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Enhancing Farmers' Adaptation to Climate Change in Arid and Semi-Arid Agriculture of India: Evidences from Indigenous practices

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ICRISAT
Science with a human face

International Crops Research Institute
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Abstract

The primary focus of this paper is on farmers' adaptation strategies against climatic variability in arid and semi-arid regions of India. The farmers' perceptions and coping practices are largely governed by village level variables governed by the weather conditions. The paper is based on the synthesis of village, farm and plot level information collected through different studies in arid and semi-arid regions of India over a period of nearly thirty years. The discussion is broadly grouped under:

A) Adaptation practices determined by (i) risk generating features of the communities' natural resource base; (ii) long and short term weather patterns; and (iii) extreme events such as severe droughts.

B) The farmers' (experience-based) perceptions about climate (weather) variability and their potential adaptation practices (including preparedness, covering both collectively and individually managed steps) are considered. These adaptation measures are classified as (a) first (b) second and (c) third order adaptations, which cover different aspects of agricultural systems affected by climatic variation.

To facilitate effective adaptation to climate change (recognizing the uncertainties and information gaps in the micro-level spatial contexts), the following important points are relevant:

a) The collection,analysis and dissemination of reliable information on climate-response related variables (including farmers' perceptions) in *a diverse micro-level spatial context;*

b) The search for indicative adaptation options for the above inventory should focus on (i) prevailing farmers' practices in different areas with varying degree of vulnerability (eg, water scarcity or aridity) and other environmental constraints; (ii) agricultural R&D and location specific usable scientific results; (iii) effective formal and informal institutions.

The overarching suggestions incorporating the above points is to diagnose and understand farmers' adaptation strategies against climate variability with a focus on *the dynamics, diversity and flexibility of adaptations*, implying search for and promotion of approaches and options to harness the opportunities in the changing economic, technological and institutional opportunities, which may even exceed the ones evolved by farmers in the subsistence-oriented, locally-focused contexts. The implementation of the above suggestions highlighting dynamism, diversity and flexibility would need both enhancement and reorientation of the capacities of the farmers and rural communities, as well as that of the institutional arrangements and innovations supporting them.

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Introduction

This paper addresses the farmers' perspectives and the capacity of rural communities to respond and adapt to the increasing climatic risk and variability particularly in dryland agriculture. It builds upon a synthesis of key observations and review of studies that have dealt with farmers' adaptations or adjustments against climatic and related variability and associated risks. It provides the missing link in the information base relating to micro-level spatial context of development planning as the farmers' experiences, perceptions and adaptation practices are largely governed by local/landscape/village level variables, which are influenced by weather conditions. These responses may be oblivious of the current mainstream debates and interventions (usually top-down) and globally (or regionally) focused discourse on climate change. The key themes of innate dynamism, diversity and flexibility are discussed in detail and highlighted for required reorientation of the development programs, recognizing the adaptive capacities of the farmers and rural communities, as well as the institutional arrangements and innovations supporting them. The changing complex of components of adaptation strategies besides highlighting their dynamic nature also widens the scope for enhancing the search of new options both of technological and institutional nature and calls for effective bottom-up approaches involving a partnership between village communities and agencies designated to help them.

This paper deals with the potential adaptation approaches and measures against climate change in the agricultural sector of arid and semi-arid tropical regions of India. These regions are also referred to as dry regions or dry farming areas in this paper. As per the projections by the Intergovernmental Panel on Climate Change (IPCC), these are amongst the regions likely to have very significant impacts of climate change. Besides, these are amongst the poorer areas of the Asian and sub-Saharan African regions, which reduces their capacity to withstand the impacts of climate change, and thereby put them in the group of geographical areas most vulnerable to climate impacts. Though put under the broad category of dry regions, within them there are several visible and functional diversities depending on the degree of aridity, soil types and man-made infrastructure.

The existing poverty and vulnerability promoting processes in the dryland regions are products of their low productivity natural resource base, including less favorable agro-climatic conditions. The consequent marginal status of these economically low-performing areas in the national context has led to their overall neglect reflected through permanent under-investment and generally inappropriate development interventions.

However, a positive feature characterizing these dry areas is the evolution of human adaptations to the above constraints including climatic variability. Two-way adaptation processes have evolved through trial and error, over generations. These involve adapting production and resource use systems to the agro-biological-climatic conditions on the one hand and adapting (or amending) the natural resource base to sustenance and development needs of the community on the other.

It may also be noted that many of the human adaptation mechanisms or measures are being slowly marginalized and rendered less effective in the context of rapid changes affecting the dry regions (as well as many other broad agro-ecological regions of the country).The above changes are rooted in the changing demographic situation, enhanced role of market forces, side effects of technological processes, public policies and interventions as well as formal and informal institutional measures directed to agriculture and rural areas.

The two points that are central to our discussion on adaptations to climate change are as follows: First, the highly variable weather (or climate) conditions in the dry regions have shaped the farmers' responses or adaptations in the past. They may offer some insights and clues for evolving place based adaptation strategies to climate change for the future.

Second, the farmer's adaptation strategies (with some intra-regional differences) are not directed to weather variability exclusively. They are addressed to multiple constraints and opportunities including those having direct or indirect links with climatic variables (O'Brian et al. 2004).

The implication of the above issues is that adaptations to changing climatic conditions in arid and semi-arid areas will involve multiple facets including harnessing of potential complementarities between traditional, farmer-evolved measures and those generated through modern technologies and management systems, as well as micro-macro links characterizing policies and institutions for dryland agriculture. The different sections of the paper specifically refer to the above issues.

The evidence, insights and understanding of farmers' strategies against climatic risks and vulnerabilities were captured through a synthesis of studies in different areas of dry regions examining the behavioral responses to climatic extreme events (eg, droughts and floods) and frequent interactions (through repeated revisits) with farmers. The investigations covered subjects such as: a) famine and famine policies; and b) effectiveness of farmer's adjustment to risk; c) the changing eco-system social system links; b) technological imperatives of sustainable agriculture in fragile regions; e) convergence between traditional and modern farming systems; f) poverty-environment links in the fragile regions; g) contributions and crisis of rural common property resources; h) economic globalization-led risks and opportunities for marginal areas and communities. The findings of the studies are revisited and synthesized in the specific context of the theme of this paper. The key references of these studies are presented by Jodha (2001).

Climate Change And Dryland Agriculture: Contexts And Adaptation Experiences

The situation in fragile and marginal regions represented by arid and semi-arid tropical areas in India, as per the experts (eg, IPCC 2007, The World Bank 2008, Kumar 2007), are likely to have increased risks and vulnerabilities due to climate change. Furthermore, our focus is on agriculture, broadly defined to cover all land based activities including annual and perennial cropping, mixed farming systems involving farm-forestry-livestock links, etc, and their resource base (eg, soil and water in particular). Agriculture not only constitutes one of the largest areas exposed to climate changes but sustains a majority of the rural population in these areas. Furthermore, the agriculture-dependent people are likely to be worse off in the face of climate change, due to their present marginality and vulnerability to risks as well as the limited resources and capacities to withstand global warming led crises (ICRISAT 2009, Jodha 1996, Kates 1985).

At the same time there is increasing concern that advocates the centrality of traditional systems with visible potential to address the above mentioned issues along with the problems of food scarcity and poverty caused not only by climate change but other emerging changes marginalizing agriculture in the developing countries (Green Peace International 2009, Oxfam International 2007). However, while assessing the potential usability and up-scaling of traditional adaptations to face the impacts of climate change, one has to focus on an operational element in the process. This element consists of "contexts" to which farmers respond when faced with climatic variability (Gadgil et al.1988; Jodha 2001, 1989; Rhodes 1997). This is illustrated by the following discussion, where farmers' coping measures against diverse weather situations in different areas are reported.

By way of a digression, it may also be noted that the mainstream global information and modeled scenarios, due to information gaps at micro levels so far, are unable to provide concrete contexts for adaptation responses.

However, in the context of the focus of the present paper, it may be reiterated that even without the currently projected climate change, the fragile regions such as the Indian dry tropical areas, have several nature-induced risks and vulnerabilities. Their specific features (specificities) such as high degree of fragility, marginality, diversity and limited accessibility, (when compared to prime land areas of the country), generate the circumstances that keep them poor and contribute to their low productivity, associated with the low attention of mainstream policy makers to their problems (Jodha 2005). However, having lived with limited and low productivity options for generations, the communities in these regions have evolved their own short and long term adaptation measures to deal with the imperatives of their largely nature generated specificities (Jodha 2001, Gadgil et al. 1988). We look at them in order to identify approaches and options that could help in shaping the future adaptation strategies against climate change. At the same time, in view of the increased intensity of climatic variability and other changes, the traditional coping strategies against climate change will have to change through amalgamation of traditional and modern technology and management based practices. This is corroborated by the evidences captured by village level studies in different parts of semi-arid and arid tropics over more than three decades. To facilitate this, identification of specific contexts (eg, indicative situations created by impacts of climate change) at micro levels will be essential.The discussion under the next section giving field evidence on adaptation measures by the farmers can help in understanding of the issues mentioned above.

Adaptation Measures

The discussion on the contexts to help adaptation responses to climate change is presented in two inter-related parts. Accordingly, first, under (A) we look at the traditional and current adaptation measures undertaken in response to specific sources of nature (including climatic variability) induced risks and vulnerabilities, and second (part B) we reflect on the farmers' practical and prolonged experience-based perception about climatic (or weather) variability that guide their decisions and actions covered by (A). The sources of both (A) and (B) are the same, ie, village and farm level studies in different districts of the arid and semi-arid states of India, as mentioned earlier.

A. Traditional Practices

An important and crucial aspect of the above mentioned contexts requiring adaptation responses is the temporal (eg, within the cropping season) and spatial (eg, within the landscape or cluster of villages) variations in the extent and intensity of climate related circumstances within the broad zones for which meteorological data are collected and presented. The recorded and analysed data may provide broad/general indicators of uncertainties and risks and needed responses. But the real on-ground, differentiated farmers' responses largely depend on their perceptions and experiences elaborated in the latter part of the paper). Thus, the temporal and spatial diversity of risk generating climatic variability, diversity of the affected people and their adaptation responses constitute the central issues while designing and promoting adaptations to climate change (World Bank 2008a).

Furthermore,the contexts or situations inducing the farmers' adaptation responses can be broadly grouped into: a) Risk, vulnerability and adaptations generating features of their natural resource base (NRB), including climatic conditions (illustrated by Table 1.), b) Risks and adaptation to short and long term variability to rainfall, c) Adaptation to extreme events, viz., droughts and floods. These are featured and illustrated in the subsequent tables where temporal and spatial differences in rainfall are treated as varied contexts inducing different coping measures by the farmers.

I. Adaptations to Features of NRB

While elaborating on the farmers' adaptations to climate change, an important feature of adaptation strategy should be noted. In the first place, the farmers' adaptations are focused on the overall features of their natural resource base (NRB) – as a source of potential risk and opportunities for the dryland communities. Climatic conditions and variability constitute one of the components of the same. Table 1 illustrates this phenomenon capturing the general situation of arid and semi-arid regions but may not fully cover some exceptions represented by soil, water, vegetation and land, which are better endowed, within the dry regions. Spatial differences within the overall complex of Natural Resource Base (NRB) is one of the key determinants of diversity characterizing risks generated by climate change and farmers adaptations. However, table 1 provides a generalized illustrative picture of these diverse issues.

Table 1. Dominant biophysical features of natural resource base (NRB, including climatic conditions), associated situations and community adaptation-response measures in drylands.

A. Features of NRB and associated situations	B. Traditional situation and responses to column A	C. Emerging changes in A & B
Water/moisture scarcity and instability, frequent droughts and scarcities	Water harvesting, moisture conservation (bunding, trenching, etc), limited groundwater harnessing, focus on crops (mixed crops) with varying drought tolerance; seasonal migration during droughts, focus on annual, perennial plant complementarities	Moisture conservation/water harvesting measures requiring group action declined due to increased social differentiation. Rapid increase in groundwater exploitation. *Reasons*: Drilling technology, govt. subsidies and high prices of irrigated crops, lost collective concerns of communities for local resources.
High fragility, erodibility of land, not suited to high intensity uses	Overall land use and folk agronomic practices focused on combining production and conservation needs; focus on practices such as shallow tillage, terracing, bunding, strip farming crop fallow rotations; more marginal lands allocated to animal grazing, common property resources (CPR)	Gradual discard of conservation promoting land use systems; enhanced land use intensity, rapid degradation of land for both cropping and grazing. *Reasons*: Population growth, backlash of R&D based modem technologies on traditional ones; decline of collective stake in local resources and social controls replaced by public laws.
Scarce and slow growing/regenerating vegetation, frequent shortage of natural biomass supplies	Traditional agroforestry/farm forestry, periodical long fallows, regulated and collective efforts to maintain CPRs, provisions of protected areas, eg, water bodies, religious sites, etc; seasonal closure/rotational use of grazing space	Traditional farm practices and institutional provisions facilitating vegetation protection/ growth discarded; new initiatives such as agroforestry with new components are yet to pick up on a large scale. *Reasons*: Reduced collective concerns/efforts; increased dependency on government subsidy programs, socioeconomic differentiation.
Soils with low nutrient and low potential for biomass and crop productivity	Farming systems focused on crop livestock complementarities, local organic inputs, periodical Resting (fallowing) of crop lands, cereal legume rotation or mixed cropping.	Decline of sources and usage of practices/ systems helping soil fertility; increasing use of chemical inputs. *Reasons*: Extension services and subsidy on chemical inputs, formal R&D indifferent to traditional practices.
Overall high degree of marginality of NRB offering limited, high risk, low productivity earning options to communities	Accepting "inferior earning options"; stabilize and enhance opportunities using the practices mentioned above; collective risk sharing during crisis; external links through migration; petty trade; relief and charity.	Gradual discard of traditional approaches due to availability of new options through development intervention (including new technologies), rising dependence on public support, diversification of sources of livelihood including public relief, out migration, earning through urban jobs, etc. Reasons: Emerging new phase of adaptation strategies.

a) Table adopted from Jodha (2005), based on evidence/inference from Arnold and Dewees 1995, Bantilan et al. (2002), Dasgupta and Karl Goran (1990), Gupta (1997), Jodha (2001, 1991a, 1991b, 1992a, 1992b, 1995, 1989a,1989b), Jodha and Mascrenhas (1985), Jodha and Singh (1982), Kerr and Sanghi (1992), Shah (1993), Walker and Jodha (1986), Walker et al. (1983), Walker and Ryan (1990), Reddy et al. (1993).

Table 1, col.1 helps to provide an indicative, integrated view of the complexity of risk generating factors and processes affecting dryland agriculture. The communities' conventional and present day responses to the same are summarized under table 1, col.2. The recent changes weakening the indigenous adaptation responses are indicated under Table 1, col.3. Table 1 does not need any explanation. Yet, one aspect needs closer attention.

Accordingly, the approach to promote future adaptation strategies against climatic risks has to incorporate responses to several other quite related changes in dry regions (see Table 1, col.3). Some of the changes, such as inappropriate intensification of land use, weakening of collective arrangements against crisis situations, mining of groundwater, side effects of new technologies and generalized public intervention, increased pressure on lands, etc, would call for approaches to enhance protection against risks created by them. Similarly, the changes such as access to off farm jobs, use of new conservation technology and public supported innovative institutional measures, etc, adding new options for the dryland farmer, would need to be encouraged and multiplied to reduce risks and vulnerabilities. To sum up, Table 1, col.3 can help in identifying indicative options for incorporation into adaptation strategies against climate change and other linked changes in arid and semi-arid regions of India. Table 1 also indicates the need for approaches to identify and integrate the elements of traditional adaptations as well as new ones into future strategies for climate change sensitive development approaches for drylands in India. This message has also emerged from more detailed and comprehensive analyses of adaptations to climate change (The World Bank 2008a and 2008b, IFPRI 2009).

II. Adaptations to patterns of long and short term rainfall

The contents of Table 1 dealing with overall NRB can be supplemented by adaptation/adjustment to climatic variability in the short and long term contexts, as manifested by the different features of farming systems in arid and semi-arid regions. The adaptation measures evolved according to environmental specificities in different dry tracts could be broadly combined under folk engineering (particularly covering engineering elements relating to land, water management), folk agronomy (covering cropping systems and practices, systems of input use, and harnessing biomass and management of mixed farming systems), institutional arrangement such as common property resources and group actions for collective defenses against nature induced risks and vulnerabilities, etc (Jodha 1989c). Most of them are selectively and jointly resorted to depending on short or long term weather conditions. Again, the number and complexity of the measures have also changed in the recent period with potential availability of new and diverse options.

The information presented in subsequent tables (2 to 5) quantitatively depicts characteristics of various locations, portraying the climatic indicators of risks and the farmers coping measures. The data on climatic variables covered by different tables reflect different dimensions of locally relevant weather patterns and how farmers respond to these aberrations.

The information in Table 2 more clearly illustrates the farmers' adjustments/adaptations to climatic risks. The village, farm and plot based information collected from three districts with different patterns of rainfall and the associated risks is presented in Table 2. The differences in adaptation measures between Akola (a semi-arid, better rainfall district of Maharashtra) and Jodhpur (an arid district of Rajasthan) demonstrate the relative extent and intensity of farmers' defensive measures against climatic risks, be it spatial diversification, crop combinations, or institutional measures evolved to meet risks and crisis caused by climatic variability.

Table 2. Indicators of the farmers' long-term strategies against weather risk in three districts with different degrees of weather risk in the dry tropical regions of India.

Details of degree of risk and adaptation	Akola	Mahabubnagar	Sholapur	Jodhpur
A. Characteristics of weather-risk				
Annual average rainfall (mm)	820	786	690	382
Probability of favorable soil moisture conditions for rainy season cropping	0.66	0.56	0.33	0.21
Length of growing season (days)	200	176	155	60
Incidence of crop failure (average of 3 yr)				
- Plots with complete crop failure (%)	4	15	17	33
- Plots with partial crop failure (%)	7	32	24	-
B. Indicators of spatial diversification				
Scattered land fragments (no.) per farm	2.8	3.4	5.8	7.3
Split plots (no.) per farm	5.0	3.5	11.2	-
Fragments (no.) per farm by distance from village				
- Up to 0.8 km	1.5	1.8	1.4	1.2
- 0.8 – 1.6 km	1.1	1.1	3.4	4.3
- More than 1.6 km	0.2	0.32	1.0	1.8
C. Indicators of crop-based diversification				
- Extent of intercropping (%)	83	76	35	100
- Total sole crops planted (no.)	20	32	34	12
- Total combinations of mixed crops planted (no.)	43		56	30
D. Crop-livestock based mixed farming				
- Ratio of land and livestock values (1976-77 prices)	93.7	95.3	91.9	63.37
- Ratio of crop and livestock incomes (1976-77 prices)	80.20	82.08	71.29	69.31
E. Occupational and institutional adjustments				
- No. of occupations (sources of income) per household	1.5	1.6	2.3	2.9
- Households with more than 2 occupations (%)	14	22	18	39
- Households with incidence of seasonal out-migration (%)	2	19.6	24	33
- Cases of land tenancy induced by risk sharing/management considerations (no.)	9	-	66	-

Table based on data from Jodha (1986, 1989b), Walker and Jodha (1986), Singh and Walker (1982); VLS-data base.

It may also be added that as the revisits to the above areas indicated, the measures to adapt to short and long term climatic variability have undergone transformation as indicated by new options in terms of new crops, new production technologies, a number of structural changes, and frequency of external links with market and public programs. This reflects the dynamics of adaptation strategies against the climatic variability.

Table 3. Changes in cropping decisions in response to soil moisture situation during planting period in three districts in the dry tropical regions of India (a= high moisture, b= low moisture situations).

Soil moisture and	Changes in the proportion of area under crops during the planting period in					
	Mahabubnagar		Sholapur		Akola	
	a	b	a	b	a	b
A. Soil moisture (mm) during (6 wk) planting period						
Mean per week	56.3	21.6	129.2 (175.2)	36.0 58.5	68.6	22.7
Range during 6 wk	48.99	21.28	67.150 (150-220)	28-41 (44-77)	63-74	12.59
B. Cropping decisions						
Cropped area (ha) per household	4.2	3.9	7.5	6.0	5.4	5.9
Proportion of the following in gross cropped area (%)						
• Intercropping	83	85	38	25	94	90
• Crops with low moisture needs	29	36	54	62	21	23
• Crops with high moisture needs	5	3	11	6	48	43
• Long-duration crops	8	7	13	8	16	11
• Short-duration crops	1	4	2	5	3	8

Source: Table adapted from Jodha (1986, 1991a).

Information in Table 3 further supplements the details indicated by Table 2. However, this table also reflects on how actual cropping decisions (as adjustments to moisture conditions) are affected by the seasonal rainfall. The table based on farm household level data from three districts covered by ICRISATs Village Level Studies (VLS), indicates differences in farmers' responses to varying soil moisture situations (eg, choice of crops with high or low moisture needs, crops with varying maturity periods, type of crop combinations, etc). The details under Tables 2 and 3 in some way compliment the discussion on farmers' experience based perception about assessing climatic variability despite their limited exposure to the formal meteorological information.

III. Adaptations to extreme events (droughts)

While the farmers' measures against climatic risks illustrated by Tables 1 to 3 generally help in sustaining livelihoods under unstable environmental conditions in the dry regions, many of them prove inadequate or ineffective during the severe drought situations. This is illustrated by farm level data from drought affected villages from different districts during different years as summarized in Tables 4 and 5.

To elaborate, Table 4 reflects on the overall sustenance income and its sources for the drought affected households in different areas. Accordingly, the drought year income generating sources included: cultivation, livestock, wages from relief works, sale or mortgage of assets, borrowings, and a few others such as handicrafts, remittances, charities, etc. The per household income levels varied between Rs 2600 to 3000. For understandable reasons, wages through relief works accounted for about one third to one fourth of the sustenance incomes during the drought years.

Table 4.Sources of sustenance income of households during drought years in different areas[a].

Details	Jodhpur (Rajasthan) 1963-64[b]	Barmer (Rajasthan) 1969-70	Banaskantha (Gujarat) 1969-70	Aurangabad (Maharashtra) 1972-73	Sholapur (Maharashtra) 1972-73	Akola	Mahabub nagar
No. of households	144	100	100	128	80	239	603
Sustenance income per household(Rs.)[c]	3333	2996	2627	2715	2944	2123	2275
Proportion(%) from different sources							
Cultivation	2.1	-	-	6.8	14.4	49	48.4
Livestock	10.2	7.2	4.8	NA	1.0	14.5	5.3
Wages from relief work[d]	24.9	52.8	31.7	56.2	46.5		23.6
Sale of assets	25.9	12.5	24.9	13.5	17.3	18.9	-
Borrowing[e]	10.4	12.8	11.7	6.3	7.9	2.3	-
Others[f]	26.5	14.7	26.9	17.2	12.9	15.5	22.8

a. Table adapted from Jodha (1978) that provides details on sources. Also see Borker and Nadkarni (1975), Chaudhari and Bapat (1975), Subramanian (1975), Singh and Waker (1982); VLS data base (2012).

b. All households include labor and artisan households and medium-size farms in addition to small and large farms.

c. Sustenance income defined as total inflow of cash and kind including borrowing except term loans unrelated to sustenance during the drought year. Value of sustenance income expressed in items of 1972-73 prices.

d. In the case of Barmer and Banaskantha it also includes institutional help in terms of free or subsidised food and fodder including those provided by the government and charitable institutions during the migration. This also includes free supply of milk powder, vitamin tablets, medicine, clothing, transport facilities, etc.

e. All borrowings – in cash or kind taken against mortgage or labor/land lease contacts and others. This does not include credit in terms of postponement/cancellation of recovery of land revenue and other dues. It excludes term loans.

f. Includes income from other casual or agricultural wage employment, transport, remittance, free help from well-off relatives. In the case of Jodhpur villages, it includes value of old stock of food grain and fodder.

Table 5. Loss-minimizing practice adopted by farmers during a drought year and a non-drought year in the study villages in Jodhpur (Rajasthan) and Mahabubnagar (Andhra Pradesh) districts in the tropical arid regions of India[a].

Item	Jodhpur[a]		Mahabubnagar[b]	
	Drought (1963-64)	Normal Year (1964-65)	Drought year (2004-05)	Normal Year (2005-06)
Characteristics of weather risk				
Rainfall during the year (mm)	159	377	449	811
Total rainy days (no.)	8	21	35	56
Plots covered by risk/loss-minimizing farm practices (no.)				
Collecting weed material as fodder	53	5	NA	NA
Harvesting field borders for fodder	68	66	NA	NA
Harvesting premature crops	27	-	NA	NA
Harvesting crop by-product only	49	2	NA	NA
Harvesting mature crop	16	144	47	62
Inter-culturing	7	65	92	86
Weeding more than once	18	-	79	72
Thinning	37	-	74	86
Abandoning post-sowing operations	36	-	50	72
Using hired resources for post-sowing operations	2	24	66	76
Harvesting premature Z. *nummularia* (bush) for fodder	92	-	NA	NA
Lopping trees for fodder/fuel	53	4	NA	NA

a. Table adopted from Jodha (1975).
b. VLS data base

One of the ways to meet the drought situation is by borrowing for meeting the current needs, by mortgaging the assets, land, livestock, etc, particularly at lower prices as the asset prices are substantially lower during the drought years. Some people also resort to attaching their family members as labor to the lender as a condition of borrowing. Generally, the impacts of climate change could result in the incidence of net indebtedness as well as net worth of assets during the drought and post drought years. This represents a less visible but more enduring impact of adaptation to the droughts in the dry areas. The semi-arid villages have developed over the years with improved rural infrastructure, educational level, etc. Population has risen enormously, which has resulted in increased exploitation of natural resources, including water and land resources. Together with other major factors contributing to vulnerability, prolonged changes in normal climate have also made families in rural SAT India quit farming, opt for non-farm work, engage in labor or community work or migrate. Migration is another age old measure to cope with the drought period crisis. According to the studies on impacts of drought years during 1968 to 1975, around 37 to 60% households resorted to outmigration during the drought periods in different districts of Gujarat and Rajasthan. The number of out migrants ranged between 204 and 250 persons per village. They stayed out as migrants for 107 to 218 days per person. Many of them migrated with their farm animals. Furthermore, 28 to 53% of the migrating animals suffered a loss through death, theft and unreasonable penalties by villagers en route.

The SAT India characterized by erratic and low rainfall makes farming a risky proposition especially amongst the landless laborers, and smallholder farmers who opt to work for governmental construction projects and other non-farm work as a primary means of risk adjustment. The ICRISAT-VLS data reported that in 1986, a majority of the population of laborers migrated along with their family members for 2-3 months (Bidinger et al. 1991). Permanent migration was not high in the past; however, the development of cities and emerging opportunities therein also resulted in permanent migration from the villages of SAT India. For a later period, ie, 1990s and onward, ICRISAT-VLS data also indicated heavy reliance on out migration during the drought years, particularly in Mahabubnagar district (Andhra Pradesh) though a pattern of out migration showed many changes, including emphasis on migration to urban areas. In some cases, the Rural Employment Guarantee Scheme had reduced the dependence on out migration. Increased dependence on non-agricultural earnings was also noted. To sum up, though currently under strain, the traditional adaptation strategies (broadly reflected through Tables 1 to 5 above) not only continue to help farmers in managing climatic risks but also contribute to their experience based perceptions to guide their responses against nature driven uncertainties and risks. This is a relatively unrecognized phenomenon, understanding of which can facilitate development of future adaptation strategies against climate change.

Experience based perceptions

Despite general lack of ready access and understanding of formal meteorological information, the dryland farmers do possess some experience and understanding of climatic happenings (at times captured through natural indicators such as the behavior of birds and other creatures as well as growth stage-based performance of some plant species), to guide their decisions and actions specially where perception and ground level situations converge. The following discussion as part B of the contexts for adaptations elaborates on this.

B Farmers’ perceptions of climatic variabilities as contexts for adaptation responses

The broad purpose of the discussions under this section is to elaborate on how in practical contexts the farmers in dry regions see and understand the emerging weather situations affecting their production environment and consequent impacts on their farming decision. The significance and relevance of such an approach can be understood by the following facts.

Agriculture in the dry regions is largely a nature-shaped and nature-driven activity, without substantial man-made support systems characterizing mainstream modernized agriculture. Hence, it is not difficult to identify the contexts or processes through which impacts of changing weather conditions (particularly rainfall) could take place (Jodha 1996). Following Kates (1985), we put these contexts in three categories. This can help in understanding the issues and areas (contexts) requiring attention to handle the problems associated with projected climate change; who could be responsible for interventions against impacts and finally where the farmers' traditional practices and support systems be of some help in evolving adaptation strategies against climate change.

The three categories of links between agriculture and climate variability (and hence its impacts) may be put as first, second and third order impacts (Kate 1985).

A The first order impacts of climate change relate to the agricultural resource base and production environment.

B The second order impacts of climate change cover affected components or features of farming systems due to already impacted resource base and production environment (covered by "A").

C The third order impacts cover macro-level aspects of agricultural systems and their links with macro level processes and activities as influenced through already impacted components of farming systems (covered by "B").

The involved variable as per the farmers' perspectives and practices, captured through already mentioned different studies for nearly 30 years in arid and semi-arid areas of India, are presented in the form of the following three tables. The structures of variables and their linkages indicated may look quite crude and simplistic, but they capture the processes through which the farmers, exposed to weather variability, relate their production and resources use, system-focused decisions and actions to face the involved risks.

The inventories of selected variables put under the three tables are based on repeated visits and interactions with farmers and field observations during the studies in dry regions of India, including those at CAZRI, ICRISAT and AERC, as already mentioned. The primary method of seeking farmers' views on the variables covered by the three tables included closer and frequent interactions with farmers as well as farm and plot level observations. The field work also included detailed discussions on interpretation of spatial and temporal differences in the status and performance of agricultural activities covering different fields and spatially differentiated locations in their own villages and some neighboring villages. The resulting synthesized information constitutes the basis of the following three tables. Before we elaborate on farmers' perceptions and their potential role in influencing their decisions and actions vis-à-vis climatic variability, a brief assertion on the same will be appropriate.

The details presented under Tables 6, 7, 8 are more of an indicative nature, which in varying degrees form parts of rainfed farmers' understanding of:

A. How bio-physical variables (items under rows of Table 6) affecting their production/resource use practices or decisions and their consequences (results) are likely to be affected by the changes in the situation of micro-level climatic variables (items under columns of Table 6) and are the key areas that may potentially be affected by climate change or climatic variabilities in the dryland farmers' context.

B. Perceptions based on past experiences of the farmers that vary according to natural resource endowments (soil type, topography, rainfall pattern, dominance of particular cropping systems, irrigation availability) as well as the economic-social conditions of the households/ communities.

Furthermore, the actual farming decisions in any year are manifestations of past experience based perceptions suiting the actual conditions during a particular cropping season/year.

The quantification of the actual situation (reflected in Table 6) is not feasible except in terms of actual farming practices linked to broad potential strategies based on convergence between realities indicated by perceptions and actual farming system/cropping decision as indicated in Table 10.

What has been indicated with reference to Table 6, applies to perceptions of second and third order impacts of climatic variability presented in Tables 7 and 8. Accordingly, the components of production environment potentially affected by micro-level climatic variability (ie, items presented under rows of Table 6, and shifted to columns of Table 7) potentially influence the components and features of farming systems (cropping and other resource management practices/measures) highlighted in Table 8.

The third order impacts of climatic variability mentioned in Table 8 includes irrigation systems, public support and relief, agricultural R&D, marketing, trade, employment, promotion, poverty eradication measures, etc, which indicates the impacts of potential changes in components of farming systems due to climatic variability, finally influencing the farmers' decisions, actions as well as use or need or access for secondary as well as tertiary level activities.

Materialization of the involved perception in terms of actual decision/action and activities are mentioned in Table 10. These can be supported by farm/village level data by looking at climatic (weather) data, especially on rainfall pattern, soil types and their variability and cropping and related activities as part of adaptation strategies during the different years.

The perception linked elements of farmers' adaptation/adjustment strategies against drought and uncertainty in dry tropical regions of India could be understood through analysis of long term farm and village level data. This will help in identifying the role of farmers' perceptions in influencing their adaptation strategies. The analysis of weather linked changes in land use and cropping patterns, input use practices and extent of external links, etc, revealed by VLS data broadly indicate this. It will be relatively easy to capture the above phenomenon when there is a greater convergence between components of perceptions and ground realities during the cropping year.

Imperatives and Present Situation of Farmers' Perceptions and Adaptations

Despite inadequacies and limitations of details projected through Tables 6 to 8, they can offer useful clues for realistic thinking and action on approaches to adaptation strategies against climate change. We pattern our discussion on the order of the above tables. Our focus will be on using the key variables and associated processes. Besides, our emphasis will be more on the issues of second order impact as it is central to adaptations through primary farm level activities.

I. First Order Impacts

Irrespective of some degree of incoherence and repetition in the listed bio-physical features of resource base and production environment of dryland agriculture, and how climatic factors affect them as perceived by the farmers, the inventory of factors and their linkages in Table 6, reveals an important insight, that through their practical experience, farmers are quite aware of the role of climatic variables in the performance and risks of their enterprises. The immediate policy implication of the above situation is quite clear. First, the need for dissemination of climate change information in more disaggregated form, including its implications linked to different agricultural areas, the agricultural enterprises (eg, crops, horticulture and their seasonality, etc) and at least covering some of the variables reported under Table 7, should become an important part of agricultural extension and information systems in different cropping zones in dry regions. This needs substantial reorientation of existing approaches of meteorology as well as agricultural extension departments, along with building new skills of the village level functionaries. Disaggregated, place (village) based data collection and analysis on these aspects is equally important. ICRISAT through its Village Level Studies (VLS) has provided information on some of these aspects (Walker and Ryan 1990). Using the VLS methodology, to capture farmers' perceptions and responses to climate change, similar studies have been initiated in six Asian countries with support from the ADB and partnership with the national institutions.

Table 6. Indicatives First-Order Impacts of Climate Variability on Agriculture through effects on its Bio-physical Resource base and Production Environment in Arid Tropical Areas.

Major components of Bio-physical resource base and production environment	Variables Potentially Affected by Climatic Variabilities						
	Temperature	Solar radiation	Precipitation	Humidity	Evapo transpiration	Soil Moisture	Runoff
1. Moisture regime	***[b]	***	***	*	***	***	***
2. Length of growing season	**	*	***	*	**	***	*
3. Microclimatic stress[a]	***	*	***	*	*	***	*
4. Weather aberrations/ extreme events	***		***	*	*	*	*
5. Seasonality	***		***			**	
6. Disease-pest complex	***	*	*	***		*	
7. Biomass productivity potential	***		***		***	***	
8. Photosynthetic responses	***	*		*	**	***	
9. Plant-input interactions[a]		*			*	*	
10. Soil Productivity	*	*	***	*	**	***	**
11. Soil erosion hazard			**		*		***

Source: Based on the farmers' perceptions and practices; table adopted from Jodha (1989a) and refined in 2010.
a. Refers to plant-nutrient interactions and water-vegetation-soil interactions.
b. Number of asterisks in different cells indicates the intensity of relationship between different variables.

II. Second Order Impact

The farmers' understanding and knowledge of the important features of their bio-physical resource base and production environment is finally reflected on how they use the positive and negative aspects of the same. The choice of farming enterprises and their specific combinations, natural resource usage systems, institutional arrangements as presented in Table 1, illustrates this. The close observers of these processes and practices (Nelson 2009, Crate and Nuttal 2009, Green Peace International 2009, etc) have focused on both adaptation and mitigation implications of these practices.

As mentioned earlier, the second order impacts of climate variability and farmers' adjustments to the same are the key areas to explore and understand the potential of traditional adaptations in the context of climate change. To facilitate this, some key features of the present situation of adaptation practices need to be understood.

Table 7. Indicative Second Order Impacts of Climate Variability on Agriculture (ie, features of farming systems) influenced by Affected Variables of Bio-physical Resources base and Production Environment in Arid Tropical Regions.

	Components of resource base and production environment				
Components/Features of farming systems	Moisture regimes, growing season, micro climatic stress (1-3)	Seasonality, weather instability (4-5)	Disease, pest complex (6)	Biomass potential, photosynthesis, plant-input interaction (7-9)	Soil chemistry, erosion hazard (10-11)
	Medium to Long term				
1. Moisture management practices/structures	***c	**			**
2. Adapted cultivars	***	**	**	**	***
3. Enterprise combination	**	**		***	*
	Immediate to Short term				
4. Risk adjustment mechanism	**	***	**	*	*
5. Agricultural activity calendar	**	***	**`	*	
6. Input use practices/ levels	***	**	**	*	*
7. Production flows	**	***	**	*	
8. Yields and returns	**	***	**	*	
(Define * / ** / ***)					

Source: Based on the farmers' perceptions and practices; table adopted from Jodha (1989a) and refined in 2010 .

a. Components are taken from Table 10, figures in parentheses refer to row numbers in Table 10.

b. Practices like mixed farming, intercropping and sequential and relay cropping designed to diversify agriculture, to guard against risks and to take advantage of complementarities and linkages between different activities.

c. Number of asterisks in different cells indicates the intensity of relationship between different variables.

Table 8. Indicative Third-Order Impacts of Climate Change on Agricultural Systems and Activities (secondary & tertiary levels) through affected Components of Farming Systems in Arid Tropical Regions.

Agricultural support systems and linked activities	Potentially affected components of farming systems[a]				
	Adapted cultivars enterprise combinations (2-3)	Moisture management, security (1)	Activity calendar, input use practices (5-6)	Risk adjustment/ crisis management (4)	Production flows, yields and returns (7-8)
1. Irrigation strategies (F &IF[c])	*[b]	***		*	**
2. Relief strategies (F & IF)	*	*		***	
3. Agricultural infrastructure (F)	**		*	**	**
4. Collective action	*	*	*	**	
5. SHG (sharing), credits, etc	*	**		*	*
6. Input supply systems (F & IF)	*	*	**		***
7. Marketing, trade, food systems (F & IF)	***		**		***
8. Migration and external dependence				***	**
9. Intersectoral linkages (F & IF)	*		**	**	***
10. Employment, income generation (F)	**	*	***	**	***
11. Special programs (F)	*	**	*	***	**
12. Agricultural planning strategies (F)	*	***		***	*
13. Agriculture R&D strategies (F)	***	***	*	**	*

*(Define * / ** / ***)*

Source: Based on processes of agricultural changes characterizing the dryland agriculture in the recent decades and their drivers as perceived by farmers and other agriculture-linked agencies.

Table adopted from Jodha (1989a) and refined in 2010.

a. Components are taken from Table 11, figures in parentheses refer to row numbers in Table 11.

b. Number of asterisks in different cells indicates the intensity of relationship between different variables.

c. 'F' indicates Formal and 'IF' indicates informal activities.

III. Third Order Impact of Climate Change

Despite farmers' measures and practices at farm and community levels to manage and sustain their farming systems and resource management, the climatic-shocks (in the form of recurrent droughts and occasional floods) are so severe that they have to depend on external links and support systems. Such dependence has become all the more unavoidable due to the pressure of changes unrelated to climate and other natural processes. As already discussed, they relate to some negative side effects of public interventions, etc, market forces and quantitative and qualitative demographic changes, along with unequal inter regional links. These factors are part of the transformation process of fragile land agriculture.

However, despite their positive contributions, most of the above macro-level changes are yet to have sufficient sensitivity and diversified elements to strengthen farmers' adaptations to diverse biophysical resource base and socio-economic situation of dryland agriculture. One of the main problems of macro level interventions is the usual extension of options and approaches evolved for well endowed, prime land agriculture to marginal and fragile areas, without understanding the latter's specificities (Jodha 2001 and 2005).

The essence of the above discussion on farmers' conventional adaptations to climate variability and their imperatives for recent thinking/interventions focusing on possible responses to projected climate change, seen through the lens of first, second and third order impacts can be summarized through Table 9.

Table 9. Important Features of Farmers' Response to 1st, 2nd and 3rd Order Impacts of Climate Variability and their Implications for Future Adaptations.

1st Order Impacts: on Biophysical Environment	2nd Order Impacts: on Farming Systems	3rd Order Impacts: on secondary and tertiary levels
1. Farmers have functional knowledge of local climate variability.	1. Farming systems with features and contents are adapted to climatic variability and stresses.	1. Adaptations involving secondary and tertiary level links and processes with key focus on disaster management, etc.
2. The formal modeled climate change related information is often neither available nor usable as this model-based aggregative knowledge does not relate to ground level, micro-level spatial diversity.	2. Current measures/practices can provide rationale (if not form) for future adaptations, but "the contexts" should be clearly known; these are largely missing.	2. Impacts of negative side effects of public policies and support system, market forces, etc, and weakening of traditional adaptations without providing effective alternatives.
3. The above (2) provides no concrete context to evolve, amend response measures by the farmers, despite potential for the same.	3. Of late, traditional adaptations to climate change are weakened due to side effects of increased role of other factors: policies, market forces, demographic changes, etc.	3. New problems hindering transformation process of dryland agriculture, requiring new adaptations covering multiple aspects involving long time learning.
4. Yet to sensitize farmers to modeled climate change; awareness generation can be helpful.	4. New adaptations or strengthening of the traditional ones call for action on multiple fronts.	4. Adaptation strategies to have integrated approach involving focus on changing agents and process.
5. Awareness generation, sensitization approaches to climate change through public agencies are needed.	5. Needed adaptation strategies for "transformed" agriculture are a key task.	5. Needed policy and institutional changes to combine adaptations with development interventions.

Building upon the inferences from Table 9 and the related preceding discussion on the one hand and rising concerns for making agricultural technologies and development support systems sensitive to climate change on the other, we outline some key steps for strengthening community adaptations to climate variability in the dry regions of India. They may offer some lead lines for future thinking and action to face the impacts of climate change.

Conclusion: Enabling adaptation process-Moving on the Action Front

The understandings generated by the above discussions indicates a number of potential approaches and options to facilitate adaptation strategies against climate change in the dryland context of India. The primary issues, central to dryland agriculture, such as those dealing with crop technologies, natural resource management and rural development programs covering community centered and infrastructure related programs are focused. The interventions and options incorporating these issues would have significant potential to help dryland farmers to withstand negative impacts of climate change. Textual Table 10 summarizes the important components to be emphasized. Being agricultural technology and resource management-centric, the table does not cover other important aspects such as factors and processes marginalizing the traditional adaptation measures; other threats beside climatic variability to which farmers have to respond; information, access and user capacities as well as customization of climatic data for farmers' use, etc, as alluded to in the paper.

Table 10. Possible Approaches to Generate Option to Revitalise Farmers Adaptation Adjustment Strategies against Climate Risks and Uncertainty in Dry Regions.

Parameters	Aspects to be Focused on to Generate Relevant Option
Area of Intervention	
Crop Technologies	Crop range: Multiple crop choice, minor crops, cropping system varieties besides hybrids Crops with: Variable maturity, variable range and date agronomy, high temporal and spatial adaptability, compatibility (for inter cropping, agro-forestry), drought resistance, high stalk component, suited to organic recycling Products with: High storability, recyclability, local processibility
Resource centered	Conservation measures with multiple objectives (productivity, etc), scale and group action neutrality. Focus on lengthening growing season and possibility of mid-season corrections.
Perennials	Fast growing, high restorability, non-competing and non toxicity type, suited to cut and carry system, complementarities between perennials and annuals: Focus on bio-mass processing/storage/recycling techniques.
Development programs	
Resource/Community centered	Silvi-pastoral/social forestry, related initiatives: de-emphasis on less known techniques; formal administration and subsidy: focus on “user group action” involvement. Equity of access, incentive for group’s action, regulation of CPRs, involvement of NGOs.
Irrigation/ soil water aspects	Focus on low water requiring crops, arrangement for equitable access to water; regulation of water usage.
Relief operations	Strong productivity component, multiple activities, emphasis on matching contribution in any form, incentive for voluntary action, involvement of NGOs. Reduce domination of formal agencies, create accountability mechanisms, focus on links between development and relief components.

Note: for further details and some quantitative evidence, see Jodha (2001, 1991b, 1989b), Walker and Jodha (1986), ICRISAT (2009), Shah (1993) Biot et al. (1995) Mruthyunjaya et al. (2003).

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About ICRISAT

The International Crops Research Institute for the Semi-Arid-Tropics (ICRISAT) is a non-profit, non-political organization that conducts agricultural research for development in Asia and sub-Saharan Africa with a wide array of partners throughout the world. Covering 6.5 million square kilometers of land in 55 countries, the semi-arid tropics have over 2 billion people, and 644 million of these are the poorest of the poor. ICRISAT and its partners help empower these poor people to overcome poverty, hunger and a degraded environment through better agriculture.

ICRISAT is headquartered in Hyderabad, Andhra Pradesh, India, with two regional hubs and four country offices in sub-Saharan Africa. It belongs to the Consortium of Centers supported by the Consultative Group on International Agricultural Research (CGIAR).

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