrigation facilities. This might question the level of integration in crop livestock systems in west Rajasthan.

2.3 Farm selection and household survey and data analysis

2.3.1 Farm selection and household survey

This study was mainly based primary data collected from sample farm households. We used village households as sampling frame and undertook village level appraisal to understand the level of heterogeneity in terms of major livelihood indicators including access to land, irrigation water, credit, training, off-farm/non-farm income and gender and used a stratified random sampling technique to select 256 farm households (about 30 farms in each village). The data was also collected on inputs and outputs of crop and livestock production and their market prices. We adopted the livelihood assets approaches (DFID 1999) and used local expertise to identify indicators of the different assets (Annexure 1). We focused on these indicators and developed structured and pre-tested questionnaires to collect data (Annexure 1). The questionnaire was administered to the sample farms between April-May 2013 and the focus was 2011/2012 production year. Further the information was also collected from published sources, literature reviewing and through case study method. The data through case studies of farmers was collected on *Zyziphus moritiana* based, *Cordia Myxa* based and pomegranate based farming systems from the villages in Jodhpur and Barmer districts. Few farmers like Nand Kishore Jaisalmeria in Manaklao village in Jodhpur in are maintaining *Zyziphus* based system profitably for more than 35 years. The assessment of potential impact of intensification of Khejri as agro-forestry on yields of rainfed crops was done by using the coefficient generated from the long term study reported by Bhati and Faroda (1999). The data on cost of cultivation and outputs like fodder, food and fuel were collected as part of field survey.

2.3.2. Approaches to farm systems typology building

A multivariate approach was used in order to exploit the large amount of recorded variables in the most efficient way. Statistical analysis was carried out by using Principal component analysis (PCA) and Cluster analysis (CA) (Usai et al., 2006; Rufino et al., 2013; Abdullah and Faye 2013; Milán et al., 2006; Riveriro et al., 2013). The suitability of PCA was determined by the Bartlett’s test of sphericity and the Kaiser–Myer–Olkin (KMO) index to measure sampling adequacy. PCA extracts linear combinations (PC) of the original variables whose weights correspond to the eigenvectors of the correlation matrix. The PCs with eigenvalues greater than 0.9 were considered in the analysis. This approach allows a large part of the total variation to be concentrated in a smaller number of standardized uncorrelated variables. The PCA was performed using the SAS Princomp procedure. Following PCA, Farmers were grouped using Hierarchical clustering analysis according to the factor scores derived from PCA. Ward's method (minimum variance) method used because it joins at each stage the cluster pair whose merger minimizes the increase in the total within-group error sum of squares, based on the Euclidean distance between centroids. It tends to produce homogeneous clusters and a symmetric hierarchy. The analysis was performed using the SAS Cluster procedure.

After completing the construction of typologies, consultations with farmers in each cluster were done to validate the typologies. For continues variables, Analysis of Variance (ANOVA), and for categorical variables frequencies were calculated for the most informative variables. The analysis was performed using SAS. Further to building farm typology and ex-ante assessment of options for farmers' resilience building and intensification trajectory was carried out in view of priority problems.

2.3.3 Economic benefits of existing and potential farm activities

In arid western Rajasthan the major dryland crops grown were pearl millet, cluster bean, moong bean, moth bean and sesame. Low rainfall (150-450 mm) and frequent droughts results not only in low yields but also very high inter-year yield variability. Coefficient of variation using district level yield data for the years 2001–2010 for all the major crops including horticulture was estimated. Net returns per hectare from different crops were calculated accounting all cost including family labour except the cost of land. Further the net present value (NPV) and internal rate of returns (IRR) over the 20 years planning period was calculated for agri-horti system as well as existing crops using following Gittinger (1982 & 1984). Experts' consultation and rainfall data of past 20 years suggests that every third year is a drought year that reduces yield by 20 to 100 % in rainfed annual crops and 10-35% in horticultural crops. Based on focussed group discussion with farmers we assumed 30% yield reduction every third year due to drought and that was accounted while calculating the NPV. The price of inputs and outputs wee estimated based on the labour cost index (7.15%) and consumer price index (7.30%) over the past 10 years taking 2014 as the base year. The suggested horticultural options were analysed considering farmers' preference and resource conditions in different farm typologies. The future stream of benefits needs to be discounted using an appropriate discount rate to obtain their net present value (NPV). There is, however, little agreement among economists regarding 'what ought to be an appropriate discount rate'. Alston et al. (1998) have argued that when analysis is conducted using constant prices, the discount rate should be a real rate of interest, and suggested that in most situations the real discount factor will fall in the range of 3-5 per cent. For agricultural projects in India, Kula (2004) has estimated a discount rate of 5.2 per cent. Alpuerto et al. (2009) have applied a discount rate of 5 per cent in their study on ex-ante assessment of the benefits of marker-assisted breeding in rice in India, Bangladesh, Indonesia and Philippines. We have applied a discount rate, r, of 8 per cent in the present study.

The management practices of arid horticultural crops like Z. moritiana, C. Myxa, pomegranate, etc have been standardized for optimizing the productivity. A number of studies has proved that perennials especially *Ziziphus moritiana (Ber)*, *Cordia Myxa (gunda)*, *Emblica* based integrated farming systems not only give better net returns but also stabilize farm income in arid western Rajathan (Meghwal, 2007; Sharma et al., 1982 and Singh and Kumar, 1993). Agri-horti system involving *Z. rotundifolia* + *V. radiata/V. aconitifolia/C. tetragonoloba* and *Z. mauritiana* + *V. radiata/C. tetragonoloba* have been found environmental friendly and economically viable even during drought years. The inventory of system showed that this agri-horti system can provide round the year supply of fodder for 5 goat/sheep ha^{-1} and fuel wood for family of 4 members, besides efficient nutrient cycling and increase in economic stability (Faroda, 1998). Gupta et al. (2000) reported that 3-years old plantation of *Z. maruitiana* @ 400 plants ha^{-1} in association with greengram performed well with seasonal rainfall of 210 mm and fruit yield from intercropped increased net profit significantly, this shows that agri-horti system minimize risk in arid regions and thus helps in imparting economic stability. Intercropping in newly planted ber orchard had no adverse effect on plant growth up to 5 years. The intercrop also exhibited higher yield when planted with ber compared to monoculture under rain fed conditions. Agri-horti system comprising *Zizyphus* + mungbean provided fruit, fuel wood and round year employment even in below average rainfall year (Sharma and Gupta, 2001). According to Singh et al. (2003) intercropping of legumes with ber orchard produced higher grain yield of intercrops by 5-20% over their sole cropping and intercropping is promising particularly during juvenile period of fruit plantation. To assess the potential of agri-horti system we used data from our case studies from Jodhpur and Barmer under rainfed as well as irrigated conditions in the context of different typologies. Based on the above review, field observations and focused group discussions with horticulture farmers and extension staff, *Ziziphus moritiana based*, *Cordia Myxa* based systems together with provision of rainwater harvesting (Tanka- underground cistern) of 60 m3 for providing supplemental irrigation to one hectare, and intensification of khejri based existing agro-forestry system are the most promising and farmers preferred options under rainfed arid ecosystems. Farms with access to assured irrigation, pomegranate cultivation was a preferred option.

Risk Benefits — Benefits from reduction in yield variance due to adoption of drought-tolerant perennials based system have been estimated using the Newbery-Stiglitz approach. It assumes that risk-averse producers benefit more from reduction in yield variance as it influences income distribution (Kostandini et al., 2009). The Newbery-Stiglitz method is outlined below:

Let, $\bar{Y}_0$ be the value of mean yield and σ_{y0} be its coefficient of variation for the existing crop. Adoption of a perennial based system changes value of mean yield to $\bar{Y}_1$ and the coefficient of variation to σ_{y1}. The benefits due to change in variance in yield then can be estimated using following Equation:

$$B / \bar{Y}_0 = 0.5\ R\ (\sigma_{y1}^2 - \sigma_{y0}^2)$$

where, B represents the monetary benefits associated with the change in reduction in yield variance, and R is the risk aversion coefficient. Note that in an open economy framework, the benefits from reduction in yield variance will accrue to the producers only.

3. Results

Often the targeting of farmers for implementing different technology dissemination and livelihood support programmes is done based on their land holding size. But for dryland regions as in our study site we found that the yield of different crops and net returns per animal did not have any relationship (Figures 1, 2 & 3). It indicates that there are number of livelihood variables other than land size which should be used to homogenously group the farmers for better targeting of technological interventions. Hence it is

Figure 1: Pearl millet yield, kg/ha across farm size

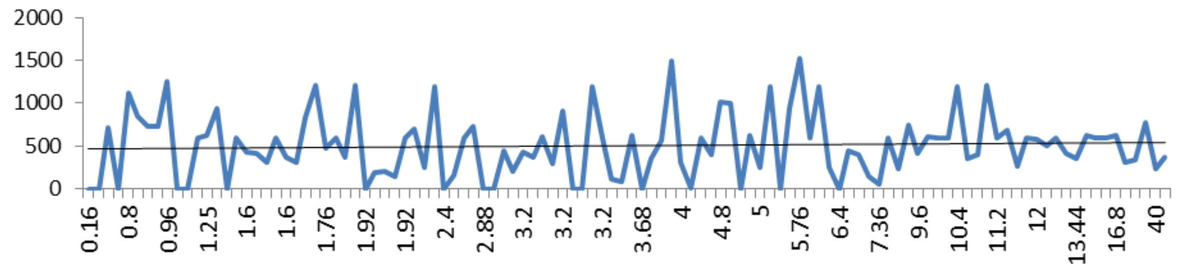


Figure 2: Cluster bean yield, kg/ha across farm size

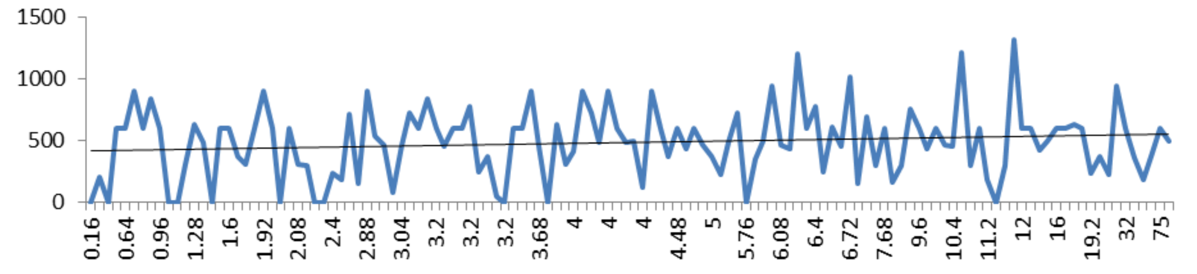
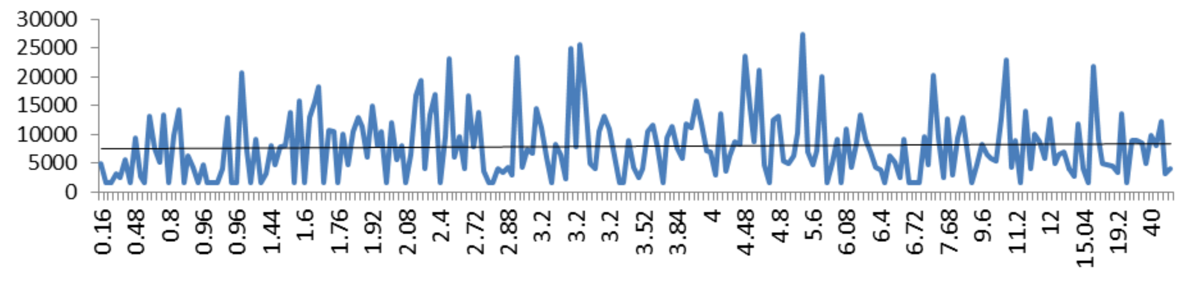


Figure 3: Income per Standard animal unit, INR/annum across farm size



3.1 Farm typology and characterization

Building farm typologies resulted into grouping of 256 farmers from 3 districts of western arid Rajasthan into 4 homogeneous clusters based on 32 bio-physical, socio-economic and ecological variables. Thirteen PC had eigenvalues greater than 0.9 and were considered for analysis. The eigenvalues of these PC ranged from 0.93 to 4.89 and they explained about 71% of the total variability (Table 2). The eigenvectors (weights) for each of the 32 descriptive variables according to 13 PC were retained for the CA.

Table 2: Eigenvalues corresponding to each principal component (PC) and relative proportion of variation

PC	Eigenvalues	Proportion of variation
1	4.8894	0.1528
2	2.5398	0.0794
3	2.2634	0.0707
4	2.0326	0.0635
5	1.7319	0.0541
6	1.3761	0.043
7	1.3342	0.0417
8	1.2713	0.0397
9	1.1551	0.0361
10	1.0868	0.034
11	1.0708	0.0335
12	0.9522	0.0298
13	0.9292	0.029

In the identified farm clusters the values of different variables varied significantly and based on that the farm typologies could be named as i) *Rainfed extensive*; ii) *Irrigated intensive*; iii) *Rainfed semi-*

intensive livestock-off-farm income based; iv) *Irrigated semi-intensive off-farm income based.* Majority of the farms (78%) fall under two rainfed extensive farm types, which is the major characteristics of this region (Table 3). In the focussed group discussion (FGDs) to validate these typologies, more than 90 percent farmers agreed to the above categorization. Grouping of the farms into typologies based on multiple livelihood variables using PCA and CA is in contrast with the generally followed categorization of farmers on the basis of land holding size such as marginal (up to 1.0 ha), small (1-2 ha), semi-medium (2-4 ha), medium (4-10 ha) and large farmer (>10 ha). Here the households with similar land holding size were part of different farm types. The land holding size in cluster 1 varied from 0.8 to 16 ha, and similarly it was 0.8-16ha; 0.24 to 19.2 ha and 0.16 – 8.32 ha in cluster 2, 3 & 4 respectively. Different farm types differed significantly in terms of their access to physical, human, social and financial capitals (Table 3). Level of manure and fertilizer use, food and fodder sufficiency, number of standard animal units, amount of borrowed capital and investments were highest in cluster 1 followed by cluster 4, cluster 3 and cluster 1. The off farm income was lowest in irrigated intensive cluster but it was more than half of the total household income in rainfed clusters 1 and 3. Crop diversity was highest on farms with access to bore-well water but it was lowest on canal irrigated farms indicating low reliability of timely access to canal water as also informed by the farmers.

Table 3: Basic characteristics of households under different farm typologies

Characteristics	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Land Holding Size cultivated, ha	6.2	6.0	3.3	3.2
Total Waste/Grazing Land	0.3	0.2	0.7	0.2
Land labour ratio	1.7	1.4	0.7	1.0
Standard animal Units (SLU)	5.0	6.2	5.1	5.1
Number of months own produce support farm family	5.4	10.4	3.8	5.9
No. of Crops Grown	2.2	5.1	3.6	1.9
% income from livestock	17.1	17.1	18.1	14.6
%income from off farm earnings	55.9	25.0	52.1	46.1
Manure Applied, Kg/Ha	70.7	2034.7	297.4	121.8
Status of feed availability (months of sufficiency)	6.3	10.1	4.7	8.3
Amount borrowed from bank/financial institutions, INR	18757	191735	179958	51174
Average distance of input market, km	15.2	16.9	6.7	3.4
Total Investment in past 5 years, INR	19112	472583	45458	79422
No. of times the farmers visits the extension officials/office/: (No)	0.3	0.2	0.0	0.4
Quantity of Fertilizer-Urea used kg/ha	0.9	82.2	11.0	15.9
Quantity of Fertilizer-DAP used kg/ha	0.9	65.4	7.2	16.5
Access to borewell for irrigation (% households)	14.4	94.11	14.66	0
Access to canal for irrigation (% households)	3.7	0.0	0.0	100
Women headed households (%)	13.9	0.0	16.7	0.0

Table 4: Estimates of area under different farm types (typology) in western arid Rajasthan

Farm typology	No farmers	Share of househ olds, %	Holdin g size, ha	No holdings across farm typology	Total cultivated area, ha	Area: pearl millet/mix crop, ha (TE 2010-11)	Actual area of W arid Rajasthan, ha

Cluster 1-Rain fed extensive	187	73.0	6.2	1688495	10468670	2937801	13637539
Cluster 2-Irrigated intensive	34	13.3	6	307630	1845780	534145.7	
Cluster 3-Rain fed semi-intensive livestock-off-farm income based	12	4.7	3.3	108711	358747	188522	
Cluster 4-Irrigated semi-intensive off-farm income based	23	9.0	3.2	208171	666146	361333.9	
Overall	256	100	5.77	2313007	13339343	4021803	5.89

It shows that for the farm typologies which work as recommendation domain for implementation of different interventions, there were many other factors than land like contribution of off/non-farm income, education, access to irrigation, training, food, level of input use, market, etc significantly influencing categorization of farms into homogeneous groups and hence the farmers response to different interventions especially in dryland regions. It came out very clearly in FGDs that all the farmers in a particular cluster whether small or large were able to manage agriculture and respond to new technologies/options in a similar manner. Traditional method targeting farmers for agricultural technology dissemination even in dryland regions has been based on land holding size to which our analysis presents contrasting results. In Jaislmer in sample villages- Dedha and Damodara with annual rainfall 170 mm, where risk of crop failure remains very high except some area under khadin system (runoff based farming), all the farmers with land holding size varying from 0.48h ha to 40 ha were grouped into one cluster (1) by PCA and CA. Frequent droughts make all the farmers-small or large highly vulnerable and they depend heavily for their livelihood on livestock rearing (also migrate if required) and off/non-farm sources of income. The livelihood strategy of these dryland farmers hardly differ on account of size of land holding only. Hence the farm typology building analysis based on PCA and CA, makes a strong case for revisiting the method/ criteria for categorizing farmers for targeting improved agricultural technologies/options and even the other livelihood improvement interventions. From the analysis it appears that these priorities are a reflection of key livelihood activities in their respective cluster and also differences in livelihood assets indicators: illustrating differences in preferences, expectations and also capacity of the farms to solve these problems. With the objective of out scaling at regional level, if the total number of land holdings in western Rajasthan (total No. 2313007) are distributed proportionality in identified farm clusters, the total area estimated based on the average landholding size in each cluster was 13.33 million ha, which quite close to the actual cultivated area 13.63 million ha in western Rajasthan (Table 4). That further validates the relevance of the developed farm typologies.

3.2 Constraints and potential intervention

As a next step, farmers' perceptions on constraints to farming systems and possible technological interventions were ascertained for each farm typology. The constraints and opportunities (potential interventions) were prioritized based on the ranking given by farmers using pairwise ranking method and are mentioned in the table 5 in descending order of priority.

Table: 5 Prioritized constraints & possible interventions identified jointly with farmers in different farm typologies

Cluster 1	Cluster 2	Cluster 3	Cluster 4
Constraints			
1. Local millet/legumes not maturing due to delayed onset of monsoon-Moong,	1. Low yielding seeds of crops	1. Loss of crop due to short LGP (moong,	1. Disease & pest in cluster bean

moth, cluster-bean affected more 2. Fodder scarcity during winter/ summer 3. High mortality in goats & sheep 4. Bad distribution of rains cause diseases in kharif 5. Dilution of cattle breed and no demand for males- low income 6. Low productivity under khadins 7. Termite and other pest in cluster bean 8. Soil degradation- No use of fertilizer and soil erosion 9. Poor quality drinking water (underground) 10. Naturally occurring medicinal plants not exploited commercially	2. Disease & pest in cumin, cluster bean, cotton, moong, moth 3. Crop damage by uncared bulls 4. Fodder scarcity and low productivity & mortality in cows/goat 5. Poor quality drinking water (underground) 6. Soil erosion 7. Low income and high risk in agriculture	pearl millet, moth, sesame) 2. Fodder scarcity and high mortality in goats 3. Low biomass yield of common pasture 4. Poor quality drinking water (underground) 5. Termite infestation in crops 6. Less income from cow, breed dilution, no market for males 7. Poor soil health	and chick pea 2. Termite in cluster bean 3. High infestation of weeds in chick pea 4. Disease in cattle 5. Poor quality of seeds 6. Irregular supply of canal water leads to low crop productivity 7. Low income
Identified interventions (opportunities)			
<u>Common interventions</u> 1. Short duration varieties of millets & legumes 2. Prophylaxis in livestock – service providers 3. Intensification of Khejri (*Prosopis Cineraria*) as agro-forestry 4. Few horti plant for each family (near homestead) 5. Upgrading goat with Sirohi breed 6. Participatory development pasture on common land 7. FYM/ composting 8. Castration of cattle males and their collective marketing 9. Top dressing of urea <u>Specific interventions</u> *Jodhpur (>250mm rainfall)* 1. Arid horticulture with tanka 2. Gum production enhancement in A. Senegal *Barmer (200-250 mm rainfall*) 1. Medicinal plants- *Shankhpushpi* as intercrop & *Agnimath* (*Clredendrum phlomidis*) as fence 2. Forestry- Khejri, Tamarind, drumstick on field bunds *Jaisalmer (<200 mm rainfall)* 1. Community fodder bank 2. Rain water harvesting for drinking- Tanka	1. Improved & short duration varieties 2. Soil test based fertilizer application 3. Agri-horti system- Ber, Gunda, pomegranate 4. Plant protection 5. Prophylaxis in livestock 6. Intensification of *Khejri* as agro-forestry 7. Vilage level seed production 8. Castration of cattle males and their collective marketing 9. Medicinal plants- *Shankhpushpi* (*Conlolvulus pluricaulis*) as intercrop 10. Bio-gas for cooking/ light	1. Upgrading goat with Sirohi breed 2. Prophylaxis in livestock – service providers 3. Grass (*Cenchrus ciliaris-CC & Lassurus syndicus-LS*) and Acacia Senegal on bunds 4. Short duration crop varieties 5. Intensification of *Khejri* as agro-forestry 6. Plant protection 7. Gum production enhancement in A. Senegal 8. Composting/ FYM 9. Few horti plant for each family (near homestead)	1. Seed treatment in chick pea & cluster bean 2. High yielding variety seeds 3. Prophylaxis in small & large ruminants- service provider 4. Introduction on horticulture- lemon, kinnow, pomegranate 5. Composting/ FYM 6. Integrated weed management 7. Plant protection 8. Village level seed production

Low awareness and poor access to improved varieties, very low/ negligible use of fertilizers and manure in cluster 1, 3 and 4, fodder scarcity and low unstable farm income were major concerns. Though the government has made efforts to supply ground water for drinking purpose, but farmers in 6 villages informed that it has negative health effects due to high salt content. Besides short duration crop varieties and livestock prophylaxis & fodder, farmers' major preference was to include agri-horticulture component in the farming system in clusters 1, 2 & 4 and intensification of Khejri as agro-forestry in clusters 1, 2 & 3. Integration of arid horticulture and intensification of khejri based agro-forestry systems was not only the priority of farmers but has been recommended by many studies (Meghwal, 2007; Singh and Kumar, 1993, Gupta et al, 2000) and has implications for the viability of farming systems in the region. Soil test based fertilizer and plant protection were priorities in cluster 2 and 4.

3.3 Returns from crops and ex-ante impact of potential interventions

At present majority of the rainfed famers opt for mix cropping using mostly broadcasting method of sowing aiming to reduce the risk, and meet household's needs of food and fodder. The average ratio of mix of pearl millet, cluster bean, moong bean, moth bean and sesame was 4:2:1.5:1.5:1. Since the level of fertilizer and manure use is negligible on rainfed farms, mixing of millets and legumes has been a traditional strategy for maintaining soil health. Before assessing the potential benefits of proposed agri-horti and agro-forestry options we worked out net returns from different crops across farm typologies (Table 6). The net returns per hectare for different crops were quite low in all the four farm types, but it was much less in cluster 1 and 3, where net returns from pearl millet and other crops were negative. In spite of negative net returns, farmers still continue to cultivate mainly for the reasons that they do not account for the cost of family labour, which varied from UDS 65 to 105 per ha for different crops; crop residues are essentially important for maintaining livestock and third, they do not have access to better options for employment. The net returns from crops in cluster 2 and 4 were relatively higher but quite low in absolute terms.

Table 6: Net returns from different crops across farm typologies in arid western Rajasthan (USD/ha)

Name of the crops	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Mix crop (Pearl millet, moong bean, moth bean, cluster bean, sesame)	59.2	128.3	2.7	118.0
Pearl millet	-16.9	43.5	-53.7	30.2
Cluster bean	121.9	178.0	-92.8	155.6
Moong bean	103.9	184.4	-46.1	
Moth bean	71.3	33.3	71.3	
Sesame	135.9	161.7		
wheat	54.6*	126.5		124.9
Chickpea	71.1*			79.8
Mustard		97.5		
Cumin		301.4		
Isabgol		23.0		

*Post rainy season cultivation using conserved moisture under runoff based *khadin* system
Source: Field survey

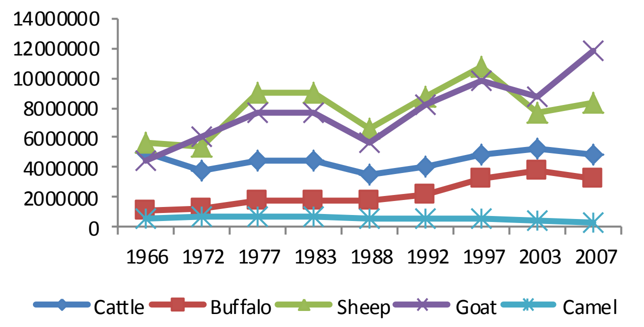
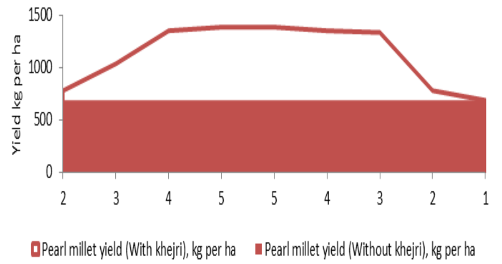


Figure 4 Temporal changes in livestock population in western arid Rajasthan

Household level primary data and case studies on *Z. Moritiana (Ber), C. Myxa (Gunda)* and pomegranate based farming system as well as studies conducted in the past suggest that agri-horti and agro-forestry should be promoted for enhancing resilience of farming systems and improve rural livelihood security in these dryland regions. For a household in the rainfed extensive system (cluster 1 & 3) based on farmers preference we propose one hectare of agri-horti system with Ber/Gunda or combination of both with 6m X 8m spacing having 200 arid fruit plants and 50 plants of Acacia Senegal/ Hardwikia binnata on the boundary. Every one hectare of such system has to have a rainwater harvesting structure (underground covered structure called *Tanka*) of 60 m3 sufficient for providing supplemental irrigation through drip system (Meghwal, 2011) in cluster 1 & 3. For cluster 2 and 4, besides *Ber & Gunda* another promising horticulture plat is pomegranate, which is being successfully grown by case study farmers in the region. These fruit plants' economic life is more than 25 years, but we have assumed a moderate project life of 20 years.

Livestock which is the most stable source of income and food for farmers in arid region has been mainly constrained by scarcity of feed and fodder. Continuous degradation of common grazing resources (Jodha, 2012) and swiftly increasing livestock population especially small ruminants (figure 4) has further aggravated the problem of fodder scarcity. At present the density of traditionally grown leguminous multipurpose *khejri* tree as part of agro-forestry system in the study villages is 8.4 tree ha^{-1} (Jodhpur), 4.5 trees ha^{-1} (Barmer) and 2.4 trees ha^{-1} (Jaisalmer) number of which has declined substantially from 27 trees ha^{-1} in Jodhpur in the past two and half decades (Jodha, 2009). Intensification of *Khejri* based agro-forestry system would not only enhance supply of nutritious tree fodder but this tree also enhances the yield of pear millet and other crops grown underneath (Bhati and Faroda, 1999). Bhati and Faroda, 1999 based on a long term experiment at Jodhpur demonstrated that in the *khejri* based agro forestry system the yield of pearl millet was significantly higher up to 5 meter distance from the tree pole as compared to control (Figure 5). Each tree results in 2.6 kg incremental production of pearl millet besides fodder, pods and twigs giving additional total benefits of USD 5.5. Moreover *P. Cineraria* also contributes in carbon sequestration to the tune of 0.63 to 0.85 tones per tree (Rathore and Jasraij, 2013). The Intensification of Khejri has got farmers high priority in cluster 1 and 3; farmers in cluster 2 were interested for it but up to 25 trees per ha. Thus we have assessed ex-ante impact of *khejri* intensification options as 25 and 50 trees per ha.

Figure 5 Pearl millet yield with and without integration of P. Cineraria, kg per ha



The net present value (NPV) and IRR estimated for three agri-horti systems for rainfed as well as irrigated clusters and to have comparison, NPV & IRR were also estimated for all major existing crops grown and *P. Cineraria* intensification options (Table 7 & 8). It is evident from the analysis that the NPV generated from the agri-horti system is 4 – 4.5 times higher as compared to rainfed crops in cluster 1 & 3. In case of cluster 2 & 4, the NPV from *Ber & Gunda* based system was 1.5 to 2 times higher than the existing crops. However in case of pomegranate the NPV was almost 5 times higher than the existing crops.

Table 7: Net present value from different crops across farm typologies over 20 years period, in USD

Crops	cluster 1		cluster 2		cluster 3		cluster 4	
	NVP- 20 years	NPV/ year	NVP- 20 years	NPV/ year	NVP- 20 years	NPV/ year	NVP- 20 years	NPV/ year
Mix crop (Pearl millet, moong bean, moth bean, cluster bean, sesame)	2110.5	105.5	3687.0	184.4	835.7	41.8	3456.3	172.8
Pearl millet	187.8	9.4	1776.1	88.8	-638.9	-32.0	1475.6	73.8
Cluster bean	3487.3	174.4	4997.5	249.6	-1333.8	-66.7	4487.5	224.4
Moong bean	2897.2	144.9	4867.2	243.4	-472.0	-23.6	1990.9	99.5
Moth bean	2162.5	108.1	1457.2	72.9	2162.5	108.1		
Sesame	3624.4	181.2	4351.0	217.5				

wheat	2648.6	132.4	5357.7	267.9			4550.0	227.5
Chickpea	3070.3	153.5					3875.2	193.8
Cumin			9570.9	478.5				
Isabgol			460.5	23.0				

Table 8: Net present value from different alternate land use systems across farm typologies over 20 years period, in USD

Alternate land use system	cluster 1 & Cluster 3					Cluste2 & Cluster 4				
	Initial investment	NVP-20 yrs	NPV/ year	IRR	Payback period, years	Initial investment	NVP-20 yrs	NPV / year	IRR	Payback period, years
Gunda- Codia Myxa based system	2371.0	13244.8	630.7	18	6	1161.3	15285.5	728.0	28	3
Ber- Zizyphu moritiana based system	2532.3	11923.9	567.8	17	6	1161.3	19286.6	801.7	30	4
Pomegranate	-	-	-	-	-	1887.1	53906.6	2567.0	44	3
Khejri- Prosopis Cineraria (+25)	32.3	1790.1	68.2	29	8	32.3	1790.1	68.9	29	8
Khejri- Prosopis Cineraria (+50)	64.5	3637.1	138.6	29	8					

Besides higher net returns, the integration of perennial component in the farming system also reduces the yield risk in drylands (Faroda, 1998).The rainfed crops yield in the study region has very high instability which is evident from high values of coefficient of variation (CV) worked out using district level yield data from 2001-02 to 2009-10 (Figure 6). The CV in yields of rainfed crops has been as high as 49.1 – 71.4 percent. Such a high variability in yields results in a big shock to the farm family and adversely affects their livelihood security. This variability is further expected to increase due to future climate change/ variability. We have estimated the benefits of reduction in yield variance due to potential adoption of agri-horti and agro-forestry systems. Rainfed clusters 1 and 3 assumed to be more risk averse and benefits more from the reduction in yield variance. Information on risk aversion, however, is limited. Binswanger (1980) reported relative risk aversion coefficients for India's semi-arid tropical region ranging from 0 to 7 with a median value of 1. Morduch (1990) and Rosenzweig and Wolpin (1993) using the household panel data for India's semi-arid tropical region for the period 1975-1984, estimated a relative risk aversion coefficient of 1.39 and 0.93, respectively. Using the same panel data with additional information for 1991, Fafchamps and Pender (1997) have estimated relative risk aversion coefficients ranging from 1.77 to 3.10. Kurosaki and Fafchamps (2002) estimated relative risk aversion coefficients for farm households in Pakistan in the range of 1.34 to 4.12 with an average of 1.83. Risk aversion behaviour of farm households is influenced by a number of factors, such as age, education, family size, access to non-farm income and ownership of assets. Binswanger (1980) found the small farmers more risk-averse than the large farmers. Likewise in Tanzania, farmers with a few assets were

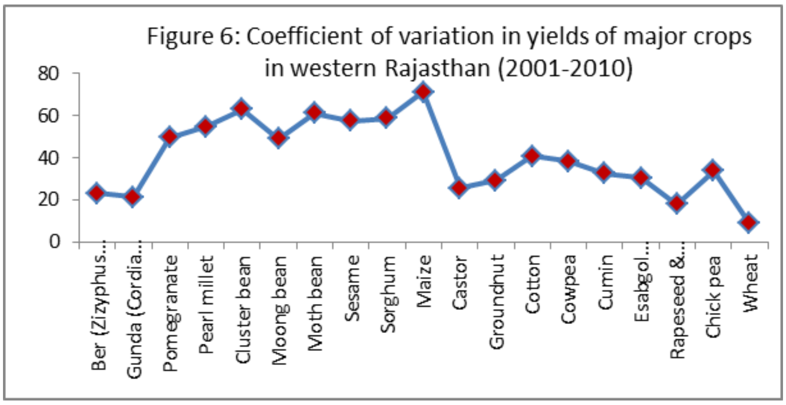


Figure 6: Coefficient of variation in yields of major crops in western Rajasthan (2001-2010)

found to specialize in crops with less variability at low yield (Dercon, 1998). We observed through focused group discussions that farmers in rainfed clusters 1 and 3 were more risk averse then irrigated ones and opted for drought hardy crops using least inputs. With this kind of relationship in view, we assumed the risk aversion coefficients as reported by Fafchamps and Pender (1997), 3.10 for rainfed clusters (1 & 3) and 1.77 for irrigated clusters (2 & 4).

Table 9: Yield variance reduction benefits

Alternate land use systems	Cluster 1	Cluster 2			Cluster 4
	Crops compared with new interventions				
	Mix crop	Mix crop	Cumin	wheat	chickpea
Risk aversion factor	3.1	1.77	1.77	1.77	1.77
Z. Moritiana based system (in USD)	25.2	31.1	22.9	-5.1	4.3
Cordia Myxa based system (in USD)	25.9	32.0	26.2	-4.2	4.9
Pomegranate (in USD)		9.2	-58.9	-26.7	-9.3

The CV of yields in agri- horti system especially *Z.moritiana* and *C. myxa* based systems (21 to 23%) substantially lower than the existing rainfed as well commercial crops like cumin. Hence the adoption of the agri-horti system would result in accruing of considerable benefits due to reduction in yield variance (Table 9). However shifting to pomegranate the does not provide such benefits as pomegranate itself quite high instability of yields (50%), the risk averse farmers are not likely to opt for this crop. Similarly the yield variance reduction benefits are negligible if we are replacing irrigated crops.

4. Discussion and Conclusions

Our analysis proved that the dryland farmers Smallholder farming systems in south Asia occur within diverse biophysical and socio-economic environments. Rural families develop different livelihood strategies driven by opportunities and constraints encountered in such environments. Agro-ecology, markets and local cultures determine different land use patterns and agricultural management practices across regions. Within localities and villages, households differ in resource endowment. Besides land size, access to credit, water, technology, the production orientation and objectives, ethnicity, education, past experience and management skills (Crowley and Carter, 2000) and in their attitudes towards risks (Salasya, 2005), shapes the type of natural resource management strategies. Household categorization is thus not only necessary to target agricultural innovations, but also to understand how the specific objectives and endowments of different household types affect resource allocation. Previous studies used various criteria and methods to categorize households for specific purposes: e.g. soil fertility research (Carter, 1997), agroforestry interventions (Shepherd and Soule, 1998), econometric and/or policy analysis (Kruseman et al., 2006), etc. A common denominator in most household clustering exercises is the use of wealth or resource endowment indicators, which are also used when farmers classify themselves through participatory wealth rankings (Mango, 1999). While all these constitute examples of structural household typologies, functional typologies that consider also the dynamics of production orientations and livelihood strategies may improve the categorization of households, depending on the objectives of the analysis (Mettrick, 1993). A closer look at each the cluster also helps to have insight on the potential complementarities and synergies between farm clusters so that farms network can be built (material flow such as feed, labour) and platform for exchange of experiences and skills can be initiated. From the analysis it appears that these priorities are a reflection of key livelihood activities in their respective cluster and also differences in livelihood assets indicators: illustrating differences in preferences, expectations and also capacity of the farms to solve these problems. Therefore we conclude that to target context specific technologies and propose a sustainable intensification or resilience pathways system analysis needs to take livelihood assets and farm priority into account. The farm typologies we proposed here may be seen as a domain to target technological innovation or development efforts.

The perennials based agri-horti system and intensification of P. Cineraria based agro-forestry system for both rainfed conditions together with rainwater harvesting as well as irrigated farms in arid regions would give substantially higher net returns than the existing crops. The additional net returns per ha per annum could be as high as about USD 500 and USD 25 due to reduction in yield variance. Technologies/ systems components that reduce variance of systems productivity with enhanced income can significantly contribute towards mitigation of drought effects; and unlike other strategies, these can provide a long-term solution too. The additional benefits USD 139 from intensification of Khejri as part of agro-forestry systems with 50 tree per ha would be much greater if farmer can put his own labour. *Khejri* which is known as the life line of desert would provide regular source of fodder for the continuously increasing livestock population on the long term basis contributing to resilience and system' sustainability.

However the farmers as well as the extension system have encouraged technologies that are more suitable to irrigated regions like overexploitation of groundwater and sub-marginal lands, and mono cropping etc with the short term objective of achieving higher profitability. That approach has encouraged resource degradation and made the farming systems more vulnerable (Jodha et al, 2012). Millions of dollars of public expenditure is being made to support rural people under extreme dryland regions to ensure their food and employment security, but there is need to have focused investment to develop integrated farming systems for capacity development of farmers on sustainable basis through convergence of different research and development programmes. Farmers to a reasonable extent also understand as emerged from the FGDs, the usefulness of perennials based integrated farming systems. But they are constrained mainly due to poor access to technical knowledge and critical inputs, lack of capital, high transactions cost of small marketable surplus. Provision of handholding support to the small farmers to access technology, inputs and market in the initial phase would be a prerequisite to develop such integrated farming systems. Initially the effort should be made in selected pockets and farm typologies depending on availability of resources, market and farmers willing ness, but there has to be a minimum number of small agri-horti units in a village so as to ensure viable marketable surplus and access to technology.

In the past, agricultural research has largely focused on yield improvement, and the on-farm research on adaptation to drought has not received adequate attention may be due to its complex nature. However, with increased frequency of droughts and increased climatic variability, there is increasing recognition of the importance of drought-adaptation research and extension. Through ex- ante evaluation of systems productivity enhancing and risk-reducing benefits of a perennials based integrated farming system in a most drought-prone region of India, this study contributes to the understanding of how on-farm research on drought-adaptation can contribute towards stabilizing farm incomes and smoothening livelihood of resource poor farmers in vulnerable regions.

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Annexure 1: Examples of focus livelihood capitals and their indicators in data collection

Natural capital		
Total cultivated land (ha)	Cost of livestock maintenance (INRs)	Access to common property resources (Scale)
Cultivated land , shared cropping and rented (ha)	Livestock feed source (type by %)	Cultivated crops and productivity (kg ha $^{-1}$)
Other owned land (ha)	Limitations of livestock production (ranking 1-8)	Application of inorganic fertilizer (kg ha^{-1})
Livestock owned (in Nr by species and age group)	Access to water (Nr by type)	Application of organic fertilizer (kg ha^{-1})
Livestock productivity (e.g. milk litre day^{-1})	Quality of water (good, average, bad)	Expense on herbicide (INRs)
Livestock mortality (Nr)	Irrigated areas (ha)	Limitations of crop production (Ranking 1-8)
Human capital		
Household members (Nr by age)	Level of education of household head	Other skills (Yes, No)
Age of the household head (Nr)	Numbers of years in farming	Livelihoods strategies (crop, livestock, off farm, combination)
Financial capital		
Expenditure by type (%)	Access to credit (Borrowed, INRs)	Saving (INRs)
Major sources of income (%)	Subsidies and insurance (Yes, No)	
Physical capital		
Access to input market (Yes, No)	Access to production facility-machinery (Yes, No)	
Access to production and processing facility-veterinary support unit (Yes, No)	Access to production facility-farm implements (Yes, No)	
Social capital		
Cast category	Social networking water users group(yes, No)	Social networking-self-help group (yes, No)
Social networking-producers group (Yes, No)	Social networking - civic group (yes, No)	Social networking credit micro finance group (Yes, No)