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Exploring agro-ecological bases of contemporary water management innovations (CWMIs) and their outscaling

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ABSTRACT

Innovations related to judicious use of scarce water resources evolved by farmers and refined by non-formal researchers termed as Contemporary Water Management Innovations (CWMIs) are now being practiced in drylands by majority of farmers in India for human and crop survival during water crisis. The study was carried out during 2017–18 in purposively selected villages of Ananthapur district of Andhra Pradesh. A sample of 120 (farmers) and 30 (mixed group of scientist's, NGOs activist and other experts) were selected randomly on the basis of the presence of and association with functional water sharing groups (WSGs). For critical analysis, a combination of focused group discussions, case study and Delphi technique accompanied by knowledge index, adoption index, multiple regression, correlation and factor analysis were used. It was found that only 20 users owned bore wells and shared with 100 farmers who did not own any bore wells. CWMI were well accepted and integrated into the culture of the dryland farmers as they comprehensively understood the agro-ecological bases for their survival and sustenance in dry land areas. 14 factors were deduced for agro ecological crises, Majority (63.33%) of farmers possessed high level of knowledge about the agro-ecological reasons behind the CWMIs and 60.83% of farmers had high (70–86%) extent of adoption of all the CWMIs and 65.8% of farmers had adopted 12 out of the 14 different practices. Need for synergy and convergence among researchers, administrations, line departments, NGOs, extension system were felt as the facilitative factors for diffusing CWMIs.

Keywords: Agro-ecological bases CWMI, Delphi technique, Dryland agro-ecosystem, Factor analysis

The major challenges in the era of global environmental problems are climate change, increasing population and natural resource degradation including soil degradation and biodiversity loss (Singh *et al.* 2017). Dryland regions experiences severe cases of agro-ecological crisis due to erratic rainfall patterns and depleting ground water resources in India. Ground water crisis accounts for 60% of the irrigated areas in the country and critical to food security (Gandhi and Namboodiri 2009). Among Indian states, about 100 districts are drought prone and face acute water scarcity during crop growth periods, Andhra Pradesh stands apart. One of the most drought prone districts, Ananthapur receives very scanty rainfall with a mean of 568.5 mm annually, way below the average for the state (Anonymous 2020).The crisis in farming sector has increased in the last two decades resulting large tracts of farm lands under severe ecological problems due to high levels of water scarcity, both from rainfall and ground water resources, leading to agro-ecological crisis (Jha 2018). Storage and exploitation infrastructure dearth and inappropriate water management mean that only 18–20% of the water is actually used (Dhawan 2017). Rain water management by farmers of dryland agro-ecosystem assumes great significance in surviving water crisis that is looming large in dryland regions of India. Here, comes the role of CWMIs being practiced by large number of farmers in drylands with promising results. Agro-ecology emphasizes the capability of local communities to innovate, evaluate and adapt them through farmer-to-farmer research and grassroots extension approaches (Altieri 2002). These innovations are driven by scientific problem-solving approaches, agro-ecological concepts and principles, as such understanding the sustainability of an agro-ecosystem is essential for generating innovations. Innovations are evolved through the traditional wisdom and ITKs of the farmers with years of their experiences of survival in the particular agro-ecosystems termed as CWMIs. These innovations are essentially indigenous in nature; most of them have been tested and refined by few interested researchers, informal water technologists and water experts from NGO and farmers. The study explored the causes of agro-ecological crises and the scientific explanations behind agro-ecological bases of CWMIs for their outscaling.

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MATERIALS AND METHODS

The study was carried out during 2017–18 in 8 villages of 3 Mandals in Ananthapur district of Andhra Pradesh. The villages were selected purposively ensuring the presence of functional water sharing groups. A sample of 120 farmers was selected randomly from these selected villages. Focused group discussions, personal interviews, case study and Delphi technique accompanied by factor analysis, multiple regression, correlation, knowledge index and adoption index were used for data collection and analysis. A sample of 30 (mixed group) scientists, NGOs activists and other experts were also interviewed to enlist constraints and suggestions in diffusing these CWMIs in similar agro-ecological conditions. Focused group discussion and personal interview was conducted as per the qualitative procedure developed by Nyumba *et al.* (2018). The step-by-step procedure for documentation in case study approach was followed as suggested by Phondej (2011) and Rashid (2019). A standardized knowledge test was developed to measure the level of knowledge of farmers about CWMIs taking into consideration the procedures adopted by Sulaiman (1989), Bonny (1991) and Sushama (1993). The knowledge index was calculated as:

$$\text{Knowledge Index} = \frac{\text{Obtained score}}{\text{Obtainable score}} \times 100$$

Extent of adoption of CWMIs developed by Sharma, 2002 was used. Adoption was measured on three-point continuum, viz. full, partial and not at all with numerical scores of 3, 2 and 1, respectively. The average score for a given CWMIs was obtained using the adoption index as:

$$\text{Adoption Index} = \frac{\text{Obtained score}}{\text{Obtainable score}} \times 100$$

The Delphi procedure consisted of a series of steps undertaken to elicit and refine the perspectives of a group of people who were either experts in the area of focus or representative of the target group (Rothwell and Kazanus 1997). The procedure developed by Delbecq *et al.* 1975 was followed. This process of synthesizing data and refining the questionnaire continued until there was a convergence of perspectives among participants as suggested by Lang (1998).

RESULTS AND DISCUSSION

Profile of the respondents: Majority (60.8%) were between primary and higher education levels, middle aged (39.16%), more than 20 years of experiences (66.8%) and middle sized family (71.7%). 51.66% of farmers were small farmers and the small farmers possessed irrigated as well as dryland and small orchard of >1 ha. Majority of the farmers (64%) were earning moderate levels of annual income (between ₹51000 and ₹90000). Majority of the farmers had frequent contact with friends and relative (91.67%), most often contacted NGO activists for information (70 %), low in goal commitment (42.5%) moderate on social capital (69.17%) and moderate on adherence to social norms (61.7%).

Major causes of agro ecological crisis

Factor 1: Early withdrawal of monsoons
Factor 2: Lack of contingency crop-water planning
Factor 3: Long dry spells leading to drought
Factor 4: Neglect of pro-active intervention
Factor 5: Over exploitation of ground water resources without any replenishment
Factor 6: Soil moisture stress due to lack of field ponds
Factor 7: Depletion of soil moisture
Factor 8: Loss in soil structure due to monoculture and chemicals leading to nutrient imbalances in soil
Factor 9: Loss of fertile top soil due to erosion
Factor 10: Ill effects of agro-chemicals on soil structure
Factor 11: Destruction of agro-ecological aspects of crop fields
Factor 12: Neglect of crop residue incorporation in farm fields
Factor 13: Non-supportive and exploitative market prices and market forces
Factor 14: Destabilizing ecological balance in nature

Catagorisation of the documented CWMIs in study area

Major category	Water harvesting	Water saving	Micro-irrigation	Conservation Agronomic practices	Water Sharing Institutional Innovations
Innovations practiced	Recharge pits (material-stones, sand layer) Slug test (water table measuring test) Soaking pits De-silting (farm ponds, water tanks, reservoirs, deep open well) Stone layering (stone pellets) Deep trenches across slope	Renovated farm pond (water harvested after renovation) Renovated bund of water body (water harvested after renovation) Surface water saving Ground water saving	Drip irrigation Sprinkler irrigation	Soil mulching Intercultural operation (sowing in line) Mixed cropping Intercropping	Social regulatory programmes (SRPs) Water sharing groups (WSGs)

Causes of Agro-ecological crisis faced by farmers of Dryland agro-ecosystem: A list of causes was prepared through focused group discussion, categorized into different sets of causes related to; erratic rainfall, depleting ground water, depleting soil moisture, declining soil fertility, conservative agronomic practices and other causes related to adverse market prices, deteriorating agro forestry and agro-ecological balance in nature. Then farmers' perception of severity of these causes was sought on a three-point continuum of more severe, severe and least severe. At first, the causes were screened by deleting the causes which had mean scores less than 2.5, two to three factors were derived from each set of causes through factor analysis. These factors were given a new name as the major cause being represented by the sub causes.

Finally, 14 major cause-factors emerged through factor analysis of 31 causes perceived as most important from the initial list of 56 causes collected from focused group discussion.

Contemporary Water Management Innovations (CWMI): In total five major types of CWMIs being practiced were observed.

The case analysis reflected that all the farmers in the water users group had a strong belief in their group effort and were thoroughly convinced about the efficacy of rain water harvesting, storing and sharing for the benefits of all the dryland farmers. They seem to be highly empowered. Intervention of the NGO *Annadata* happened at the most opportune time and their staff started mobilizing people for group actions. At first farmers were skeptical, hesitant and reluctant to join hands. Through several meetings and discussions, farmers were apprised of the changes happening in the village due to global climate change and rains becoming quite unpredictable and erratic. But once the water sharing group got initiated results got realized in the first crop season itself with assured crop harvests for every member's family. Farmers could get lifesaving irrigation at critical stages of crop. They were saved from worries and misery and were quite happy as all the farmers could fetch good returns from farming. Farmers started appreciating the value of rain water, promoted water harvesting in the village through collecting water in tanks, increasing percolation of rain water through digging deep trenches across the slope of their lands, summer ploughing to keep the fields ready for water absorption and percolation, reducing run off and erosion of top fertile soil.

Knowledge of Agro-ecological bases of CWMIs: Water management strategies that support agricultural intensification across agro-ecological zones and hydrologic basins are required for building resilient agrarian communities (Cofie *et al.* 2015). All the farmers shared the agro-ecological principles and rationale behind the community participation and community management of common property resources of rain water through rain water harvesting, saving, sharing and using judiciously through micro-irrigation systems. All the farmers have comprehensively followed the agro-ecology behind hydrological cycle of water harvesting and water saving for future contingencies. The knowledge levels of agro-ecological principles and hydrological cycle were very high among the majority of farmers.

Mean knowledge index score of farmer respondents was 90.67. This means that the farmers had very high level of knowledge on water sharing processes. The standard deviation was 3.06 indicating very high consistency among the farmers. The scores ranged from 80.77–96.15 out of a total of 100. Majority (63.33%) of farmers possessed high level of knowledge about the agro-ecological reasons behind the CWMIs. The frequency distribution of farmers on their level of knowledge appeared to be highly skewed towards higher scores of knowledge on agro-ecological bases of CWMIs. In the context of technology, micro-irrigation (MI; drip and sprinkler systems) has the potential to address problems like water scarcity and emission of greenhouse gases from agriculture (Suresh *et al.* 2020). After farmers have understood the agro-ecological bases of CWMIs

Table 1 Distribution of farmer respondents on Knowledge Index and Extend of Adoption of Respondents on water management innovations

Knowledge index of respondent	n=120		Extent of adoption of water management innovations	n=120	
Mean	90.67		Mean	78.63	
Standard Deviation	3.06		Standard Deviation	8.07	
Range	80.77 – 96.15		Range	55.21-90.62	
Frequency distribution	*Frequency*	*Percent*	*Frequency Distribution*	*Frequency*	*Percent*
Low (<87.61)	12	14.40	Very Low (<62.29)	2	1.7
Medium (87.61 - 93.73)	10	12.00	Low (62.29-70.36)	14	11.67
High (>93.73)	76	63.33	Medium (70.36-86.5)	73	60.83
Total	120	100.00	High (86.5-94.57)	31	25.83
			Very high (>94.57)	0	0.0
			Total	120	100.00

Table 2 Constraints and suggestions in the way of diffusing CWMIs

Constraints faced by farmers	Median value	Q1	Q3	IQR	QD	Remark
Constraints						
The formal research organizations in agriculture and water science and technology do not have the inclination and drive to take up large scale longitudinal research studies to evolve new technologies on rain water harvesting and rain water use efficiency.	5	5	5	0	0	HH
Non availability of research based information on rain water harvesting, rain water use through micro-irrigation among members of water user groups.	4	3	4	1	.5	HH
Lack of government support for research programme for large scale rain water harvesting, ground water aquifer recharge and water sharing groups of farmers.	3	3	4	2	1	MH
Socio-political dynamics of dominance, social exclusion of resource-poor and dalits from water sharing group of farmers.	4	4	4	0	0	HH
Neglect of traditional wisdom, and existing water conservation structures had leading to erosion of indigenous knowledge and social capital of villages	5	4	5	1	.5	HH
Lack of conviction, initiative and faith in people's participation of farmers in the efficacy of water management innovations forming, water user groups and their accountability.	5	5	5	0	0	HH
Non-co-operation of bore well owners and other people to work together for the social benefit of all villagers.	4	3	4	1	.5	HH
Lack of policy framework and innovative social regulation programme for managing ground water resources and judicious use of rain water and ground water resources.	3	3	4	2	1	MH
No guidelines with District administration for reward and punishment for encouraging community level water harvesting and sharing.	5	5	5	0	0	HH
Suggestions for extension strategies						
Empirical data on designing, running social institutions for social learning on rain water use	5	5	5	0	0	HH
Project of longitudinal agro-ecological studies for assessing rain water harvesting and rain water use efficiency on villages and watersheds through convergence approach	4	3	4	1	.5	HH
Creating awareness and devising action plans for motivating and mobilizing farmers for community level rain water harvesting and sharing travel workshops in the drought-hit villages.	3	3	4	2	1	MH
Developing extension literature on agro-ecological rationale behind contemporary water management innovations	4	4	4	0	0	HH
Special course on agro-ecology concepts and principles of cyclical complementarities in agro-eco systems at graduate level	5	4	5	1	.5	HH
Encouraging conviction of profitable production under deficit irrigation for among dryland farmers through study tours to innovative farmers showing	4	3	4	1	.5	HH
Development of Group extension methodologies at block level for convergence of all line departments for mobilizing dryland farmers for efficient rain water, and ground water management.	4	4	4	0	0	HH
Need for evolving Administrative guidelines for rain water harvesting aquifer recharge and ground water use for all drought-hit districts	5	5	5	0	0	HH
Development of model training unit for saving and sharing through sprinklers and drip irrigation systems at KVKs level in drought-hit districts and in arid and semi-arid areas	3	3	4	2	1	MH

**HH-high consensus with high importance, MH-medium consensus with high importance.*

comprehensively they begin to adopt the CWMIs to mitigate the dryland situation in the research area.

Data depicts that about 60.83% of farmers had high (70–86%) extent of adoption of all the CWMIs (Table 1). With respect to water harvesting innovations, about 65.8% of farmers had adopted 12 out of the 14 different practices, indicating a very high extent of adoption among farmers. Majority of farmers were adopting water harvesting innovations from moderate to high levels. Similar results were reported by Namara *et al.* (2007) where it was found that majority of the current adopters of low-cost micro-irrigation systems were the better-off farmers and the most important determinants of micro-irrigation adoption included access to groundwater, cropping pattern, high annual income cash and level of education of the farmers. The results are in consonance with Rao *et al.* (2018) where they found that there were remarkable changes in the livelihood, cultivated area and crop production under rainfed conditions with critical irrigation. Water being central to sustainable agricultural intensification, directly affects several dimensions of sustainability, including social, economic, health, and environmental aspects (Connor, 2015). Frequent occurrences of droughts and heavy rains and floods affect the livelihoods of rural households in dryland areas with limited irrigation facilities (Pani *et al*. 2019).Water conservation and cutting down on wastage holds the key to bring irrigation facilities to every farm in the country (Kumar 2018). In order to diffuse CWMIs among farmers in similar dryland agro-ecosystems, opinions were sought from experts and their consensus was achieved through Delphi technique.

The results (Table 2) shows that the most important constraints turned out to be lack of longitudinal research studies on evolving technologies for efficient rain water harvesting followed by non-availability of empirical information on rain water harvesting, rain water use through micro-irrigation is available, and lack of motivation on social institutions, community mobilization for managing common property resources. In fact, these water management innovations demand participation by all the farmers as harvesting rain water requires group actions by all in a concerted manner. The study get supported by Narayana moorthy (2007) who found that the major problems are the lower precipitation for decline in tank irrigation and decrease in tank irrigation has increased costs of cultivation for the land constrained farmers.

The final suggestions came after analysis to formulate extension strategies for diffusion of CWMIs and there emerged nine major issues including need to evolve research based data, need of convergence approach, creating awareness and designing action plans for motivating and mobilizing farmers, development of model training unit, need of administrative guidelines for rain water harvesting and related issues, convergence of all line departments , special course on agro-ecology concepts at graduate level, extension literature on agro-ecological rationale and farmer to farmer extension through visits were major issues for diffusion of CWMIs. The results are in line with Lise *et al*. (2019) where it was found that, in water scare regions, conflicts on water sharing can be resolved and equitable rights of farmers for irrigation can be assured with strong institutional set up and Pani *et al.* (2019) who advocated special attention to the issues of benefits of groundwater recharge, rainwater harvesting and higher agricultural production.

Six of the 14 major causes of agro ecological crisis relates directly or indirectly to water. Majority of farmers were adopting water harvesting innovations from moderate to high levels. All the farmers have comprehensively followed the agro-ecology behind hydrological cycle of water harvesting and water saving for future contingencies. The knowledge levels of agro-ecological principles and hydrological cycle were very high among the majority of farmers. On the basis of *high consensus with high importance,* there is a need for synergy between surface and aquifer storage to attain sustainable water policy and practices in sustainable manner. In order to achieve more use of water, prioritization of water usage along with water budgeting, harnessing circular economy in water usage, and developing institutional mechanisms will be the key for these contemporary innovations.

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