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Causes of agro-ecological crises related to soil moisture and soil fertility faced by farmers of dryland agro-ecosystem: A critical analysis

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Abstract
Soil moisture in the Anantapur district was quite low due to on an average 42 percent of annual rainfall was subject to a high degree of variability, with low mean of 329.9 mm. the effective rainfall was computed to be 198 mm which was very low. It indicates the part of the rainfall that was available as soil moisture in the root zone to meet the crop Evapo-Transpiration requirement of the crops was facing crisis in the reasons. The soil-moisture stress condition under different stages of crop growth caused inadequate plant population; higher percentage of flower drop; poor seed setting, etc. and thereby had implications for crop yields. Soil fertility crisis was due to drought condition because most of the nutrient diffused in the plant with availability of soil moisture. Soil moisture and soil fertility crisis is a great problem in arid and semi-arid regions of the country. Farmers Anantapur region were facing severe soil moisture and soil fertility crisis and losing crops. Climate change aberrations have further worsened the already grave situation. As these conditions continued to prevail, at regular intervals, over the years a critical analysis of causes of agro-ecological crisis related to soil moisture and soil fertility was delineated through focused group discussion, personal interview and factor analysis. An attempt has been made in eight villages of three Mandals in Anantapur district of Andhra Pradesh to analyse the cause behind the agro-ecological crisis with a sample of 120 farmers selected randomly. The major findings were: Among the causes related to soil moisture and soil fertility was Loss in soil structure due to monoculture and chemicals leading to nutrient imbalances in soil, Loss of fertile top soil due to erosion and Ill effects of agro-chemicals on soil structure.

Keywords: Agro-ecological crisis, dryland agro-ecosystem, soil moisture and soil fertility

Introduction
Water is the most important input in agriculture. A farmer cannot think of cultivating any crops without water to irrigate the crops (Anonymous, 2018) [1]. From ages, agriculture has been dependent on water from rainfall. Rainwater gets soaked into soil, percolates stored as soil moisture. Water has a vital role to play in securing the prosperity of an agriculture based nation such as India. One of the most drought prone districts of Andhra Pradesh, Anantapur receives very scanty rainfall with a mean of 568.5 mm that is way below the average for the State (Census of India, 1981) [3]. Agriculture is primarily rain-fed but fluctuating monsoons and near-perennial drought had forced the villagers to rely on groundwater for their agricultural and personal needs because of this worst situation the ecosystem gets disturbed adversely, agro ecological crisis were set in the Anantapur district, which can be seen as the adverse conditions of climate change endangering the sustainability and enhancing the vulnerability of dryland agro-ecosystem system (Down to Earth, 2018) [4]. Agro-ecological crisis can be witnessed in terms of loss of landscape diversity of vegetation, farm crops and farm animals, loss of soil quality and signs of degradation or resource losses due to soil erosion, deforestation, habitat fragmentation, decline in on-farm resource use efficiency especially of water and nutrients, dependence on external inputs and incidence of pests, diseases and weeds resulting in, crop damage (Altieri, 2002) [5]. Due to drought condition and less availability of soil moisture in the soils of Anantapur was poor in organic carbon content, low in available nitrogen, and are highly erodible (Rukmani, R., & Manjula, M, 2009) [6]. While the application of manure make availability of more soil moisture even when rainfall is low, improve the soil texture and meet the nitrogen requirement of the soils, application of inorganic fertilisers will address the dearth of other nutrients, such as, potassium, phosphorous and other micro nutrients in the soils. The magnitude of soil and water erosion that happens in Anantapur district calls for massive efforts for conservation of soil and water resources here (Jagadish Timsina, 2018) [7].

The district needs a combination of short, medium, and long-term measures of soil and water conservation and drought proofing (Central Research Institute for Dryland Agriculture, 2002, 2004a, and 2004b) [8-10].

Material and methods

The study was conducted in dryland agro-ecosystem of Andhra Pradesh. District Anantapur (Rayalaseema region) is purposively selected as large number of farmers are facing very grave situation in Anantapur due to agro-ecological crises (The Hindu, 2017). A pilot study was conducted before the actual start of research work to check the availability and time taken by the farmers in this areas (Lancaster GA, Dodd S, Williamson PR (2004) [12]. To study the determinants and generalize the findings in this study a critical analysis of causes of agro-ecological crisis was delineated through focused group discussion, personal interview and factor analysis (Bryant, F. B., & Yarnold, P. R. (1995) [13]. The causes of agro-ecological crisis as perceived by farmers was drawn from them through focused group discussion. Then a list is formed and categorized into sets like causes related to erratic rainfall and depleting ground water. Since the pilot study revealed the availability of farmers from the identified list of water sharing groups with the purpose of validating and checking reliability of the schedule developed with the perceived causes and respondent's perception of degree of severity of these listed causes was measured on three-point continuum viz., 'most severe', 'severe' and 'less severe' and given scores of 3, 2, and 1. Farmer respondents were asked to respond to each cause and state their perceived level of severity. Data collected were from 120 farmers analysed with the help of SPSS 20.0 and Excel Stat software to draw valid conclusion. To achieve this, a two-step process was adopted. First the respondents of the study were asked to respond on the perceived severity of the causes agro-ecological crisis, then select the top most important causes (based on the mean values arranged in a descending order) only those were taken which had a mean score of more than 2.5 (out of a maximum score of 3) for factor analysis, which is a data reduction statistical procedure through correlations of correlations. Factor analysis used here to further reduce the number of causes of agro-ecological crisis as a confirmatory approach.

Results of Factor analysis of causes of agro-ecological crisis related to Soil moisture

Among the causes related to soil moisture stress, only four were found to be perceived as more important based on the mean scores of severities of causes, as given in table 1. Only those were taken which had a mean score of more than 2.5 (out of a maximum score of 3) for factor analysis.

Table 1: Mean ranks of severity perceived by farmer respondents on the soil moisture related causes of agro-ecological crisis n=120

S. No.	Soil moisture related causes	Mean	SD	More severe	Severe	Less severe
1.	Hot winds reduce soil moisture and lets the soil to dry up totally.	2.96	0.180	116 (96.7)	4 (3.3)	0 (0.00)
2.	Due to excessive weed growth, water uptake by weed and excessive evapotranspiration from foliage, soil moisture gets depleted.	2.83	0.374	100 (83.3)	20 (16.7)	0 (0.00)
3.	Very low relative humidity in fields	2.79	0.407	95 (79.2)	25 (20.8)	0 (0.00)
4.	Lack of water harvesting and storage structures in the fields	2.71	0.552	92 (76.7)	22 (18.3)	6 (5.0)

Now these four causes related to soil moisture stress were factor analysed and the final factor loadings are given in table 2.

Table 2: Factor loadings of causes related to soil moisture stress n=120

Causes related to soil moisture stress	Factors	
	1	2
Lack of water harvesting and storage structures in the fields	0.835	0.136
Due to depletion of soil moisture, the roots of crop plants may fail to take up nutrients from dried up soil	0.830	-0.101
Hot winds reduce soil moisture and lets the soil to dry up totally.	-0.179	0.749
Due to excessive weed growth, water uptake by weeds and excessive evapotranspiration from foliage, soil moisture gets depleted.	-0.214	-0.712

Under factor 1, two cause-variables have got high factor loadings and two were: first, 'lack of water harvesting and storage structures in the fields' and second, 'due to depletion of soil moisture, the roots of crop plants may fail to take up nutrients from dried up soil'. Considering the key issue in these two causes, this factor is named as Soil moisture stress due to lack of field ponds.

In cases of acute shortage of water during mid-season of a crop, if the water storage is available in field ponds, that will help reduce soil moisture stress. Field ponds would provide immediate access to water in cases of acute shortage. Agro-ecological conditions will be conducive and supportive to plant growth if water storage structures like water tanks, field ponds are available. Since they are not available, crop plants suffer badly due to soil moisture stress and begin withering and drying up. All this leads to poor nutrient uptake from dried up soils.

Under the factor 2, two cause-variables have got high factor loadings and two were: first, 'hot winds reduce soil moisture and lets the soil to dry up totally', and the second, *'due to* excessive weed growth, water uptake by weeds and excessive evapotranspiration from foliage, soil moisture gets depleted'. Hence this factor is named as 'depletion of soil moisture'.

Plants require adequate moisture in their root zones for nutrient uptake and water uptake. Keeping soil moisture intact is the most difficult job of dryland farmers. Hence conserving soil moisture is quite essential. If proper measures are not taken, hot winds exhaust soil moisture and dry up the top soil, causing severe case of moisture stress. In the same manner if the weeds are not removed in time, they draw up soil moisture in excess and through evapotranspiration from the excessive weed growth leads to soil moisture loss.

Farmers need to take proper measures to conserve soil moisture by proper mulching to avoid hot winds and removal of weeds to conserve soil moisture. Any neglect of these timely interventions leads to depletion of soil moisture causing severe moisture stress to plants and death of plants.

Results of Factor analysis of causes of agro-ecological crisis related to Soil fertility

Among the causes related to soil fertility, only nine were found to be perceived as more important based on the mean scores of severities of causes, as given in table 3. Only those were taken which had a mean score of more than 2.5 (out of a maximum score of 3) for factor analysis.

Table 3: Mean ranks of severity perceived by farmer respondents on the Soil fertility related causes of agro-ecological crisis n=120

No.	Soil fertility related causes	Mean	SD	More severe	severe	Less severe
1.	Indiscriminate use of chemical pesticides	2.91	0.342	111 (92.5)	7 (5.8)	2 (1.7)
2.	Bulk density of soil gets increased due to heavy application of chemical fertilizers. So the water absorption capacity and holding capacity of water in soil gets reduced.	2.89	0.425	112 (93.3)	3 (2.5)	5 (4.2)
3.	Due to soil erosion, soil nutrients get lost.	2.85	0.358	102 (85.0)	18 (15.0)	0 (0.00)
4.	Loss of ammonia of urea fertilizers into atmosphere.	2.85	0.496	109 (90.8)	4 (3.3)	7 (5.8)
5.	Sometimes the vegetative growth may be good due to balanced use of fertilizers. But the reproductive stage growth period reduced leading to lower yields.	2.82	0.381	99 (82.5)	21 (17.5)	0 (0.00)
6.	Loss of soil micro nutrients adversely affecting soil fertility	2.79	0.538	102 (85.0)	11 (9.2)	7 (5.8)
7.	Continuously cultivating crops without application of any farm yard manure and other organic manures.	2.78	0.433	95 (79.2)	24 (20.0)	1 (.8)
8.	Los of soil fertility due to leaching of soil nutrients into deep layers of soil	2.61	0.488	74 (61.7)	46 (38.3)	0 (0.00)
9.	Flow of polluted water in crop fields	2.57	.866	94 (78.3)	6 (5.0)	20 (16.7)

Now these nine causes related to soil fertility were factor analysed and the final factor loadings are given in table 4.

Table 4: Factor loadings of causes related to soil fertility n=120

Causes related to soil fertility	Factors		
	1	2	3
Continuously cultivating crops without application of any farm yard manure and other organic manures.	0.911	0.04	0.108
Loss of soil fertility due to leaching of soil nutrients into deep layers of soil	0.626	0.501	-0.317
Sometimes the vegetative growth may be good, but the reproductive period gets reduced leading to lower yields.	0.867	-0.201	0.132
Due to soil erosion, soil nutrients get lost	0.116	0.883	-0.029
Loss of soil micro nutrients adversely affecting soil fertility	-0.21	0.693	0.212
Indiscriminate use of chemical pesticides	-0.03	0.115	0.832
Bulk density of soil gets increased due to heavy application of chemical fertilizers. So the water absorption and holding capacity of soil gets reduced.	0.154	-0.008	0.823

From among nine, only seven have been taken for factor analysis, because these two factors had insignificant eigen values. The results in the table above indicate the high factor loadings on each of the seven causes related to soil fertility. These seven causes were grouped through factor analysis in three factors. Based on the causes (variables) loaded on the factor, a new name is given to each factor. Here for the two factors the following names are given.

Factor 1:	Loss in soil structure due to monoculture and chemicals leading to nutrient imbalances in soil
Factor 2:	Loss of fertile top soil due to erosion
Factor 3:	Ill effects of agro-chemicals on soil structure

Under factor 1, three cause-variables have got high factor loadings and three were: first, 'indiscriminate use of chemical pesticides' the second, 'bulk density of soil gets increased due to heavy application of chemical fertilizers. So the water absorption and holding capacity of soil gets reduced', and the third, 'sometimes the vegetative growth may be good, but the reproductive period gets reduced leading to lower yields'. Keeping the key issues in mind, this factor is named as 'Loss in soil structure due to chemicals, monoculture and leading to nutrient imbalances in soil'.

Monoculture of crops without adopting any crop rotation or intercropping may result in loss in soil fertility. In the same way, loss in soil fertility may also result due to leaching of essential plant nutrients. Imbalances in plant nutrients in soil may result in excessive vegetative growth and low levels of reproductive growth leading to loss in yields and economic benefits.

Under factor 2, two cause-variables have got high factor loadings and two were: first, *'due to soil erosion, soil nutrients get lost'*, and the second, 'Loss of soil micro nutrients adversely affecting soil fertility. This factor is given a new suitable name as *'loss of fertile top soil due to erosion'*, as it involves two causes dealing with erosion of fertile top soil. Essential micro-nutrients may get lost due to erosion of top soil, either through run-off water or through hot winds in dryland areas. Loss in essential and micro-nutrients adversely affects soil fertility.

Under factor 3, two cause-variables have got high factor loadings and two were: first, *'sometimes the vegetative growth may be good, but the reproductive stage growth period reduced leading to lower yields'*, and the second, 'Loss of soil micro nutrients adversely affecting soil fertility.

This factor may be named as *'Ill effects of agro-chemicals on soil'*. Due to indiscriminate application of chemicals—fertilizers and pesticides, the soil structure and nutrient availability may get adversely affected.

Discussion on the results of analysis of causes of agro-ecological crisis

A list of causes was prepared through focused group discussion, categorized into different sets of causes related to depleting soil moisture, causes related to declining soil fertility, Then farmers' perception of severity of these causes was sought on a three-point continuum of more severe, severe and less severe were analysed.

First the causes were screened by deleting the causes which had mean scores less than 2.5 from this most important causes, 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 causes.

Finally, the major *cause-factors* that emerged were five reduced through factor analysis of 13 causes perceived as *most important* from the initial list of 20 causes collected from focused group discussion. They are:

Factor 1:	Soil moisture stress due to lack of field ponds
Factor 2:	Depletion of soil moisture
Factor 3:	Loss in soil structure due to monoculture and chemicals leading to nutrient imbalances in soil
Factor 4:	Loss of fertile top soil due to erosion
Factor 5:	Ill effects of agro-chemicals on soil structure

A cursory look into the causes of agro-ecological crisis listed above would reveal that these causes were essentially due to *'man-made errors'* to *Mother Nature* and complete neglect of any pro-active ameliorative measures for recuperative and regenerative farming systems.

Conclusion

The causes of agro-ecological crisis faced by farmers were analysed and the results have succinctly brought the major causes of the agro-ecological crisis. In fact, agro-ecology, if not taken care of at every step may become vulnerable and gradually may get destroyed. The water conservation structures like check dams and ponds have been neglected resulting poor percolation into the soil. With increased run off water causing soil erosion has resulted in loss of fertile top soil and along with it the essential and micro-nutrients. With complete neglect of agro-ecosystems, the problems got aggravated and compounded and completely destroyed natural resources of agro-ecosystems of dryland regions. The most essential resources got depleted: the rain water, soil fertility and micro-nutrients. Hence, the corrective measures started with understanding the hydrological cycle, ways of water harvesting, saving and water sharing.

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