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Understanding soil and water conservation benefits adoption paradox in drought prone areas of Karnataka, India through financial viability: Case of field bunds

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ABSTRACT

Aim of this study is to understand existence of the paradox of non−adoption of beneficial soil and water conservation (SWC) measures. Study is based on plot level primary data collected from drought prone areas of Karnataka state, wherein the probability of droughts is around 70%. We have shown that increasing climate variability, which is manifesting in terms of increasing frequency of consecutive droughts, is making investment on field bunds economically non−viable, and driving farmers to the dilemma of 'whether to adopt or not−to adopt'. The results from different scenarios and cases indicate that adoption of field bunds technology is not economically viable, barring under few drought situations. The study infers that increase in climate variability might be one of the most probable reasons for existence of the paradox in drought prone areas.

1. INTRODUCTION

Agricultural vulnerability to climate change is one of the greatest challenges to sustain agricultural production (Mase *et al.,* 2017). Among the different sectors, agriculture is comparatively more vulnerable, and within agriculture sector, rainfed areas are highly vulnerable to climate change and its variability. Risks associated with increasing climate variability pose technological and economic challenges to societies which are highly dependent on agriculture for their livelihood (Molua, 2002).

Karnataka is the second most drought prone state in India after Rajasthan (Nagaraja *et al.,* 2011). The State is witnessing frequent droughts; sometimes these could be severe as well as consecutive (KSNDMC, 2018). O'Brien *et al.* (2004) and Kumar *et al.* (2016) reported that the State is highly vulnerable to adverse effects of climate change and its variability. This high vulnerability of the State can be attributed to a sizable area under rainfed agriculture, and erratic and scanty rainfall with spatial and temporal variability.

In the drought prone areas of the State, moisture stress during crop growth period is a major challenge to crop production, emphasizing needs of conserving soil moisture. For conserving soil moisture, adoption of soil and water conservation (SWC) technologies is critical because of their various synergetic and positive impact on sustaining natural resources and rendering resilience to crop production in drought prone areas (Kato *et al.,* 2011; Kassie *et al.,* 2008; Singha, 2019). In Karnataka, largely, SWC technologies are being implemented through watershed development programmes. Despite continuous efforts, adoption of SWC technologies is quite low (Pender and Kerr, 1998; Kerr and Sanghi, 2002). This is true inspite of well documented economical and environmental benefits of SWC technologies (Shiferaw and Holden, 2000; Kassie *et al.,* 2008). This phenomenon can be termed as "soil and water conservation benefits: adoption paradox" which states that "why seemingly beneficial technologies are not being adopted by the farmers at sizable scale"? (De Janvry *et al.,* 2016) Therefore, there is a need to comprehend this paradox. For low adoption of SWC technologies, there could be a host of factors (socio−economic, physical and institutional), but in this research paper our focus only on 'the financial viability or perceived profitability of field bund which is an important SWC technology for drought affected parts of Karnataka. Among the various factors influencing the adoption of SWC technologies, financial viability is most critical one (Shiferaw and Holden, 2000; Baidu−Forson, 1999; Mbaga−Semgalawe and Fomer, 2000). Moreover, financial viability not only encourages adoption but also serves as an important factor for continued use of SWC measures (Teshome *et al.,* 2016). With this background, the main aim of the paper is to understand the SWC benefits adoption paradox in the drought prone areas of the State in context of field bunds.

2. MATERIALS AND METHODS

Status of Droughts in Karnataka State

Because of uncertain and erratic rainfall, Karnataka is witnessing frequent droughts of severe to moderate degrees, causing colossal loss to crops and lives, and forcing farmers to migrate for their sustenance (KSNDMC, 2018). A considerable shift in rainfall pattern (amount, intensity and distribution) has been observed all over Karnataka in last three decades (KSNDMC, 2020).

For instance, the State has witnessed recurring consecutive droughts for three years during 2001–02, 2002–03 and 2003–04 adversely affecting crop production across the State. More recently, many districts consecutively have been declared as drought hit during 2008 to 2013. The severity and extent of crops losses were higher in the dry zones having light and shallow soils wherein the crop failures are common due to droughts (Biradar and Sridhar, 2009). Furthermore, during *kharif* season in northern districts of the State, it is projected that drought incidences may increase by 10–80%. In districts like Koppal and Yadgir, it is projected that the frequency of drought could even double during *kharif* season (BCCI–K, 2011). From Fig.1, as per GoI (2020) data related to declaration of districts as 'drought affected' during 2000 to 2015, it can be seen that the probability of occurrence of drought is more than 66% in most of the districts.

The worse part of the droughts is that these can be consecutive, as shown in Fig. 2. Consecutive droughts severely affect farm economy as the coping capacities are reduced due to their continuance, leading to distress migration. From 2001 to 2015, a perusal of Fig. 2 shows that most of the districts have many times witnessed consecutive drought of 4 years, which could be even for 5 years in some districts.

Data and Methodology

For the study, primary data were collected pertaining to the year 2019–20 following a combination of purposive and simple random sampling. Drought prone areas of the State were purposively selected. Then, four districts, namely Koppal, Tumkur, Bidar and Gadag, were randomly selected from drought prone areas of the State. Later, from each selected district, two sub–watersheds were randomly selected, and from each selected sub–watershed, farmers were randomly selected. In addition, control farmers were also randomly selected from selected sub–watersheds of adjacent untreated watersheds. In this manner, for this study, 593 farmers (sample units) cultivating maize, *ragi* (finger millet), sorghum and redgram on 1204 field plots were selected. Primary data was collected on pre–tested well structured questionnaire from these sample units through personal interviews for estimating the economics of the crops cultivated with field bunds, the main SWC technology of the study area. Field bund, the SWC technology purposively chosen for this study, is an earthen embankment constructed along boundary lines of individual field plot to conserve soil and moisture within the field plot itself. Employing non–parametric and semi–parametric approaches, it was estimated from the above collected primary data that on an average, the net revenue was around ₹ 7500 ha^{-1} due to adoption of field bunds (Kumar *et al.,* 2020). Initial investment was ₹ 10,000 ha^{-1} for constructing these bunds.

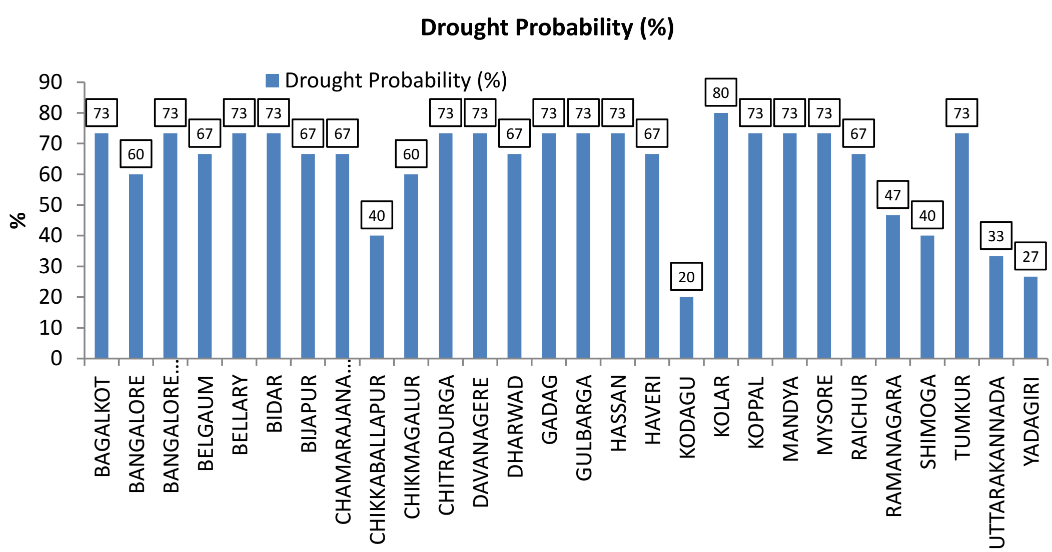

Fig. 1. Frequency of drought declared in district by Government of Karnataka

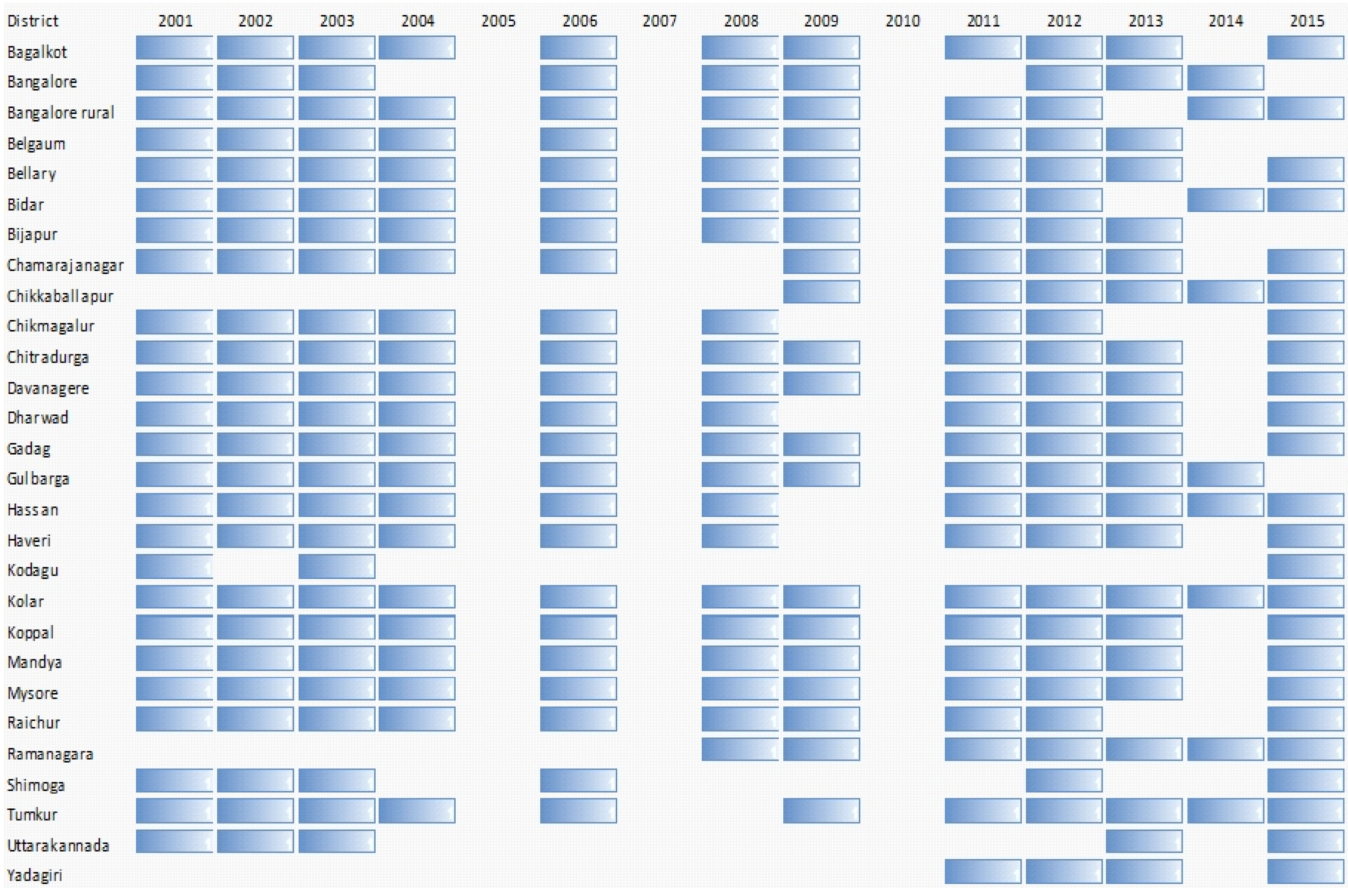

Fig. 2. Scenario of consecutive droughts in the different districts of Karnataka state

Net present value (NPV) was utilized for financial feasibility analysis in the study. Life of the bunds was assumed to be 15 years, though a well maintained bund can last for more than 15 years. For factoring in risks of crop production in the study areas, a slightly higher discount rate (15%) was assumed for computation of NPV. The NPV was computed for different scenarios considering probability and timing of droughts.

NPV was computed using the below given equation:

$$NPV = \sum_{i=0}^{i=15} \frac{B}{DF} - \sum_{i=0}^{i=15} \frac{C}{DF}$$

Where, *B* is benefit of interventions, *C* is cost of interventions, *DF* is discounting factor $\frac{1}{(1+r)^t}$; i = 0, 1, 2,. . . , 15 and *r* is discounting @ 15%.

Scenarios and Cases

Different scenarios were considered to study the sensitivity of financial viability of investment in field bunds to time and/or probability of occurrence of droughts.

Scenario 1 − Sensitivity of financial viability to post adoption drought occurrence: Under this scenario, the sensitivity of financial viability of investment to the time of occurrence of droughts was studied. For this, five cases were simulated / generated, namely 'normal years', '1st year drought', '2nd year drought', '3rd year drought' and '4th year drought'. First case is a 'normal years' scenario, which is an assumption generally utilized while computing financial viability of the SWC technology. In case of 'normal years' *i.e.* no occurrence of drought over the years, it was assumed that the flow of net revenue (benefits from intervention) will remain same over the years during the life of the project *i.e.* life of the field bund. However, this assumption seems unrealistic, particularly in rainfed areas, where frequent droughts of severe to moderate degrees are very common, leading to frequent crop failures. The '1st', '2nd', '3rd' and '4th' year drought stand for drought in the 1st, 2nd, 3rd, and 4th year of adoption of the field bund technology, respectively. Here, in all the scenarios, it is assumed that other than the drought year, the other years are normal years, though this assumption is not in accordance with the status of droughts in the State, as stated above. In a drought year, farmers suffer loss of revenue, and most of the times, even the cost of cultivation is not recovered, and thus net returns are negative. Since, data for establishing relationship between the degree of droughts and extent of loss of yields / revenue is not available, therefore, for sake of simplicity, it was assumed that net revenue is zero in the year of drought.

Scenario 2 − Sensitivity of financial viability to probability of drought occurrence: Five cases were simulated *viz.,* normal year, 50%, 66%, 75%, and 80% probability of drought occurrence for assessing sensitivity of financial viability of field bund adoption to different probabilities of drought. Here, a 'normal year' is the same as defined in Scenario 1, whereas '50%' stands for drought occurrence in alternate years; consequently, the net revenue is zero in alternate years and the average revenue is half of that of a normal year. Similarly, in case of 66%, 75%, and 80% probabilities of drought occurrence, the net revenue is one−third, one−fourth and one−fifth, respectively of a 'normal year'.

Scenario 3 − Sensitivity of financial viability to post adoption drought occurrence probability and time: Combined cases of timing and probability of drought occurrences post adoption were also simulated for capturing cases that represent real situations in drought prone areas of the State. If drought occurs in first year after the adoption of farm bunds and the probability of drought occurrence is 50%, then it means that drought will continue occurring in every alternate year afterwards. Similarly, if drought occurs in first year after the adoption of farm bunds and the probability of drought occurrence is 66%, then it means that drought will continue occurring in every two out of three years afterwards. Similarly, other combinations of drought occurrence moments in time and probability of occurrences were constituted.

3. RESULTS AND DISCUSSION

Effect of Moment of Drought Occurrence in Time

Sensitivity of financial viability of investment in field bunds to time of occurrence of droughts is presented in Fig. 3, which indicates that when there is a drought in first year of adoption of field bunds, *i.e.* just next year after the adoption of field bunds, the NPV is reduced by ₹ 7319 on ha^{-1} basis from ₹ 50021 ha^{-1} (of normal year) to ₹ 42702 ha^{-1}. Similarly, droughts in the 2^{nd}, 3^{rd} and 4^{th} years of adoption reduce the NPV by ₹ 6653, 6048 and 5499 ha^{-1}, respectively. The reductions in NPV values as a result of loss due to drought in the respective years clearly show the degree of sensitivity of financial viability of field bunds to time of occurrence of droughts. As the drought occurrence gets delayed after the year of adoption of field bund technology, the deviation from a normal year's NPV decreases. In all these scenarios, under the assumption that after a drought in a given year the following years are normal years, the results indicate that the investment is worth taking as the NPV values are positive. In case if drought is experienced continuously over the years after adoption, the losses will cumulate over the years, resulting in high aggregate loss.

Effect of Frequency of Drought Occurrence

Sensitivity of financial viability of field bunds to frequency of drought occurrence post their adoption is depicted in Fig. 4 through five scenarios as defined above. In case of 50% drought probability which indicates that there is a drought in alternate year; hence the net revenue is zero in alternate years and the average revenue is half of that of a normal year. Similarly, in case of 66%, 75%, and 80% probability of drought occurrence, the net revenue has been assumed to be zero for 2 years out of three, three years out of four, and 4 years out of 5, and consequently, the average net revenue is one−third, one−fourth and one−fifth, respectively of a 'normal year', respectively. Fig. 4 indicates that as the probability of drought occurrence increases from 50% to 66%, 75% and 80%, the average NPV reduces drastically. When there is drought probability higher than 66%, average NPV becomes near to zero showing an indifferent situation for farmers *i.e.* 'dilemma to adopt or not−to−adopt'. As shown earlier, in most of the parts of the State, drought occurrence probability is more than 66% resulting in negative NPV values, indicating financial non−viability of investment made in field bunds. From this, it can be stated that the financial viability of investment in field bunds is highly sensitive to probability of drought occurrences, rendering disincentives to farmers as far as adoption of field bunds is concerned.

Combined Effects of Time and Frequency of Droughts

For depicting existing situation in drought prone areas of the State, more realistic scenarios, by considering timing

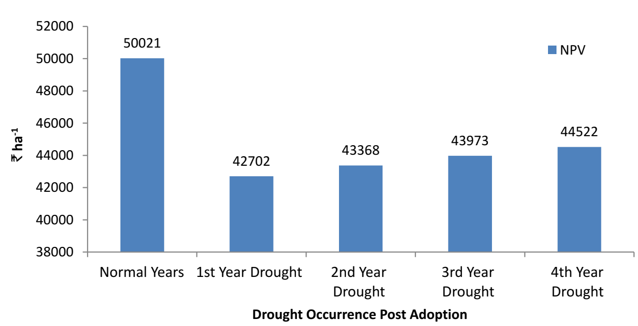

Fig. 3. Effects of drought occurrence on net present value (NPV) post adoption of field bund technology

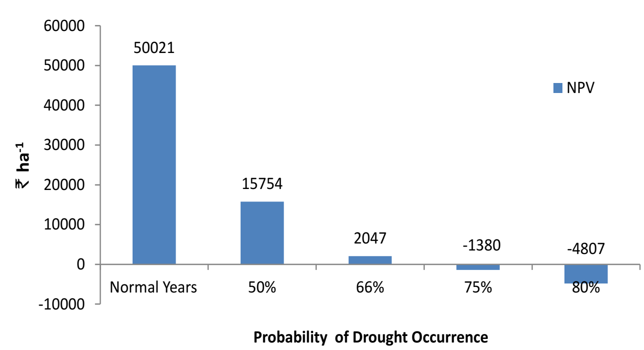

Fig. 4. Effects of frequency of drought occurrence on net present value (NPV) post adoption of field bund technology

as well as probability of drought occurrence post adoption of field bunds, were simulated.

When the probability of drought occurrences is 50% and 66%, then in case of all moments of drought occurrences in time, as defined above, field bunds are financially viable as evident from positives values of the NPVs (Fig. 5). However, when the probability of drought occurrences is 75% and 80% and if a farmer copes with these droughts in the first and second years of field bund technology adoption, then the field bunds are not financially viable, leading to losses. Given the probability of droughts and their consecutiveness in the State, the likelihood of facing the scenario of drought in the first and / or in second year of adoption of field bunds along with more than 70% probability of occurrences of droughts is very high, leading the farmers to perceive about the ineffectiveness of field bunds to generate sufficient profit from its adoption. Due to this reason farmers turn out to be reluctant to adopt field bunds, and even to invest for its regular repair and maintenance, which in turn worsens the prospects of getting potential benefits from its adoption in coming years. In other words, the major reason for low adoption or poor maintenance of field bunds, in particular, and for SWC measures, in general, is the occurrence of droughts in initial years (1−2 years) of their adoption. This mirrors the findings of the previous studies (Reddy *et al.,* 2004; Bouma *et al.,* 2007). Moreover, the unpleasant experience of no visibly differentiable impact between adopters and non−adopters of field bund technology also influences the behavior of other farmers in their social network.

4. CONCLUSIONS

The main aim of the paper is to understand the prevalence of the paradox of non−adoption of beneficial SWC measures in the case of field bunds technology in drought prone areas of Karnataka State. It was observed that if probability of occurrence droughts is approximately more than 70% in a drought prone region and if farmers of such a region face droughts in initial years (1−2 years) of the adoption of the SWC technology, the adoption of field bunds technology is not financially viable. Since chances of facing such situation are high in drought prone areas, the reluctance to adopt field bunds technology, in particular, and SWC measures, in general, by farmers, in spite of their well documented benefits, will be high resulting into prevalence of the paradox in rainfed drought prone areas.

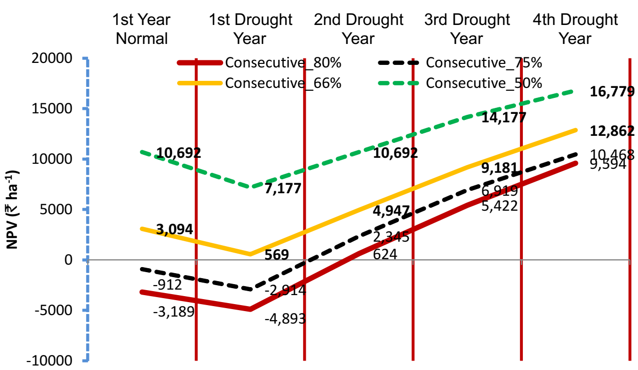

Fig. 5. Effects of timing and frequency of drought occurrence on net present value (NPV) post adoption of field bund technology

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