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Potential sites for different *in-situ* moisture conservation measures in Western Vidarbha zone of Maharashtra using geospatial techniques

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ABSTRACT

The Western Vidarbha zone of Maharashtra has an average annual rainfall of around 800 mm with 84% of the rainfall during south-west monsoon and the mean annual rainfall varies spatially from 732 mm to 1273 mm in different sub-districts. Normally, in these areas dry spells are experienced during July, August and September which coincides with the vegetative or reproductive stages of major rainfed crops and it results in the reduction of crop yield drastically. *In-situ* moisture conservation measures are followed in these areas to conserve the moisture in the soil and to increase the crop productivity. In addition to this, providing one or two supplemental irrigation to these rainfed crops during critical growth stages or prolonged dry spells can increase the crop yield considerably. In order to make the Western Vidarbha zone of Maharashtra more resilient to the impact of climate change, suitable *in-situ* moisture conservation measures and rainwater harvesting / groundwater recharge structures were planned using a novel and robust approach with geospatial techniques. Among the selected *in-situ* soil and water conservation (SWC) interventions, conservation furrow and contour cultivation are very suitable for all the districts followed by broad bed furrow (BBF) and ridge and furrow systems. Out of the total area, conservation furrow is found suitable for 51.5% of the area and contour cultivation for 22.5% area. Also, adoption of suitable water harvesting structures like percolation tanks, farm ponds and check dams are also very essential for the sustainable water management for climate resilient agriculture in Western Vidarbha zone of Maharashtra.

1. INTRODUCTION

In the developing countries like India, soil and water are the two important natural resources needed for the agricultural production to meet the food requirements for the growing population. The current degradation of these natural resources has particular significance because of the result of the change in climate conditions experienced in recent years (Kumari *et al*., 2020; Adams *et al*., 1990). The pressure created by the increasing demands of the population tends to increase both the water demands as well as the erosion rates. One of the main limitations experienced in agriculture production is shortage of water during prolonged dry spells and post monsoon season due to uneven distribution of rainfall and declining ground water levels (Shekhar *et al*., 2020; Halder *et al*., 2020). The adoption of *in-situ* SWC techniques and water harvesting structures helps to overcome these water stress to a great extent (Rejani *et al*., 2015; Rajitha *et al*., 2018; Patode *et al*., 2017). These *in-situ* soil and water conservation (SWC) interventions are developed to balance the use of natural resources while practising agriculture by conserving the moisture in the soil and the water harvesting structures helps to provide supplemental irrigation during prolonged dry spells based on the amount of runoff potential available (Akilapa *et al*., 2020; Bhattacharya, 2015).

Previous studies confirmed the adoption of *in-situ* SWC interventions like ridge and furrow, BBF, compartmental bunding, conservation furrow, modified crescent bunds etc increases the productivity, decreases the runoff rate, retards the soil erosion, increases the soil moisture content and recharges the aquifer (Mohamadi and Kavian, 2015; Ahmad *et al*., 2020, Bhave and Pophare, 2019; Wendt *et al*., 2021).

There are several methods with which we can plan and locate the suitable sites for the *in-situ* SWC interventions and water harvesting structures. Normally, field survey and geospatial techniques are widely used.

Identifying the suitable sites for rainwater harvesting structures with the help of survey is one of the difficult and time taking tasks for planners. Hence, recent advances in RS and GIS provides very useful information in undertaking the integrated resource analysis and provides reliable and accurate information on natural resources, which is required for planned and balanced development at watershed level (Saha *et al*., 2021, Asgari, 2021). Singh *et al.,* 2021 used RUSLE model and geospatial techniques for estimating the soil loss in Maharashtra. These are the two new technological tools which come up to meet the ever-increasing demand for more accurate and timely data / information. In order to identify potential sites for rainwater harvesting structures in the study area, a multi parametric dataset comprising satellite data and other conventional maps including land use / land cover (LU/LC), lineaments, soils, slope, rainfall and drainage lines (Kulkarni *et al*., 2021; Singh *et al*., 2021, Bekele, 2021) are very essential. After preparing the thematic layers, different features / classes of individual themes are to be identified and the potential site suitability map can be derived. The present study was focused on the planning of suitable sites for different *in-situ* SWC interventions for the Western Vidharba region of Maharashtra using geospatial techniques.

2. MATERIALS AND METHODS

Study Area

The study area, Western Vidarbha zone of Maharashtra, lies between 19°15' to 21°45'N latitudes and 75°45' to 79° 45'E longitudes with an elevation ranging from 100 m to 1179 m above mean sea level (Fig. 1) and major portion of region is characterized by clayey, clay loam and loamy medium deep to very deep black soils (Source: NBSS& LUP). It is a semi-arid region consists of Akola, Washim, Buldana, Yavatmal, Amaravati, Wardha and Nagpur districts covering an area of 62352 km². The selected area has an average annual rainfall of around 800 mm with 84% of the rainfall during south-west monsoon. The mean annual rainfall varies spatially from 732 mm to 1273 mm in different sub-districts (Fig. 2). Normally, in these areas dry spells are experienced during July, August and September which coincides with the vegetative or reproductive stages of major rainfed crops and it results in the reduction of crop yield drastically (Chary *et al.,* 2016). The major crops are grown in Western Vidarbha zone are cotton, soybean, green gram, pigeon pea, sorghum and *rabi* chickpea. *In-situ* moisture conservation measures are followed in some areas which helps to conserve the moisture in the soil. In addition to this, providing one or two supplemental irrigation to these rainfed crops during critical growth stages or prolonged dry spells can increase the crop yield considerably.

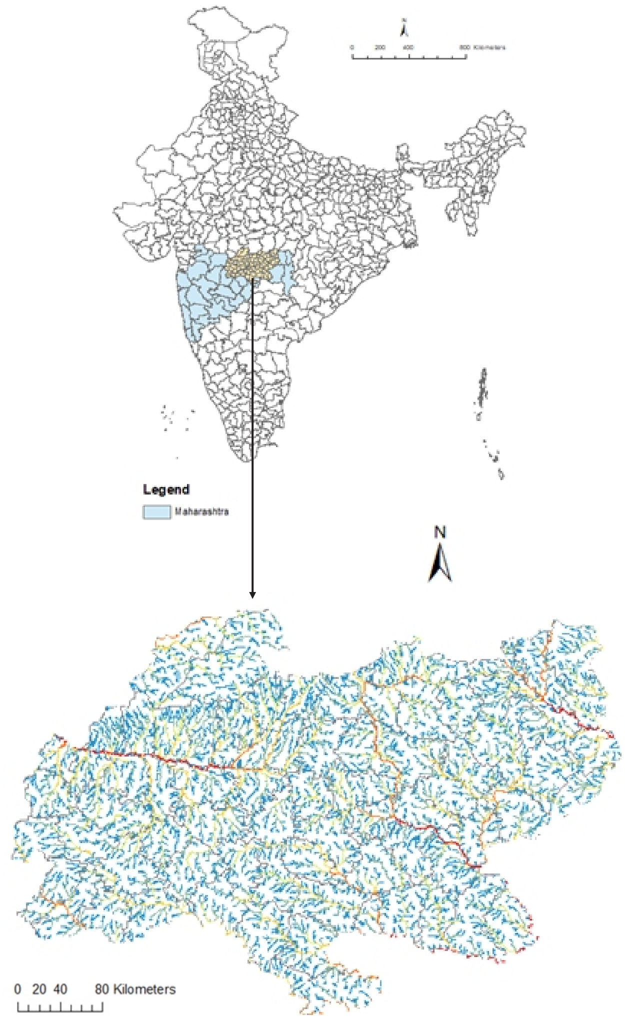


Fig. 1. Location map of the study area

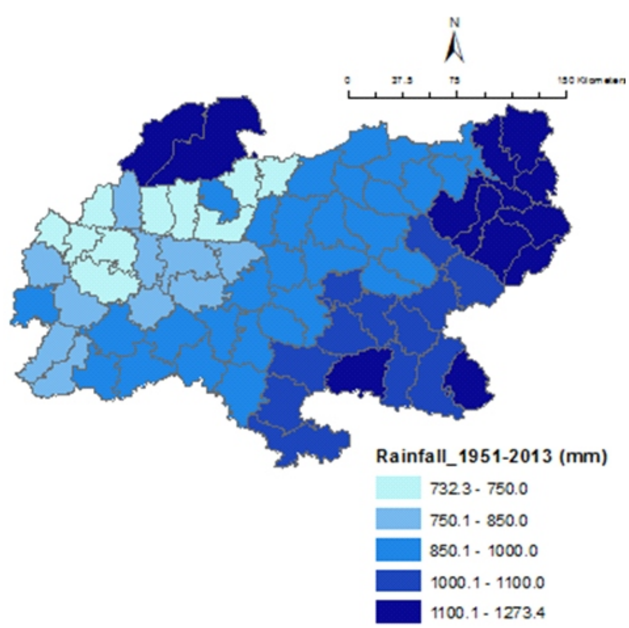


Fig. 2. Distribution of mean annual rainfall at Western Vidarbha zone of Maharashtra

Under the NICRA-Technology Demonstration Component, KVKs of Maharashtra in collaboration with MGNREGA, Agricultural Department and Watershed development programs has taken up *in-situ* moisture conservation measures like farm bunding, ridge and furrow, opening of furrow, continuous contour trenching and bunding, furrow irrigated raised bed etc. and it conserved the soil moisture, reduced erosion and increased the crop yield. In addition to this, desilting / construction of water harvesting structures like community ponds, farm ponds, *jalkunds*, check dams etc. created additional water storage and facilitated in providing supplemental irrigation to crops and enhanced groundwater recharge (Singh *et al.*, 2021). The planning and adoption of these interventions are very essential to improve the soil moisture, reduce the erosion and enhance the crop productivity and net returns. Identifying the suitable sites for *in-situ* interventions and rainwater harvesting structures with the help of survey is one of the difficult tasks for planners and hence an attempt was carried out to develop a methodology to plan these interventions with geospatial techniques.

Planning of *in-situ* Interventions and Water Harvesting Structures using Geospatial Techniques

The high spatial variability in rainfall and runoff potential shows the need for adoption of site specific interventions for the area (Fig. 2). Proper selection of suitable sites for *in-situ* interventions and water harvesting structures are key factor for effective erosion control, harvesting the runoff and moisture conservation. Considering the time consumption for conventional geographical surveys for identification of potential sites, suitable sites for different SWC interventions were planned using a novel and robust approach using geospatial techniques. Thematic layers of slope, soil, rainfall, runoff potential and LU/LC were prepared. These thematic layers were intersected (overlay) in Arc-GIS and the resultant attribute table was obtained. The selected criteria pertaining to each intervention (Table 1) was applied in the attribute table for identifying the suitable locations for different *in-situ* SWC interventions (Rejani *et al.,* 2015). The interventions selected for Western Vidarbha zone of Maharashtra includes conservation furrow, broad bed furrow (BBF), ridge and furrow, contour cultivation, small pits and semi-circular bunds (Table 1). The area suitable for each intervention was quantified from attribute table using Arc-GIS. Similarly, suitable locations for water harvesting structures were also identified using the criteria provided in Table 2 (Rejani *et al.,* 2017). The identified locations were exported to Google earth and validated by visual interpretations as well as using ground truth data.

3. RESULTS AND DISCUSSION

Suitable Locations for *in-situ* Moisture Conservation Measures and Water Harvesting Structures

The high spatial variability in rainfall ranging from 732 to 1273 mm during 1951 to 2013 shows the need for adoption of

Table: 1
Preliminary site selection criteria for planning of different *in-situ* soil and water conservation interventions

Structure	Slope (%)	Permeability	Runoff coefficient	Soil type	Rainfall (mm)	Soil depth (cm)
Ridge and furrow (field crops)	2-15[b]	Low[a&b]	Medium / high[a&b]	Loamy / loamy skeletal	>350[c] &<1000	>50
Semi-circular bunds (tree crops)	5-15[b]	Low	Medium / high	exclude sandy soil[b]	>200 & <4000[b]	100-150[b]
Small pits (shrubs, tree crops and waste land)	2-10[b]	Low	Medium / high	exclude sandy soil[b]	>350 and <=4000	>50[b] (shrubs) >100[b] (tree crops)
BBF (field crops)	<=3[e]	Low	Medium / high	clayey and loamy soil	>750	100-150
Compartmental bunding (field crops)	<=1[e]	Low	Medium / high	clayey soil[e]	>400 and < 750	>50[e]
Conservation furrow (field crops)	<=10[e]	Low	Medium / high	exclude sandy soil[b]	<=1500	<100
Contour cultivation and mulching	<=5[d]	Low	Medium / high	exclude sandy soil	>350 & <4000	>100[d]

(Source : Rejani et al., 2015; [a]Shanwad et al., 2011; [b]Pauw et al., 2008; [c]Anschütz et al., 1997; [d]Kalgapurkar et al., 2012; [e]TNAU, 2021)

Table: 2
Preliminary site selection criteria for the planning of different water harvesting structures

Structure	Slope (%)	Runoff coefficient	Stream order	Watershed area (ha)	Soil type	Rainfall (mm)
Farm ponds (crop land)	<=5	Medium / high	1-2 or without drains	>1-2	Clay, sandy clay loam	>500
Check dams (crop, scrubs / trees)	<=15	Medium / high	3-4	25	Clay, sandy clay loam	>700
Percolation tanks (scrub land)	<=10	Low	1-4	25-40	Light sandy soil	>700

(Source : Rejani et al., 2017)

Table: 3
Prioritization of different *in-situ* interventions for western Vidarbha zone of Maharashtra

Districts	District area	Suitable area (% of district area) for different *in-situ* interventions							
		Small pits	Adjusted contour / graded bunds	Ridge and furrow	Compartmental bunding	Contour cultivation	Semi-circular bunds	Conservation furrow	BBF
Nagpur	86973.0	8.8	0.6	2.4	0.0	22.2	0.9	47.8	10.6
Amaravati	108872.0	8.9	0.7	7.2	0.0	24.9	1.4	56.6	12.8
Yavatmal	127655.0	9.5	1.5	1.3	0.0	18.9	0.8	43.8	9.0
Akola	33942.0	5.4	0.7	11.6	10.4	28.4	2.1	65.1	13.6
Buldana	51854.0	5.3	1.4	26.9	4.3	22.4	3.4	47.8	6.5
Wardha	77634	12.3	1.1	4.8	0.0	19.8	0.9	47.2	10.2
Washim	20072	4.6	0.2	3.1	0.0	23.5	2.3	65.4	11.8
Total	507002.0	8.14	0.98	8.17	1.72	22.50	1.60	51.55	10.40

site-specific water management practices in the Western Vidarbha zone of Maharashtra (Fig. 2). Also, the higher spatial variability in runoff potential ranging from 10.1% to 21.3% of mean annual rainfall and considerable variability in the irrigation requirement of major crops in the study area (Rejani *et al.,* 2020) gives more scope for planning of location specific SWC interventions. Hence, identification of suitable sites for *in-situ* interventions and water harvesting structures are very essential for erosion control, harvesting the runoff and moisture conservation. In order to make Western Vidarbha zone of Maharashtra more resilient to the impact of climate change, suitable *in-situ* moisture conservation measures and water harvesting structures were planned and prioritized using a novel and robust approach using geospatial techniques. Among the selected *in-situ* SWC interventions, conservation furrow and contour cultivation are very suitable for all 7 districts followed by BBF and ridge and furrow system (Table 3). Area under each intervention was quantified using Arc-GIS. Out of the total area, conservation furrow was found suitable for 51.5% of the area and contour cultivation for 22.5% area. The sub-district wise suitability of selected *in-situ* moisture conservation measures were determined individually and was overlayed and merged to obtain the suitability map for the selected region (Fig. 3a to 3g, Fig. 4a and Fig. 4b). The potential sites identified were validated using Google earth and ground truth (Fig. 4c). Based on the suitability of each intervention and preference of the individual farmer, the potential locations can be selected by the planners for adoption so as to enhance the crop productivity. Generally, sowing across the slope, opening of furrows and mulching are followed for *in-situ* moisture conservation in these selected districts (Chary *et al*., 2016).

The conservation furrow was found suitable for 65.4% area of Washim, 65.1% area of Akola, 56.6% area of Amaravati, 47.8% area of Buldana and Nagpur, 47.2% area of Wardha and 43.8% area of Yavatmal (Table 3). Whereas, contour cultivation was suitable for 28.4% area of Akola, 24.9% area of Amaravati, 23.5% area of Washim, 22.4% area of Buldana, 22.4% area of Buldana, 22.2% area of Nagpur, 19.8% area of Wardha and 18.9% area of Yavatmal. BBF was found to be suitable for 13.6% area of Akola district, 12.8% area of Amaravati and 11.8% area of Washim. *In-situ* moisture conservation technique, ridge and furrow technique was found to be suitable for 26.9% area of Buldana and 11.6% area of Akola districts. Small pits are found as preferable options for 12.3% area of Wardha whereas compartmental bunding for 10.4% area of Akola district (Fig. 4a). Further, suitable locations for water harvesting / groundwater recharge structures were also determined by following the criteria depicted in Table 2 (Fig. 4b). Based on the suitability maps, conservation furrow and contour cultivation are very suitable for Western Vidarbha zone of Maharashtra followed by BBF and ridge and furrow system. This technology is very precise, easy to adopt, less time consuming and has the ability to process large area in less time. This technology can be well adopted for the planning and management of *in-situ* moisture

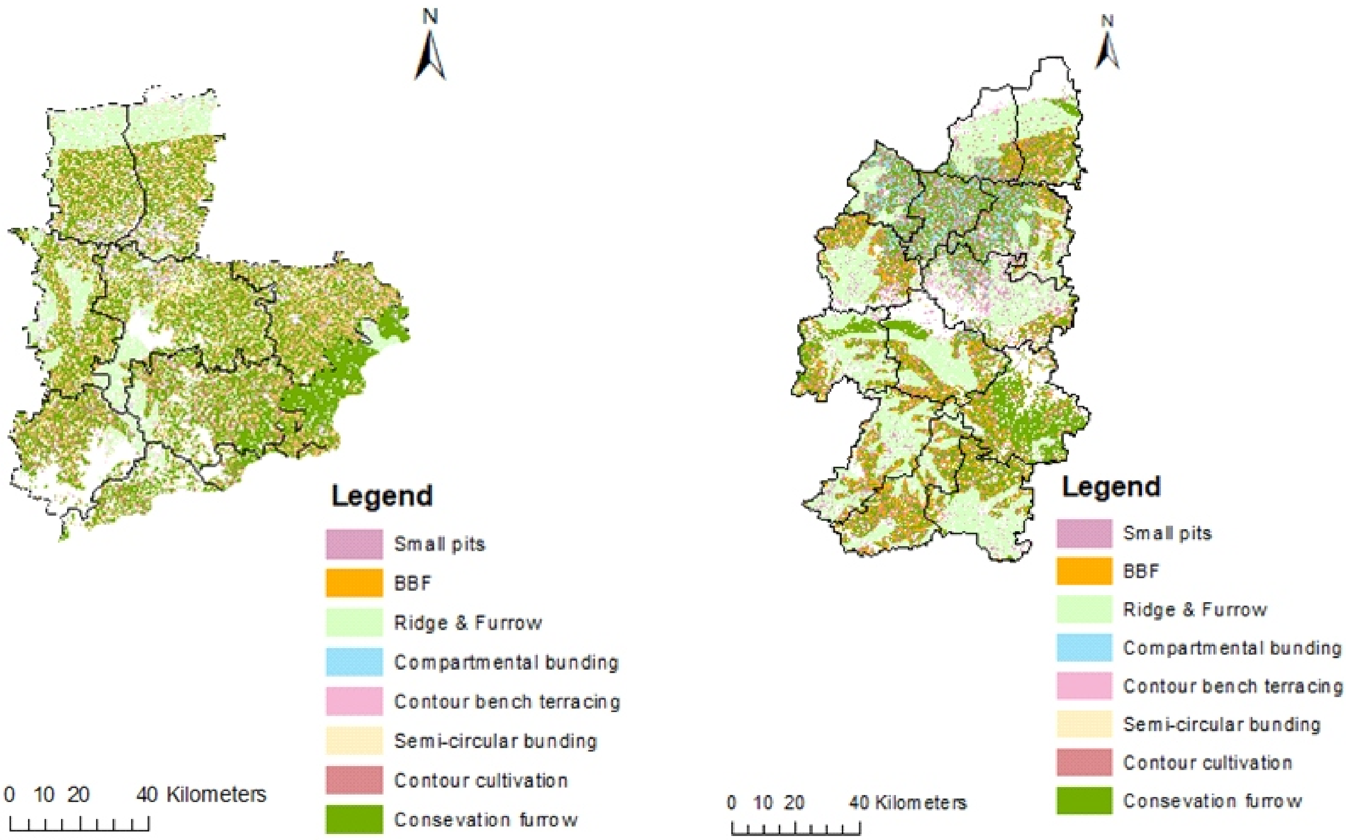


Fig.3a&b. Suitable *in-situ* interventions identified for Akola and Buldana districts

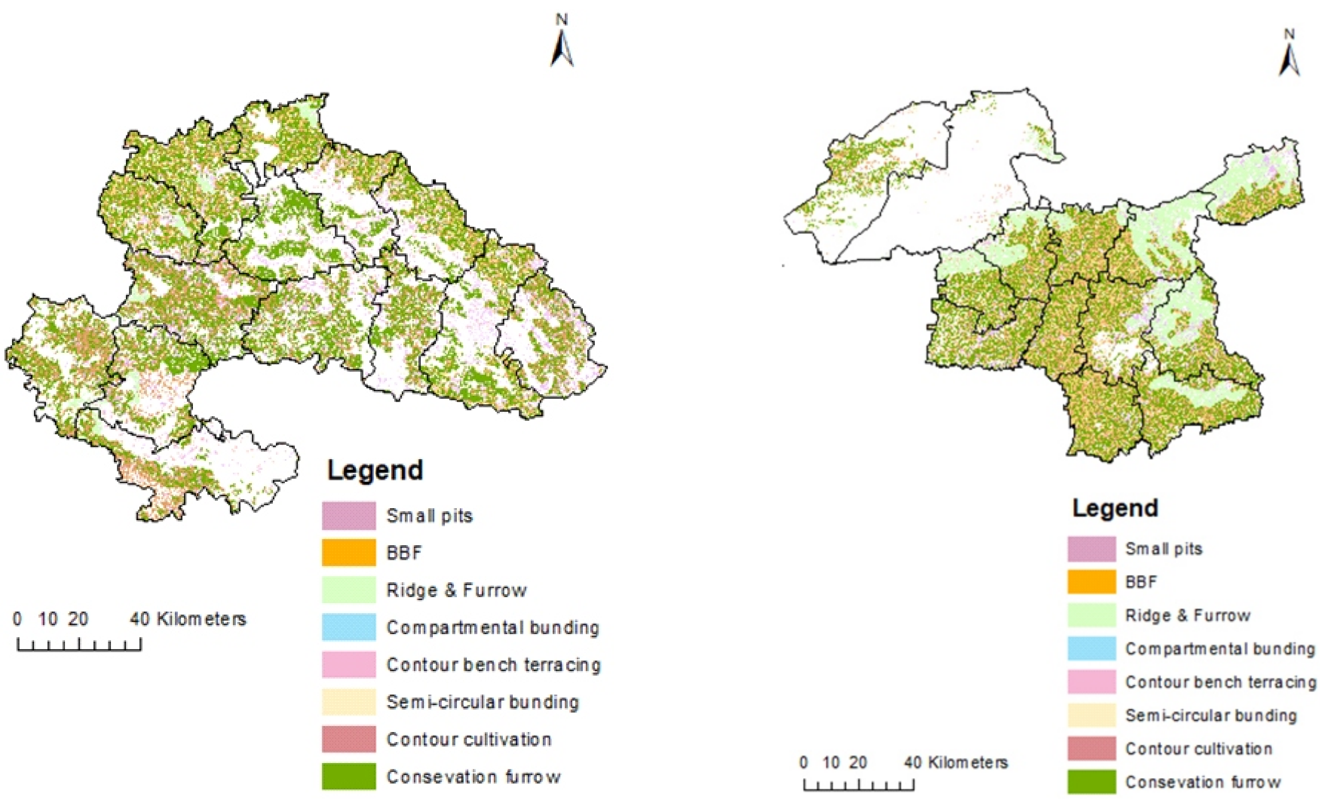


Fig. 3c&d. Suitable *in-situ* interventions identified for Yavatmal and Amaravati districts

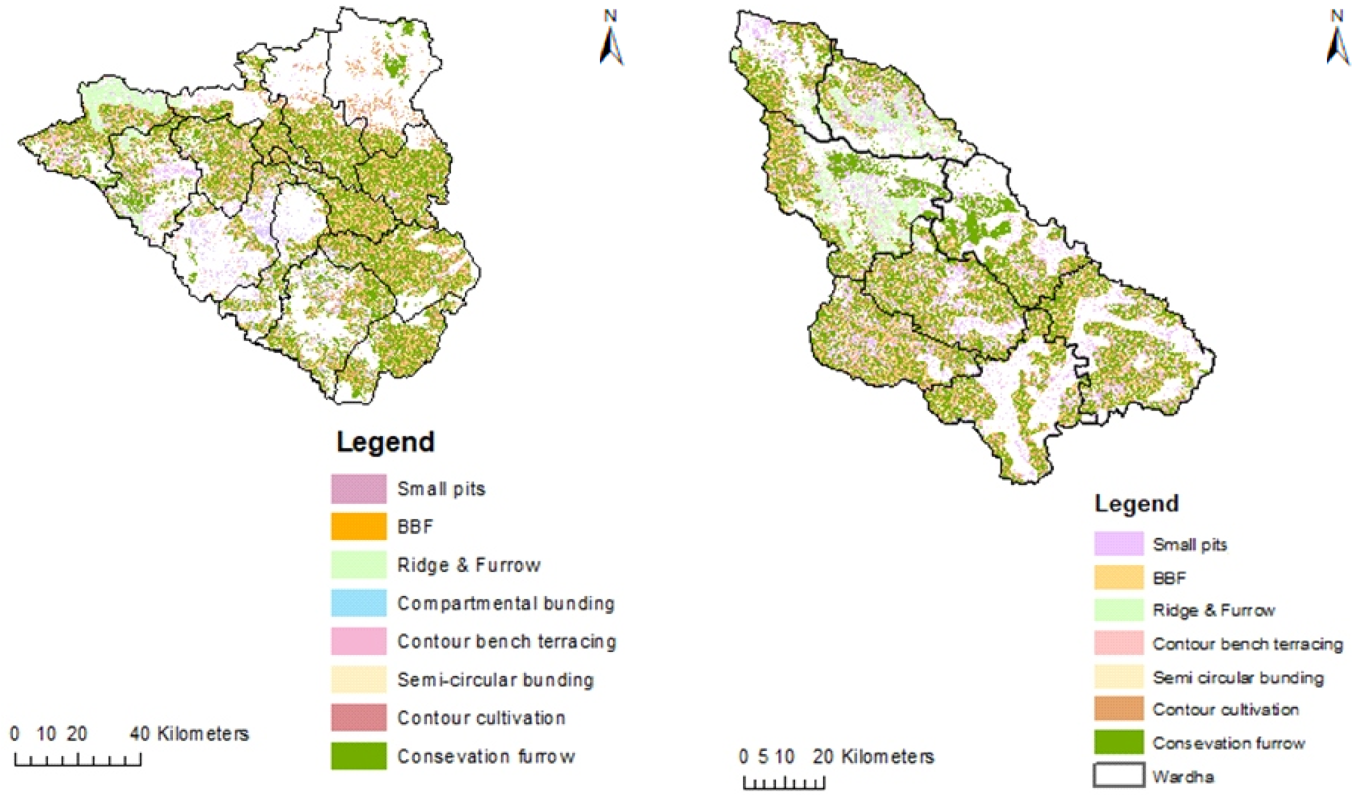


Fig. 3e&f. Suitable *in-situ* interventions identified for Nagpur and Amaravati districts

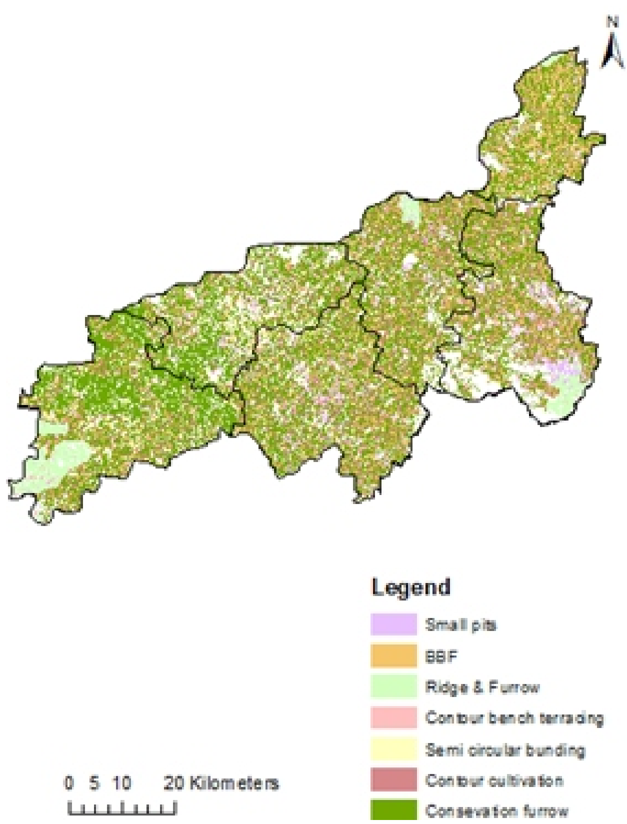
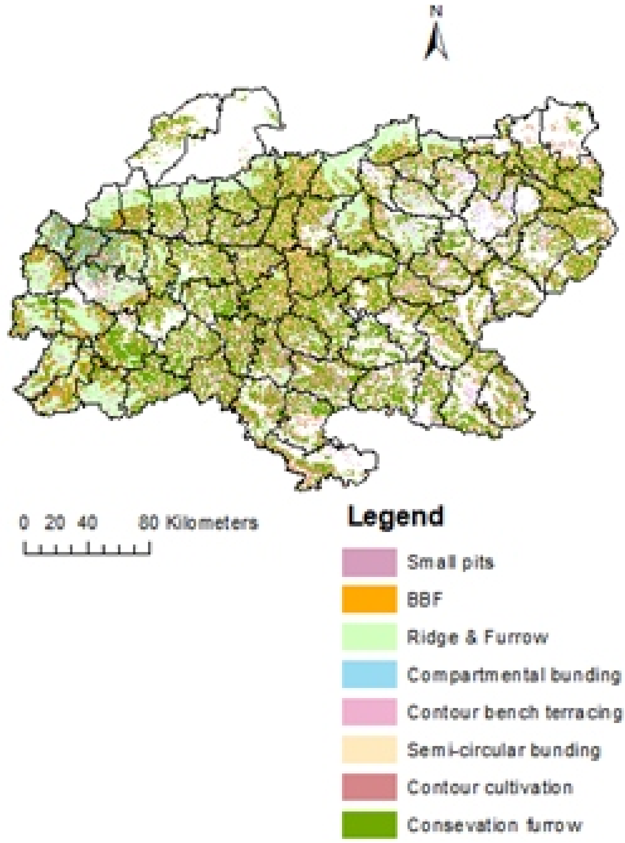


Fig. 3g. Suitable *in-situ* interventions identified for Washim district

conservation techniques and water harvesting structures for watersheds, catchments as well as at district wise planning. Singh *et al.,* 2021 reported that *in-situ* moisture conservation measures like farm bunding in Amaravati district increased crop yields in soybean, cotton and chickpea by 38, 32 and 42%, ridge and furrow in Amaravati, Pune and Nandurbar enhanced bajra and maize yield by 48% and 32%, opening of furrow in cotton and pigeon pea at Aurangabad district increased cotton yield by 23.2% and pigeonpea yield by 26.4%, continuous contour trenching and bunding in soybean, cotton and jowar at Nandurbar district reduced moisture stress and increased crop yield by 19%, 23% and 11% and furrow irrigated raised bed for high value crops in Ratnagiri district resulted in additional returns of 60.5% more over farmers practice. Traditional SWC practices like contour cultivation, mulching and stone bunding are also followed by tribal farmers in Koraput district of Orissa (Dash *et al.,* 2017). Bhattacharyya *et al.,* 2016 reported the suitability of BBF for black soils and conservation furrows for red soils with moderate slopes (0.2% to 0.4%) receiving 500-600 mm rainfall.

4. CONCLUSIONS

In-situ moisture conservation, rainwater harvesting and its optimal utilization for supplemental irrigation using efficient application methods and groundwater recharge are generally recommended as climatic resilient adaptation strategies for rainfed agriculture. The Western Vidarbha



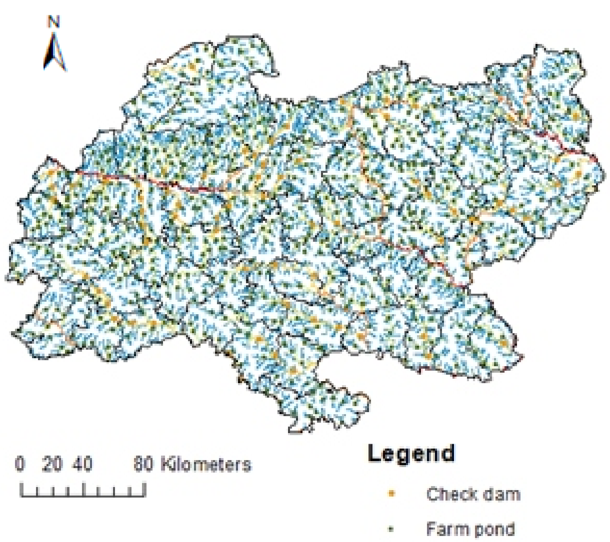


Fig. 4a&b. Suitable *in-situ* interventions and water harvesting / recharge structures identified for western Vidarbha zone of Maharashtra

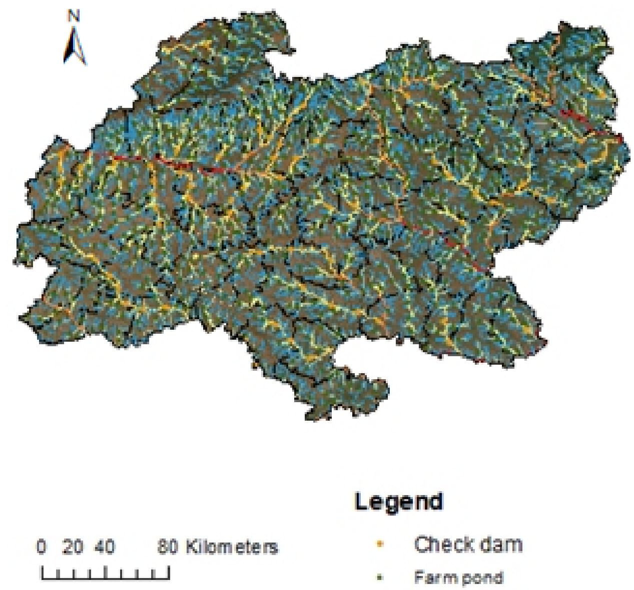


Fig. 4c. Validation of potential sites for different soil and water conservation interventions using Google earth and ground truth

zone of Maharashtra has mean annual rainfall varies spatially from 732 mm to 1273 mm in different sub-districts. Usually dry spells are experienced during July, August and September which coincides with the vegetative or reproductive stages of major rainfed crops and it results in the reduction of crop yield drastically. Planning and adoption of suitable interventions at sub-district level for *in-situ* moisture conservation, supplemental irrigation and groundwater recharge are of prime concern for sustainable water management for climate resilient agriculture in Western Vidarbha zone of Maharashtra. In view of the difficulty in identifying the suitable sites for *in-situ* interventions and rainwater harvesting structures with the help of survey, an attempt was carried out to develop a methodology to plan these interventions using geospatial techniques. The suitable area under each intervention for different sub-districts was determined using Arc-GIS showed that conservation furrow was suitable for 51.5% of the area and contour cultivation for 22.5% area followed by BBF (10.4% area) and ridge and furrow. Small pits and compartmental bunding are suitable in few districts. Similarly, adoption of suitable water harvesting structures like percolation tanks, farm ponds and check dams are also very essential for the sustainable management of Western Vidarbha zone of Maharashtra. This methodology is precise, easy for adoption and could be utilized by stake holders for planning interventions in watersheds or catchments or sub-districts or districts or even for large areas.

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