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ABSTRACT

Major portion of the Deccan falls in the hot and semi-arid eco-region and is subject to periodic droughts of varying intensities, high soil erosion rates and rapidly depleting groundwater. Lack of irrigation water from different sources reveals that small and marginal farmers are vulnerable to precipitation changes, resulting in declining crop yields and water availability. Integrated Watershed Management (IWM) is an accepted practice for ensuring natural resource conservation, sustainable crop production and improvement of the socio-economic conditions of stake holders. Data collected from various watershed projects over the last three decades indicate that while crop yields increase by 15-40% and soil loss decrease by 2-10% due to various interventions (change in cultivars, improved production technologies, resource conservation practices and increased awareness), these improvements are not sustained due to a variety of reasons - changing rainfall patterns, cultivation of water intensive crops, excessive use of water resources, poor interest of stakeholders in natural resource conservation, and market dynamics. There are indications that benefits from IWM may fail under ongoing climatic changes indicating that treated areas remain vulnerable; this may also be due to several policy issues that encourage indiscriminate use of scarce water resources. There is an urgent need to revisit, review and modify existing policies of agricultural development in the semi-arid rainfed region so that the direct and indirect effects of watershed interventions become climate resilient and stakeholder vulnerability decreases.

1. INTRODUCTION

It is estimated that to maintain food security in India around 377 million tonnes (mt) of food grains are required by 2050 (Amarsinghe *et al.*, 2007). However, productivity trends indicate a decline or static yields in some crops. Even if there is a positive growth rate which may be less than the population growth rate, it is bound to have adverse implications for food security. As in other parts of the world, in India also drylands-degradation-poverty and hunger overlap (Reddy and Reddy, 2002). About 30% of the population in India's degraded semi-arid regions are below the poverty line (Bouma *et al.,* 2007). Rainfed agriculture contributes to 45% of the total food grain production in India and will also be crucial for maintaining food security given the fact that even after realizing the full irrigation potential, about half of the net cultivated area will remain dependent on rainfall (Dehadrai, 2008; Dalai *et al.,* 2014 and Panigrahi *et al.,* 2007). Rainfed areas suffer from a number of bio-physical and socio-economic constraints that directly affect crop, livestock and human population. Land degradation, poor productivity, low level of input use, poor level of technology extension and adoption, acute scarcity of fodder in the summers and ownership of large number of animals as a 'buffer' for hard times are some of the characteristic features of small land owners in the semi-arid region.

Nearly 60% of the net sown area in India is rainfed, which produces 87% of the pulses and coarse cereals, 77% of the oilseeds and 66% of the cotton of the country indicating that rainfed agriculture cannot be ignored (Venkateswarlu and Prasad, 2012). Studies indicate that during the last decade the area under coarse cereal production (which are usually drought tolerant) in India declined by 8% (31 to 28 m ha) while production increased by 20% (Venkateswarlu and Prasad, 2012). Available data indicates that there has been a certain amount of slackness, due to a variety of socio-political reasons, in which there has been an indifferent attitude towards these areas.

2. MATERIALS AND METHODS

In this paper we have attempted to assess the vulnerability of rainfed areas in the Deccan region (covering the states of Karnataka, Tamil Nadu and Andhra Pradesh) to ongoing climatic (mostly rainfall) variations and the challenges faced by farmers in these areas to cope with water stress, in view of the collapse of traditional water harvesting systems and continued over-extraction of groundwater. Finally we emphasize that under the present conditions of unpredictable rainfall situations and unrestricted ground water extraction, the vulnerability of farmers has not decreased and it is necessary that investments on watershed projects be continued which must accommodate activities that will provide protection from climate change impacts by the use of site specific interventions alongwith participatory ground water management, so that they serve their ecological, social and economic functions.

Vulnerability of Rainfed Areas to Climate Change and its Impact

India is one of the most vulnerable countries to climate change (FAO, 2002), with rainfed agriculture being the worst affected. Among different farm categories, small and marginal farmers are more vulnerable since they are totally dependant on agriculture for their livelihood (Conway 2008). Small farmers have nil to little investment capacity for using modern and capital intensive crop practices and soil and water conservation measures (Reddy *et al.,* 2015), and this low productivity-low income-low investment, and high dependence on rainfall is a vicious cycle which continues to operate at the farm-level. There are reports that prolonged low intensity droughts which cause crop failure, results in financial stress and household food insecurity and, force small and marginal farmers to take unsecured loans at high interest rates (Udmale *et al.,* 2014).

Precipitation forecasts for the Deccan under the likely climate change scenarios suggest higher but more variable rainfall, except in the drier parts, where rainfall could decrease. A recent study observed a declining trend in rainfall during the SW monsoon of 1 mm per day per 100 years or 6% in 50 years (Anonymous, 2012). Similarly in the same report, a warming trend in Karnataka has been observed for the period June to September in north interior Karnataka. Average temperatures may rise further by 1.7^{0}C to 2.2^{0}C by the 2030's. A review by Jat *et al.* (2012) covered the experiences of dryland systems in Asia and Africa. Wani *et al.* (2009) reported that, assuming a 3.3^{0}C rise in temperature by the end of this century a 27% and 38% reduction in average yield of sorghum and groundnut may be expected.

In rainfed agriculture climate variability, particularly intra-seasonal variability, is important since soil moisture limitations during crop growth stages will reduce crop yield and thereby increases the risk of crop failure, while in the arid and semi arid areas, higher temperatures will shorten the crop cycle and reduce crop yields (IPCC, 2007). In a recent paper (Kumar *et al.,* 2016) the authors estimated the vulnerability of the state of Karnataka to climate change impacts and reported that 70% of the cultivated area of the state was extremely to highly vulnerable to climate change.

Crop failure is very common because of low to moderate levels of drought in rainfed areas. Rockstrom and Falkenmark (2000) reported that even a decrease of one standard deviation from the mean annual rainfall often leads to a complete loss of the crop. Dry spells of 2-4 weeks with no rainfall during critical crop growth stages causes partial or complete crop failures almost every cropping season (Sharma *et al.,* 2010) in rainfed areas. It has been observed that the frequency of 'below-normal rainfall' in arid, semi-arid and sub-humid regions is 54 to 57%, and severe droughts occurred once in every eight to nine years in the arid and semi-arid areas of the Southern India.

An example of the high spatial variability in rainfall is indicated in one district from Karnataka, Chitradurga, which has a dubious distinction of having frequent droughts. In a recent report, this district has been ranked at serial number 22 (out of 499 districts), indicating a high prioritization for development of rainfed areas (NRAA, 2012). Mondal *et al.* (2014) estimated the SPI (Standardized Precipitation Index) values for 36 years rainfall data (1971-2009) for Chitradurga district in Karnataka, which shows that the value was negative for 56% of cases and 3 years *viz.*, 2004, 2005 and 2006 experienced moderate to severe drought with the values being less than -1 (Fig. 1).

Animal husbandry in the semi-arid region is an important multi-purpose component of farming (Challinor *et al.*, 2007) and livestock plays an important role in drought prone area particularly dairying (Gururaj *et al.*, 2015) for small farmers, since livestock production is less susceptible to variations in rainfall and other climatic factors (Biradar and

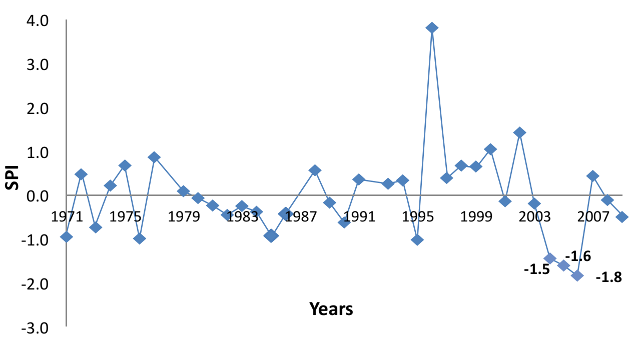

Fig. 1. Annual SPI values for 36 years rainfall at Chitradurga district

Sridhar, 2006). Droughts and rainfall variability can trigger periods of severe feed scarcity, especially in dry land areas, which can have devastating effects on livestock populations (Thornton *et al.*, 2014). Thus, marginal and small farmers are affected by climatic aberrations in two ways-low to nil agricultural produce from their holdings and poor productivity (milk and meat) of domesticated animals.

Status of Groundwater in the Deccan Region

Since rainfall occurrence in the Deccan region is low (500-700 mm year^{-1}), agricultural production has increased at the cost of ground water extraction. Between 1970 and 1994, the area under groundwater irrigation became more than doubled (Shah, 2002). By 2002, this has increased by 3.5 times while the area under canal irrigation increased by 1.5 times (Reddy, 2006). The dramatic expansion in the use of groundwater can be attributed to the fact that inherent risk of recurrent droughts in the dry zones and supportive policies for smallholder irrigation has led to increase in groundwater utilization. However, excessive extraction without sufficient investment in re-charging facilities has resulted in rapid and wide spread depletion. Depleting groundwater resources had been manifested in the increased costs of drilling and water extraction. Some studies indicate that up to 50% of wells once in use have completely dried-up (Reddy, 2005).

Recent estimates show that Net Groundwater Availability (NGA) is 30.76, 15.30 and 20.65 Billion Cubic Meters (BCM) in Andhra Pradesh, Karnataka and Tamil Nadu (all three states are highly dependent on groundwater). In Andhra Pradesh and Tamil Nadu, a decline of NGA to the tune of 6.65 and 0.6%, respectively, was reported in the last half decade (Table 1). Contrarily, an increase to the tune of 3.31%

Table: 1
Groundwater (BCM) status in three states of the Deccan

Particulars	Andhra Pradesh		Karnataka		Tamil Nadu	
	2004	2009	2004	2009	2004	2009
A. Annual replenishable groundwater resources	36.50	33.83	18.81	15.93	23.07	22.94
B. Net Groundwater Availability	32.95	30.76	14.81	15.30	20.76	20.65
C. Irrigation	13.88	12.61	6.01	9.75	16.77	14.71
D. Domestic and Industrial uses	1.02	1.54	1.00	0.97	0.88	1.85
E. Annual Groundwater Draft Total (C+D)	14.90	14.15	10.01	10.71	17.65	16.56
F. Net Annual Ground Water Availability for future irrigation development	17.65	15.89	6.18	6.48	3.08	4.70
G. Stage of Groundwater Development (%)	45	46	68	70	85	80

BCM - billion cubic meters; Source: CGWB (2006 and 2011)

NGA was observed in Karnataka, however, groundwater consumption (for irrigation purposes) has increased by 62.23% in the same period (*i.e.* 2004 to 2005). The Stage of Groundwater Development (SGD) is 46, 70 and 80% in Andhra Pradesh, Karnataka and Tamil Nadu, respectively, out of which Karnataka and Tamil Nadu are unsafe (SGD > 70%, Shankar *et al.*, 2011). In the last one and half decade, the percentage of unsafe districts has increased tremendously and around 27, 42 and 40% of districts in Andhra Pradesh, Karnataka and Tamil Nadu, respectively are unsafe (Table 2). The situation indicates that the natural buffer of groundwater availability in the region for use in periods of low rainfall or near- drought situations is already in a critical stage and there is very little option available to rely on this resource for either agriculture or meeting drinking water requirements in the future.

Watershed Development in the Deccan and Groundwater Exploitation

India has adopted integrated watershed management as a viable strategy for improving productivity in drought-prone and water-scarce areas (Farrington *et al.*, 1999). In the 11th Plan (2007-12) nearly 0.1 m ha was treated at a cost of US $ 478 million (₹ 3059.56 crores) and another 7.021 m ha is still left to be treated. It has been estimated (Sharda *et al.*, 2008) that an area of 4.33, 6.19 and 2.83 m ha in the states of Karnataka, Andhra Pradesh and Tamil Nadu, respectively have been treated till March 2007 at a cost (in million ₹) of 117, 222 and 122, in the same sequence. But the economic and environmental impacts of the program and the sustainability of the interventions have recently been questioned (Joshi *et al.*, 2004[a], 2004[b] and Reddy *et al.*, 2007). In an interesting article by Samra and Sharma (2009) the authors commented that even after spending nearly ₹ 192,510 million (US $ 4500 million) for watershed development, the results have not been very 'visible' and in many cases the entire watershed had reverted back to its pre-project phase, due to lack of focus on sustainable livelihood opportunities, absence of interest by communities in natural resource conservation and missing links on issues of sustainability of production systems.

Table: 2
Percent of unsafe (SGD>70%) districts in three Deccan states

Year	Andhra Pradesh	Karnataka	Tamil Nadu
1995	0	5	29
2009	27	47	69

The impacts of watershed interventions are directly linked to increased groundwater availability for irrigation (Joshi *et al.*, 2004[b]), making groundwater management one of the key issues for the success and sustainability of watershed programs in the dry zones. However, since watersheds are inhabited by a diverse group of farmers with fragmented land holding patterns and resource use rights (Kerr, 2001 and Joshi *et al.*, 2004[a]), so inherent diversity in social and bio-physical attributes within watersheds often becomes a hurdle for collective decision and action. We attempted to analyse the impact of a few watershed projects in the semi-arid region on ground water exploitation and the changes that occurred after implementation of watershed projects. In a study by Rao *et al.* (1993) it was reported that while watershed development led to a 100% reduction in runoff and improved ground water levels, it also led to a 36% increase in area under assured irrigation that increased crop yields by 69%. Shivamurthy *et al.* (2006) reported from Karnataka, that the net irrigated area increased by 26% and yield of water from wells increased by 70%. As a consequence, the area devoted to water intensive crops like paddy and sugarcane increased from 33 acres to 114 acres while it declined in areas outside the watershed. They also reported inequity in access to groundwater, with 15% farmers having access to 25% of the ground water.

In another study in K.D. Pally watershed (Adhikari *et al.*, 2012) in Ananthapur district of Andhra Pradesh, the average irrigated area increased to 106.5 ha in the post-project period (2005 to 2008) as compared to 37.2 ha in pre-project period. Correspondingly, the average groundwater draft increased to 68.2 ha m. Out of this, 53.9 ha m of irrigation water was met by direct rainfall and natural recharge plus recharge due to existing WHS in the vicinity. In addition, six more water harvesting structures, constructed in the post-project period, have created a potential recharge of 4.5 ha m. Yet, there is an average deficit of ground water (9.77 ha m) (Table 3). This over exploitation was 99% (14.5 ha m) higher in 'below normal' rainfall year (2006) when compared to 3.2 to 7.2 ha m in normal years (2005-2008). Nevertheless, it appears that the contribution of these WHS is not able to cope up with the ever increasing groundwater exploitation. This is evident from the increase in well intensity which increased from 1 bore well/km^2 (1985-2000) to 3 bore wells/km^2 during 2000-03 and 5 borewells/km^2 during 2005-08 (in post-project) in the watershed. The number of wells has tripled (from 13 in 2000 to 41 in 2008; Table 4). As a consequence, the depth of bore wells has increased from 30 m in 1995-2000 to 106 m in 2004. This trend *viz.*, increase in well intensity and deepening of bores, has had an adverse effect on the functioning of old open wells and also sub-surface inflows into water bodies. Eighteen open wells (of average depth of 15 m) existing since 1975 have dried up post-2006 due to the indiscriminate drilling of bore wells. Further, failure rate of the bore wells commissioned since 2000 was three out of one successful bore well and resulted in increasing the financial liability of the farmer.

More recently in another watershed (Netranahalli) in the Chitradurga district, the number of bore wells were enumerated and compared with the pre-project status (unpublished data, Table 5). There was an increase of 320% in the number of bore wells but continued poor rainfall years for the last three years has forced many farmers to go in for drilling of new tube wells, with a large number of failures. Rainfall during 2008 to 2013 was 277, 773.8, 861.2, 338.5 and 458.9, respectively, averaging 453.3 mm which is just at par with the long term average, but this did not help in reducing the demand for water, since a bulk of rainfall is received in 31 rainy days. Rainfall during the study period (except 2009 and 2010) was poorly distributed and near drought conditions forced many farmers to dig more and more wells with the hope of getting water. The depth of the water table has now increased to 200-240 feet and the cost of each well is approximately ₹ 0.65 lakhs. These 'failed' investments have forced many farmers into debt trap for loans taken for digging the well and for cultivating 'commercial' crops like Bt. Cotton, hybrid maize (corn) and paddy (rice).

Table: 5
Changes in number of borewells in Netranahalli watershed over a 6 year period

	2008 (Pre-project)	2014 (Post-project)	% increase
No. of borewells existing	250	1050	320
No. of borewells functonal	122	235	92.62
Percentof failed borewells	51.2	77.6	

Table: 3
Increase in groundwater use for irrigation with time at K.D. Pally watershed

Period (years)	Irrigated area ha	Irrigation quantity required ha m	Water availability* ha m	Over exploitation ha m	% of excess exploitation in low rainfall year over a normal year (%)
Pre-project	37.2	21.42	53.94	0	
Post-project					
2005	96.4	61.64	58.41	3.23	
2006	113.5	72.74	58.27	14.47	99.8
2007	113.3	72.55	58.40	14.15	
2008	102.9	65.76	58.52	7.24	
Av. of Post-project	106.5	68.17	58.40	9.77	

**Sources of water availability includes rainfall, natural recharge and recharge from WHS both within and outside the watershed*

Table: 4
Increase in bore well intensity in the K.D. Pally watershed

Period	Year	No. of additional bore wells	Cumulative number of bore wells	Bore well intensity (nos./sq.km)
Pre-project	Before 1985	3	3	Negligible
Pre-project	1985-90	2	5	Negligible
Pre-project	1990-95	1	6	Negligible
Pre-project	1995-2000	3	9	1
Pre-project	2000-01	4	13	2
Pre-project	2001-02	6	19	2
Pre-project	2002-03	10	29	3
Post-project	2005-08	12	41	5

Similarly in the Ramsagar watershed in the Chitradurga district, there were 47 bore wells irrigating 74 ha including supplemental irrigated area in the pre-project period. The year-wise increase in bore wells and irrigated area is presented in Table 6. The number of wells increased from 47 (2008-09) to 66 (2013-14) and the irrigated area has almost doubled (154 ha) in the post project period from only 74 ha in the pre-project year (2008-09). The cropping pattern has also changed in favour of dry-cum-wet crops with lesser water requirement by crops such as maize, onion, red gram, chilli, sorghum, sunflower and *bajra*. The command area per well in pre-project was 1.6 ha while it ranges from 1.4 to 2.3 ha in the post-project period, depending on the rainfall received which indirectly re-charges ground water.

In a recent paper by Grewal (2016), it was reported that construction of 15 earthen dams and levelling of 85 ha of wastelands led to increase in water harvesting but also led to significant increase in number of tubewells (2 to 128 no.'s) which led to a decline in watertable by 3.6 m and change in cropping patterns. The above conditions suggests that there is an urgent need to take up measures for controlling groundwater recharge and exploitation simultaneously and guidelines issued for groundwater exploitation must be strictly implemented. The groundwater in deep aquifers, that is supposedly meant for meeting drinking water requirements in lean years, should not be drawn.

Prevailing market conditions influence land use and agricultural decision making which may end up with indifference towards rainfed farming. In a simple analysis of trends of the cultivation of coarse cereals and minor millets in the states of Andhra Pradesh and Karnataka, there was a clear trend of a decline in areas earlier used for the cultivation of crops that were climate resilient and could be grown with little inputs and still provide enough for the grower to survive. In 2000, the area under traditional crops (*bajra*, *jowar*, *ragi*, groundnut, niger and safflower) was around 22.8 and 31.3 m ha (TE 2000) in Andhra Pradesh and Karnataka, which has now reduced to 15.8 and 22.1 m ha (TE 2011), respectively (Indiastat, 2014). It means that the area under traditional crops, which are also less water 'demanding' crops, is declining at an annual rate of 2.73 and 2.40% in Andhra Pradesh and Karnataka, respectively. More precisely, every year around 0.54 and 0.64 m ha area under these crops is being replaced by high value and water intensive crops such as rice, maize and cotton etc. (Fig. 2).

Surface Water Harvesting Structures in the Deccan and their Present Status

Tanks as an important source of irrigation have lost their importance over the last three decades in both Karnataka and Andhra Pradesh. The total area (m ha) irrigated by canals increased from 9.2 to 15 in 60 years while the area irrigated from tanks decreased from 4.2 m ha to just 1.9 m ha in the same period (Fig. 3). But during this period, the area irrigated by wells increased by a whopping 80.35% (from 6.6 to 33.6 m ha; Fig. 4).

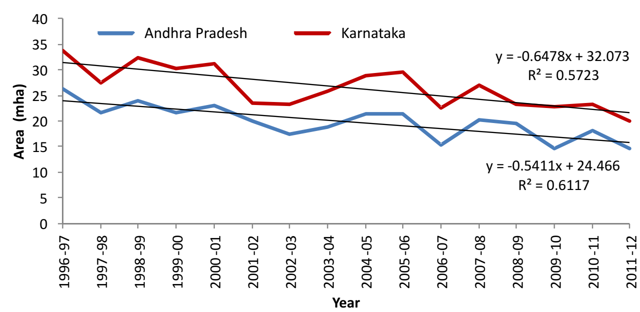

Fig. 2. Declining area under traditional crops in the Deccan region

Table: 6
Increase in number of bore wells and irrigated area in the Ramsagar watershed

Year	No. of working bore wells	% increase of bore wells over pre-project period	Irrigated area (ha) including supplemental irrigation	% increase of irrigated area over pre-project	Command area (ha/well)
Pre-Project					
2008-09	47		72.0		1.6
Post-project					
2009-10	55	17.0	78.30	8.4	1.4
2010-11	62	31.9	109.29	51.4	1.8
2011-12	67	42.6	120.11	66.4	1.8
2012-13	75	59.6	147.98	105.0	2.0
2013-14	66	40.4	154.00	113.0	2.3

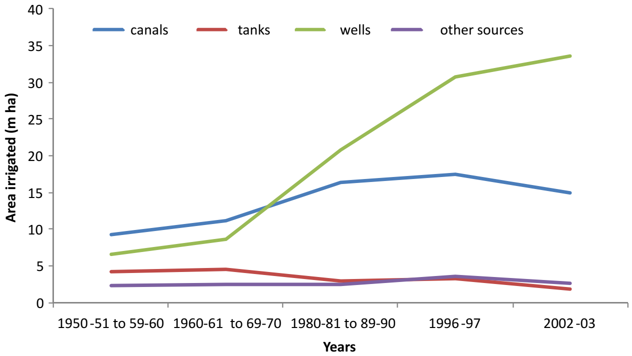

Fig. 3. Trends of changes in sources of irrigation and area irrigated in India over different periods of time
(Source: Indian Agric. Statistics, Vol. I, MoA, GoI)

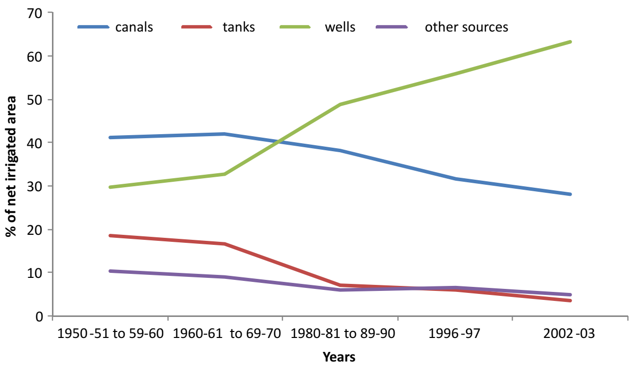

Fig. 4. Trends of changes in % net area irrigated in India from various sources over different periods of time
(Source: Indian Agric. Statistics, Vol. I, MoA, GoI)

The proportion of area irrigated from tanks has declined (Fig. 5) from 39% in 1955 to 14% during 2005. Existing tanks perform far below their capacity level and the gap between the irrigation potential created and actually irrigated has been reported to be 40-60% depending on the rainfall received during the year. According to the 2nd minor irrigation census of 2005, it was reported that 29,187 tanks were not in use in AP. In Karnataka also the situation is grim, in spite of having 36,672 tanks, with a declining trend of irrigation being done in only 2.40 lakh ha (35% of the total potential irrigated area). The situation is a matter of concern since most of the area in these two states surface water harvesting had been hugely popular because of the underlying geological features that permit water retention in ponds and tanks for a long time. The role of groundwater in expansion of irrigated area can be realized from the fact that in the last one and a half decade, there has been an increase in irrigated area by 1.97 m ha, out of which 96% is only from groundwater. During the same period, the area irrigated from traditional sources of irrigation (tanks and others) has reduced by 0.96 m ha.

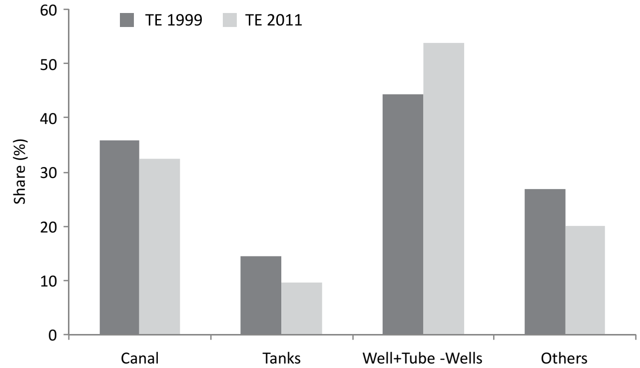

Fig. 5. Trends of change in sources of irrigation in three states of the Deccan

Consequently, the share of groundwater in irrigation has gone up by 10%, while the share of canals, tanks and others have fallen by 4, 6 and 10%, respectively (Indiastat, 2014).

However, inspite of the presence of a large number of tanks and water harvesting mechanisms, the situation on the ground is a matter of concern. In a recent study conducted in some districts of Karnataka and AP on the status of community owned water resources, it was observed (Table 7) that the capacity of these tanks has been greatly reduced; silt accumulation and broken embankments are widespread problems. The maintenance was poor, with choked-up inlet channels, change in land use of the contributing areas and even construction of houses in the dried up tank bed by encroachment. The tanks, if they function at all, are used as percolation tanks in most villages. Access to private source of irrigation (wells) has therefore become a disincentive to farmers for non-cooperation in the collective action for tank and channel upkeep. Further, famers are of the view that the state has not shown any interest in - (a) associating them in taking steps to maintain the tanks (b) collecting user fees (c) deputing staff to inspect the tanks before the cropping season (d) failure in carrying out annual maintenance. When supply is constrained, improved and community driven demand management practices that also include water-saving technologies, participatory ground water management, policy and institutional reforms are needed to create incentives for *in-situ* water conservation.

Making Stakeholders Climate Resilient - The Way Forward

Climate change is now considered inevitable and has begun to manifest itself in many ways. Developing

Table: 7
Silt accumulation and reduction of storage capacity in some selected water storage tanks in two states of the Deccan

S.No.	Name of tank	Catchment area (ha)	Water spread (ha)	Storage capacity (ha m)	Range of silt accumulation (ha m)		% reduction of storage capacity	
					Min.	Max	Min.	Max.
	Karnataka							
1	Appenahalli *kere*	1739	39	178.29	5.2	10.4	3	6
2	Rayapura *kere*	2040	70	127.35	6.1	12.2	10	20
3	Gandabommana halli	19940	178	796.9	35.8	71.6	5	10
4	Sasawada *kere*	3810	75	88.15	11.43	22.86	13	26
5	Nagalapura *kere*	797	29.72	48.79	2.4	4.8	5	10
	Andhra Pradesh							
6	Dodagatta MI tank	10723	140.2	201.9	32.2	64.4	16	32
7	Malliketti MI tank	12005	80.94	131.2	36	72	27	54
8	Godisalapalli tank	2590	32.19	57.2	7.77	15.54	13	26
9	Madanahalli	2838	32.95	32	8.5	17	16	32
10	Shreedharagatta tank	7688	82.18	150.2	23.1	46.2	15	30

Source: Unpublished data

countries are more vulnerable due to a variety of factors that encompass bio-physical, socio-economic, technological, policy and political issues. There has been a declining trend in public investment in agriculture in India but a continuous increase in agricultural subsidies (Nin-Pratt *et al.*, 2010). The total amount of subsidy to agriculture has increased from US $ 7.93 billion in 2000-01 to US $ 24.33 billion in 2013-14. During the same period, fertilizer and food subsidies have grown up by 5 and 7.5 times, respectively. In spite of having achieved food self-sufficiency in the country, minor aberrations in rainfall distribution and timing has been noticed to cause serious economical and political turmoil, as has been observed in the past few years.

Integrated watershed projects have provided significant benefits in terms of natural resource conservation, production enhancement, augmentation of water supplies and a general trend of diversification towards cropping practices that are water 'demanding' due to a preconceived notion that these projects result in increased water availability. Existing policies (of unlimited subsidy) which have become distorted, are detrimental to equity and for the livelihoods of the poor than incentive-based policies that enhance equity and sustainability of water and groundwater use. The long-term benefits from sustainable use of groundwater are likely to be much higher than unregulated depletion that will foreclose future possibilities, and further increase vulnerability of rural poor to droughts and other shocks. Under the existing situation of decreasing water availability, increased diversification skewed towards water demanding crops and increasing uncertainty of rainfall, it is difficult to continue with the existing production levels, if urgent steps to reduce water consumption in the hard rock regions are not taken immediately.

Changing patterns of rainfall and runoff are expected to significantly impact groundwater recharge and availability, adding a further dimension of uncertainty to this critical resource. Conjunctive use and participatory management of groundwater and surface water can be a key adaptation strategy in such situations. The role of groundwater in sustaining production and livelihoods in the drylands during times of crisis would therefore become even more important and there is a need to create a people's movement for using and managing groundwater.

While agricultural production continues to diversify, cereals will continue to be important due to the National Food Security bill (Kadiyala *et al.*, 2012). This is also necessary due to recent reports of an increasing number of children being under nourished. There is therefore, a need to re-look into the practise of diversifying at the cost of excessive water consumption and deprive resource poor farmers of the much needed water during times of crisis. The rainfed Deccan region, home to drought resilient crops, has the potential to provide food security from a diverse range of pulses, coarse cereals and oilseeds and it is the cultivation of these crops that need to be popularized in the region, so as to provide a buffer for dry conditions. This needs to be pushed forward by dovetailing technological interventions with market dynamics and providing incentives to producers to grow crops which are climate resilient (oilseeds and pulses). This needs to be combined with practices like micro-irrigation, sprinkler irrigation and *in-situ* moisture conservation practices that can provide moderate insulation from climatic vagaries. Social equity and inclusiveness should be the pillars on which Indian agriculture should progress to meet the future and not on a skewed trajectory which benefits only the resource rich land owners.

3. CONCLUSIONS

Integrated watershed projects usually lead to increase in surface water availability and enhanced ground water recharge. But this often leads increased extraction and inequity in distribution, leaving small and marginal farmers vulnerable to disturbances in precipitation patterns. There is an urgent need to adopt practices like participatory ground water management, do away with subsidies that led to over extraction and cultivate crops that are resilient to climatic aberrations.

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