Journal of Agrometeorology 17 (1) : 55-60 (June 2015)

Location specific *insitu* soil and water conservation interventions for sustainable management of drylands

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ABSTRACT

Identifying the suitable sites for *insitu* and *ex-situ* soil and water conservation interventions with the help of survey is one of the giant tasks for planners. Considering the time consumption for conventional geographical surveys for identification of potential sites, a methodology is being developed using the remote sensing and GIS techniques to find the suitable locations for different *insitu* soil and water conservation interventions. Different thematic layers of slope, soil, rainfall and land use land cover was intersected in ARCGIS and the selected criteria for each intervention was applied for identifying the suitable locations. This methodology was applied for identifying the suitable locations of different *insitu* soil and water conservation interventions such as contour bunds, semi-circular bunds, small pits, contour bench terraces, contour ridges and stone bunds in Adilabad District of Telangana state. Among the different interventions selected, stone bunds, contour bunds and small pits are more suitable for major portion of the Adilabad District. This methodology deciphers more precise, easier and less time consuming planning technique which has the ability to process districts or even large catchments.

Key words: Adilabad, GIS, soil and water conservation interventions

Dryland in India is experiencing more frequent water scarcity events usually in summer months as well as in years with deficient monsoon rainfall and drought years. In these regions, agriculture is the prime source of income for local inhabitants and recent environmental externality is a threat to the agricultural sustainability. One of the major constraints for agricultural production is the availability of irrigation water during dry spells. Sometimes, droughts may generate severe water shortage even for drinking purpose due to decline of groundwater table. Adoption of *insitu* soil and water conservation techniques and construction of rainwater harvesting structures are very essential for the semi arid and rainfed regions due to the erratic nature of monsoon rainfall. The integrated watershed management is a concept and approach in the sustainable development of land and water resources. Watershed development projects are designed to harmonize the use of water, soil, forest and pasture resources while raising agricultural productivity by conserving moisture in the soil and increasing irrigation through tank and aquifer based water harvesting.

Many workers from all over the world have confirmed the potential of soil and water conservation and rainwater harvesting to enhance the productivity (Ramakrishnan *et al.,* 2009; Kadam *et al.,* 2012). The construction of some of these structures decreases the runoff rate, retards the soil erosion, increases the soil moisture content and recharges the aquifer (Ramakrishnan *et al.* 2009; Aladenola and Adeboye, 2010). Failure of structures are mainly due to improper selection, spacing, improper construction and due to no proper treatment of adjacent area contributing to the catchment area. Identifying the suitable sites for rainwater harvesting structures with the help of survey is one of the giant tasks for planner. Considering the time consumption of conventional geographical surveys for identification of potential rainwater harvesting structures, the remote sensing and GIS have been used by several workers (Jasrotia *et al.,* 2009; Singh et al., 2009; Chowdary *et al.,* 2009; Ramakrishnan *et al*., 2008; Ramakrishnan *et al.,* 2009; Shanwad *et al.,* 2011). Thematic layers of landuse/land cover, lithology, soils, slope, rainfall and drainage naps were generated, a set of criteria was applied and potential site suitability map was derived (Ramakrishnan *et al.,* 2008). The accuracy of prediction was estimated on the basis of proximity between derived and field validated sites. In 75% of the cases, the sites derived fall within 15 m distance of field identified sites.

Wherever, vegetative measures and other *insitu* conservation practices are inadequate to handle large flows of water, permanent structures are used as control measures. Hence, planning and adoption of *insitu* conservation practices is more important. Planning of *insitu* soil and water conservation techniques based on soil loss (Reddy *et al.,* 2005); soil, rainfall and slope of the land (Reddy *et al.,* 2005; Pathak *et al.*, 2009; Srivastava *et al.,* 2010); slope and soil depth (Kalgapurkar *et al.,* 2012) precipitation, slope, soil depth, texture, salinity, land use land cover and geological information (Pauw *et al.,* 2008) were reported by earlier researchers. Only limited studies was reported for planning of *insitu* soil and water conservation interventions for drylands. Over the years, many technologies have been developed to address the above problems, but not optimally designed and adopted for Adilabad District. Hence, the present study was taken up with the objective of developing a methodology for working out the exact locations for different *insitu* soil and water conservation interventions and to identify the suitable ones for the sustainable planning and management of large catchments.

MATERIALS AND METHODS

The study area

Telangana is one of the 29 states of India, situated on the country's southern region. It is a semi-arid area and has a predominantly hot and dry climate with a mean annual rainfall of about 755 mm during southwest monsoon (July to September). Summer starts in March, and reaches its peak in May with an average of 42 °C. Two major rivers, the Godavari and the Krishna, flows across the state. The state comprises of 10 districts. The selected district, Adilabad, is in the Telengana region and is located in Godavari river basin. Adilabad district lies between 18°40' and 19°56' N latitude and 77°46' and 79°59'E longitude with an undulated topography ranged from 91 to 666 m above MSL. Major portion of Adilabad is characterized by clayey soil with moderate to severe erosion and the depth of the soil ranged from very shallow to very deep.

Data used

The rainfall grid data of Aphrodite (1951-2007) was used for the spatial analysis of rainfall (http://www.chikyu.ac.jp/precip/products/index.html). The data pertaining to 47 grids covering Adilabad district for the 57 year period was interpolated and used for deriving the mean annual rainfall (Fig.1).

For the estimation of area under different LULC, the LULC data (2004-2012) from NRSC Hyderabad (http://bhuvan.nrsc.gov.in/gis/thematic/index.php) was used and the area was estimated using ARCGIS.

Identification of suitable locations for different insitu soil and water conservation interventions

The Godavari river basin was delineated using Shuttle Radar Topography Mission (SRTM) (90 m resolution) Digital Elevation Model (DEM) following the standard procedure (Rejani et al., 2014). The slope map was derived using Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) (30 m resolution) DEM (http://gdem.ersdac.jspacesystems.or.jp/) and Land Use Land Cover Map for the period 2011-12 (1:50,000 scale) was obtained from NRSC Hyderabad. The soil map from NBSS & LUP and the Aphrodite mean annual rainfall data derived for the 57 year period was used. The thematic layers of slope, soil, rainfall and LULC was prepared in same projection in the GIS domain. These thematic layers were clipped to the district boundary and was intercepted in GIS environment using overlay-intersect tool. Then the criteria described in Table 1 essential for selection of each *insitu* soil and water conservation intervention was incorporated in the intercepted attribute table in ARCGIS 10 and the corresponding suitability map was derived. These criteria were fixed for a specific intervention based on the slope (%) of the land, permeability of the soil, runoff, soil texture, soil depth, rainfall, LULC etc (Ramakrishnan *et al.,* 2008 & 2009; Kadam *et al.,* 2012; Shanwad *et al.,* 2011; Pauw *et al.,* 2008; Justine *et al.,* 1997). The forest area in LULC should be eliminated while planning interventions. The area corresponding to selected intervention was estimated from the derived map using GIS. Then the suitability maps pertaining to each intervention were prioritized based on the area of coverage estimated and these individual maps were overlayed to obtain the final suitability map with the combination of these interventions.

RESULTS AND DISCUSSION

Land use land cover change in Adilabad District

The land use land cover change for the period 2004 to 2012 showed that there is not much change in the area under landuse land cover like deciduous forest, degraded forest, scrub land, water bodies etc. A slight decrease of area under waste land and *rabi* crop area was noted. The *kharif* crop area was less in drought years like 2004 and

Table 1: Site selection criteria for different *insitu* soil and water conservation interventions

Structure	Slope(%)	Permeability	Runoff coefficient	Soil type	Rainfall (mm)	Soil depth (cm)
Contour ridges / furrows(range lands)	5-30%[b]	Low	Medium/high	Slopes>20% - exclude sandy soil [b]	>350 [c]	>30[b]
Contour ridges/furrows (field lands)	5-15%[b] (0.5 to 3)[e]	Low [c]	Medium/high [c]	Silty loam to clay loam [c] ;if Slopes> 20% - exclude sandy soil [b]	>350 [c]	>50[b]
Contour ridges /furrows (tree crops)	2-15% [b]	Low [a & b]	Medium/high [a & b]	Slopes>20% - exclude sandy soil [b]	>350 [c]	100-150 [b]
Semi-circular bunds (shrubs)	5-10% [b]	Low	Medium/high	exclude sandy soil [b]	>200 [b]	>50[b]
Semi-circular bunds (field crops)	5-10% [b] (<5% [c])	Low	Medium/high	exclude sandy soil [b]	>200 [b]	>50[b]
Semi-circular bunds (tree crops)	5-15% [b]	Low	Medium/high	exclude sandy soil [b]	>200 [b]	100-150[b]
Small pits (shrubs)	2-10% [b]	Low	Medium/high	exclude sandy soil [b]	>350	>50[b]
Small pits (tree crops)	2-10% [b]	Low	Medium/high	exclude sandy soil [b]	>350	>100[b]
Small runoff basins (shrubs)	2-5% [b]	Low	Medium/high	exclude sandy soil [b]	>350	>50 [b]
Small runoff basins (tree crops)	2-5% [b]	Low	Medium/high	exclude sandy soil [b]	>350	100-150[b]
Runoff strips (shrubs)	2-10% [b]	Low	Medium/high	exclude sandy soil [b]	>350	>50[b]
Runoff strips (field crops)	2-10% [b]	Low	Medium/high	exclude sandy soil [b]	>350	>100[b]
Contour bench terraces (tree or field crops)	20-50% [b]	Low	Medium/high	exclude sandy soil [b]	>350	30-50 [b]
Stone bunds (tree or field crops)	0.5 to 3% [c]	Low	Medium/high	Clayey soil [c]	>200 [c]	>150[c]
Contour bunds (field crops)	1-6% [a]	Medium to high	Medium/low	exclude deep clayey soil [a]	>200 [c]	<100[c]
Contour bunds (tree crops)	<=5% [c]	Low	Medium/high	exclude sandy soil [b]	>200 [c]	>150[c]
Contour cultivation and Mulching	<=5% [d]	Low	Medium/high	exclude sandy soil	>350	>100[d]

(Source : [a]Shanwad *et al.,* 2011; [b] Pauw *et al.,* 2008;[c]Justine *et al.,* 1997; [d]Kalgapurkar *et al.,* 2012)

2009 whereas the area under current fallow, double crop and *rabi* crop increased shows the scarcity of monsoon rainfall for cultivating the *kharif* crop in these two years.

Variation of rainfall

The spatial variation of annual rainfall in Adilabad District ranged from 20 to 28% during 1951 to 2007. The regions with less mean annual rainfall showed more variation compared to other regions (Fig.1). The temporal variation in mean annual rainfall was 25.4% and number of rainy days was 17.0% in Adilabad. The temporal variation in the rainy days was more in the last one decade showed the variability in the rainfall distribution. Rainfall distribution which contributed the runoff (1971 to 2012) is very important from hydrological point of view. In Adilabad, 59.3% of the rainfall received during 1971 to 2011 was distributed from rainfall <25 mm/day, 22.8% from 25 to <50 mm/day, 9.5% from 50 to <75 mm/day, 4.3% from 75 to <100 mm/day and 4.1 % from rainfall intensities >= 100 mm/day. The larger distribution of low intensity rainfall of less than 25mm/day showed the prime need to adopt *insitu* soil and water conservation interventions to conserve the moisture in the soil itself. The black soil (clayey texture) along with the high rainfall events in Adilabad is contributing to more surface

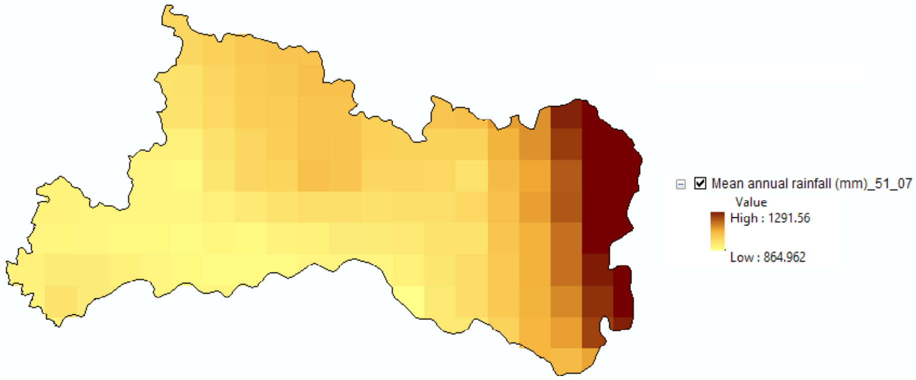

Fig.1 : Spatial distribution of mean annual rainfall in Adilabad (1951-2007)

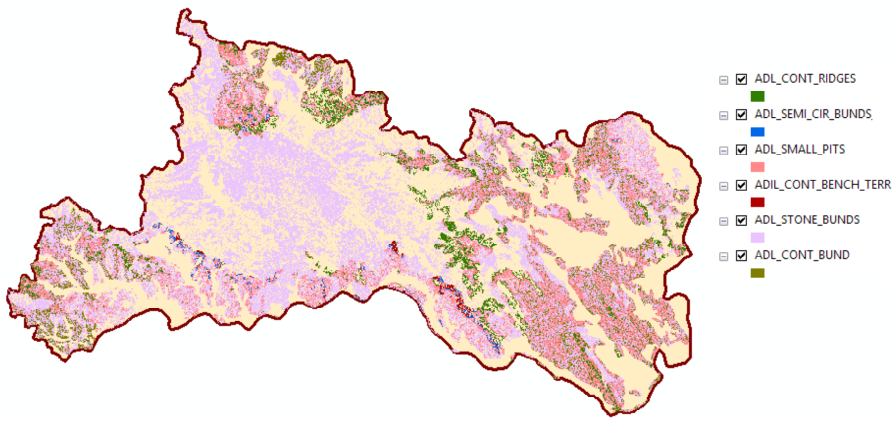

Fig.2 : Suitable locations for different *insitu* soil and water conservation interventions for Adilabad District

Table 2: Area suitable for different *insitu* soil and water conservation interventions in Adilabad District

Insitu soil and water conservation interventions selected	Area suitable (km^2)	% of total area
Stone bunds	6902.5	43.02
Small runoff basins	1915.5	11.94
Small pits (trees)	2203.34	13.73
Semi-circular bunds (trees)	555.4	3.46
Runoff strips	1479.1	9.22
Contour strips	2203.3	13.73
Contour ridges	555.3	3.46
Contour bunds	3363.7	20.96

runoff in Adilabad. This showed the additional scope for planning rainwater harvesting structures like ponds, check dams etc for the critical irrigation in Adilabad district.

The mean annual AET derived from MODIS data for Adilabad district was 1221 mm whereas the mean annual rainfall was 948 mm. This shows the possibility of extraction of groundwater or other sources to meet the additional AET demand in Adilabad District. Overlaying of groundwater status data in GIS showed that the regions of low rainfall with large variation in rainfall distribution come under critical groundwater exploitation category. *Insitu* soil and water conservation interventions and rain water harvesting structures can substantially reduce the groundwater exploitation or the decline in groundwater levels. Hence preference could be given to these regions while implementing watershed treatments.

Suitable locations for insitu soil and water conservation interventions

The Godavari river basin was delineated using DEM and the slope map was generated. The slope map, rainfall map, Land Use Land Cover map and soil map was clipped using the Adilabad district boundary. Major portion of Adilabad District has slope upto 5% and limited area have slopes more than 20%. The soil map showed that major portion of the area have clayey soil with low drainage and the depth of the soil varied from very shallow to very deep. The thematic layers of soil, rainfall, slope and LULC was intercepted and the criteria was incorporated in GIS for identifying the suitable locations for different *insitu* soil and water conservation interventions like contour bunds, semi-circular bunds, small pits, contour bench terraces, contour ridges and stone bunds in Adilabad District. The locations suitable for different *insitu* soil and water conservation interventions for Adilabad region was derived and presented in Fig.2. Among the *insitu* soil and water conservation interventions selected, the interventions like stone bunds (43% of area), contour bunds (21% of area), contour strips (14% of area) and small pits (14% of area) were more suitable for Adilabad District compared to other interventions like contour ridges and semi-circular bunds (Table 2). This methodology can be well adopted for the planning and management of *insitu* soil and water conservation interventions at district level or even for large catchments.

CONCLUSION

Considering the time consumption for conventional geographical surveys for identification of potential sites, a methodology was developed using the remote sensing and GIS techniques to find the suitable locations for *insitu* soil and water conservation interventions required for increasing the productivity of agricultural lands at District level. This methodology was applied for identifying the suitable locations for different *insitu* soil and water conservation interventions like contour bunds, semi-circular bunds, small pits, contour bench terraces, contour ridges and stone bunds for Adilabad District of Telangana state. Among the *insitu* soil and water conservation interventions selected, the interventions like stone bunds, contour bunds and small pits are more suitable for major portion of the Adilabad District compared to interventions like contour ridges and semi-circular bunds. This methodology can be well adopted for the planning and management of *insitu* soil and water conservation interventions at district level and for large catchments.

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Received : December 2014 ; Accepted : April 2015