# Impact of watershed interventions on soil fertility status in Bundelkhand region of semi-arid tropics, India

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**ABSTRACT :** The present study was conducted at ICAR-Central Agroforestry Research Institute, Jhansi to assess soil fertility status of groups of watershed along with control area. Soil samples were collected from three villages (Parasai, Chhatpur and Bachhauni) of watershed site-I of Jhansi district (U.P.), three villages (Shivrampur, Kundar and Dabar) of Tikamgarh district (M.P.) of watershed site-II and two villages (Ganeshgarh and Nayakhera) of Jhansi district (U.P.) as control site. The samples were collected from 0-15 cm soil depth with auger in grid fashion, following standard protocols and assessed for fertility parameters. The soils were slightly (pH: 7.3-7.8) to moderately alkaline (pH: 7.8-8.4). The organic carbon status ranged from low to medium, and available nitrogen (N) was found mostly in low category. The soil available phosphorus (P) was low to medium; available potassium (K) in medium range; and available sulphur (S) in low category. Regarding available micronutrients, boron (B) and zinc (Zn) were in low category, and level of copper (Cu), iron (Fe) and manganese (Mn) were in sufficient range. The assessment of soil fertility in watershed sites revealed that, watershed site-I had better soil fertility status as compared to watershed site-II and control site. Thus, the fertility status data suggests that organic carbon, N, P, S, B and Zn were major soil fertility constraints in the studied watershed areas in Bundelkhand region of semi-arid tropics, India.

**Key words:** Agroforestry, central India, micro-nutrients, soil nutrients and watershed.

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## 1. INTRODUCTION

The soils in semi-arid tropics (SAT) are mostly under *rainfed* conditions and generally occur in regions with little rainfall, high temperature and sparse vegetation. The agricultural activities in these regions are under high pressure of climate change and varying socio-economic conditions. All these reasons coupled with other factors make these soils inherently low in soil fertility. In order to make these soils productive, the restoration of water and soil infertility problems need to be addressed simultaneously (Sahrawat and Wani, 2013; Wani *et al*., 2015). Less attention had been given so far for restoration of soil fertility in *rainfed* conditions, owing to their fragile behavior and too much of spatial and temporal variations. In order to understand the working of any ecosystem, assessment of its variability is quite important. Variability is one of the intrinsic characteristics of soil quality and within same ecosystem; soil properties may show significant spatial variations (Robinson and Metterninch t, 2006).

The current and future food security of the country is feasible only by harnessing the huge untapped potential of *rainfed* agriculture through improved management of land, water, nutrients and other natural resources (Wani *et al*., 2009; Rockstrom *et al*., 2010; Wani *et al*., 2012). We have to produce more food from less land in days to come by efficient utilization of natural resources. Under such conditions, integrated watershed development programme along with agroforestry interventions needs to be strengthened to get desirable benefits so that the system can efficiently cope up with long dry spells, vagaries of crop yield reduction and threatened livelihood security. Implementation of *in-situ* and *ex-situ* interventions such as field bunding, along contours bunding, cultivation across slopes and building of checkdams, low cost gabions, etc. facilitate harvesting of rain water, reduction in runoff, increase in percolation and halting erosion. Other than moisture conservation measures, in watershed sites, some interventions such as integration of improved varieties of crops and fruit species like *Emblica officinalis, Psidium guajava, Citrus* species*, Punica granatum, Carissa carandas, Mangifera indica, Artocarpus heterophyllus, Ziziphus* species etc.; and budding with improved varieties in homegardens to increase nutritional security, may enhance productivity of watershed areas. Further, many multipurpose trees can also be planted on farmers' fields as boundary plantation, agroforestry, live fence including, *Dalbergia sissoo, Tectona grandis,* *Eucalyptus* species, bamboo species, *Acacia senegal, Acacia nilotica* etc. To stabilize the bunds, planting of bajra-napier hybrid, slips of guinea grass, etc. on bunds proved very effective. All interventions in watershed sites bring changes in soil fertility and productivity which help in sustaining agricultural production and strengthening the livelihood support to inhabitant of watershed areas. Thus, considering the above facts in mind, a study was planned to assess the soil fertility of watershed sites with reference to control in Jhansi district of Uttar Pradesh (U.P.) and Tikamgarh district of Madhya Pradesh (M.P.) of Bundelkhand in SAT region of central India.

## 2. MATERIALS AND METHODS

### Site description

Bundelkhand region (23° 8'- 26°31' N and 78°11'- 81°30' E) spread over 7.16 million ha in central India, covering seven districts of U.P. (Jhansi, Jalaun, Lalitpur, Hamirpur, Mahoba, Banda and Chitrakoot) and six districts of M.P. (Sagar, Tikamgarh, Chhatarpur, Panna, Damoh and Datia), is resting on vast granite massif. The region receives an average rainfall varying from 750-1100 mm annually. The present study was conducted to assess soil fertility of cluster of villages in two watershed areas developed by ICAR-Central Agroforestry Research Institute (CAFRI), Jhansi in past years along with one cluster of villages as control for comparison. The ICAR-CAFRI, Jhansi and International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad in association with farming community identified the Parasai-Sindh watershed site of Babina block of Jhansi district in 2011 in order to integrate agroforestry based watershed interventions and to restore water recharge, increase water use efficiency with possible benefits in terms of ecosystem services. This was considered as watershed site-I. The watershed site-I lies between 25º 23´ 56´´ to 25° 27´ 9´´ N and 78° 19´ 46´´ to 78° 22´ 43´´ E. The total area of the site is 1246 ha and situated at 270-315 m above mean sea level. More than 85% area is agricultural land (Singh *et al.,* 2016a). Soil samples were collected from three villages, namely Parasai (29 samples), Chhatpur (32 samples) and Bacchauni (31 samples) from a depth of 0-15 cm soil layer. The Garhkundar-Dabar watershed in Niwari Tehsil of Tikamgarh district of M.P. was considered as watershed site-II. The watershed area falls between 78º 52´ 39´´ to 78º 54´ 44´´E and 25º 26´ 23´´ to 25º 28´ 32´´ N with an altitude of 230-280 m above mean sea level. The total area of watershed is 850 ha. More than 50% area was forested (Singh *et al*., 2016b). The watershed was developed in 2005-06. The soil samples from three villages, namely Kundar (27 samples), Shivrampur (26 samples) and Dabar (28 samples) were collected. Apart from aforementioned two watershed sites, two villages in Jhansi district, namely Nayakhera and Ganeshgarh were considered as control site. From Nayakhera, 19 samples and from Ganeshgarh, 32 soil samples were collected. In general, the major type of soil is *Rakar* (entisol) and *Parwa* (alfisol). *Rabi* crops include *Triticum aestivum, Cicer arietinum, Pisum sativum, Brassica* species etc., and *kharif* included *Arachis hypogaea*, *Vigna mungo, Vigna radiata, Sesamum indicum* etc. Commonly found tree species in the region are listed in Table 1.

### Soil analysis

The soil samples were collected with the help of soil auger from well distributed spots in individual plots in zigzag manner. Further, the bulk soils were reduced in volume by following the process of quartering. The soil samples brought to laboratory were air-dried, followed by grinding and sieving with <2 mm sieve, and subsequently analyzed for soil chemical parameters. The soil pH (1:2.5) and electrical conductivity (EC) (1:2.5) were measured using standard procedures (Jackson, 1973). The estimation of organic carbon (OC) was done by Walkley-Black method (Walkley and Black, 1934), available nitrogen (N) by alkaline potassium permanganate method (Subbiah and Asija, 1956), available phosphorus (Olsen's P) by sodium bicarbonate ($NaHCO_3$) as an extractant (Olsen *et al*., 1954), available potassium (K) by ammonium acetate method (Hanway and Heidel, 1952), and available sulphur (S) was measured using 0.15% calcium chloride ($CaCl_2$) as an extractant (Williams and Steinbergs, 1959). Micronutrients *viz.,* zinc (Zn), copper (Cu), iron (Fe) and manganese (Mn) were extracted by DTPA using the procedure outlined by Lindsay and Norvell (1978), and available boron (B) in soil was estimated by hot water soluble method (Gupta, 1967). The level of deficiency and sufficiency with respect to micronutrients, and low, medium and high ratings for macronutrients were interpreted as per criteria given in Table 2. All the analytical data of soil chemical parameters were computed to assess the variability through average, standard deviation (SD), coefficient of variance (CV), standard error and range.

**Table 1. Common plant species found in the studied watershed areas in Bundelkhand.**

| Common name | Scientific name | Uses |
|---|---|---|
| Palas/ Dhak | *Butea monosperma* | Gum, leaves for dona/platter making, wood for fuel-wood, small agricultural implements |
| Neem | *Azadirachta indica* | Timber for agricultural implements, fuelwood, medicinal uses |
| Sagaun | *Tectona grandis* | Timber |
| Shisham | *Dalbergia sissoo* | Timber/ fuel-wood |
| Babool | *Acacia nilotica* | Fuel-wood/ fodder/ small agricultural implements |
| Kumat | *Acacia senegal* | Live fence/ fuel-wood/ gum |
| Arjun | *Terminalia arjuna* | Bark for medicinal purposes |
| Chirol | *Holoptelea integrifolia* | Fuel-wood |
| Ber | *Ziziphus mauritiana* | Edible fruits |
| Bamboo | *Bambusa* species | Handicrafts and multiple purposes |
| Mahua | *Madhuca latifolia* | Edible and mahua butter |
| Bael | *Aegle marmelos* | Fruit/ medicinal uses |
| Kardhai | *Anogeisus pendula* | Gum/ fuel-wood/ fodder |
| Semal | *Bombax ceiba* | Floss/ fibre |
| Khair | *Acacia catechu* | Kattha/ fuel-wood |

**Table 2. Ratings of fertility for available soil nutrients.**

| Nutrients | Fertility ratings | | |
|---|---|---|---|
| | **Low** | **Medium** | **High** |
| Organic carbon (%) | <0.5 | 0.51-0.75 | >0.75 |
| **Macronutrients (kg ha$^{-1}$)** | | | |
| Alkaline $KMnO_4$- nitrogen (N) | <280.0 | 281-560 | >560 |
| Olsen's phosphorus (P) | <10.0 | 11-25 | >25 |
| Ammonium acetate- potassium (K) | <120.0 | 121-280 | >280 |
| Sulphur (ppm) | <10.0 | 10-20 | >20 |
| **Micronutrients (ppm)** | **Deficient** | **Sufficient** | **Excessive** |
| Boron (B) for sands, loamy sand | <0.5 | 0.5-2.5 | >2.5 |
| Zinc (Zn) | <0.6 | 0.6-1.5 | >1.5 |
| Copper (Cu) | <0.2 | 0.2-5 | >5.0 |
| Iron (Fe) | <2.5 | 2.5-4.5 | >4.5 |
| Manganese (Mn) | <2.0 | 2-4 | >4.0 |

**Source:** Singh *et al*. (2005); Patil *et al*. (2016)

## 3. RESULTS AND DISCUSSION

### Soil reaction and electrical conductivity

The glimpse of soil pH values for watershed site-I revealed that mean value was 7.62 with CV of 1.58% and ranged between 7.50-7.74. While, in watershed site-II, the mean value was 7.98 with CV of 1.88% and in control site, it was 7.75 with CV of 2.18% (Table 3). The relatively low value of CV suggests less level of spatial variation in soil pH. However, the values ranged between slightly alkaline (7.3-7.8) to moderately alkaline (7.8-8.4).The EC values for three sites showed that mean values for watershed site-I was 0.13 dS m$^{-1}$, followed by watershed site-II (0.16 dS m$^{-1}$) and control site (0.17 dS m$^{-1}$). The slightly higher CV of 11-12% suggests some extent of variation in EC spatially. Though, the soluble salt content in the watershed and control sites were making it non-saline.

### Organic carbon and macronutrients

The organic carbon content in both control site (0.38%) and watershed site-II (0.44%) were in low range; while, in watershed site-I, it was recorded in medium range (0.66%) having standard deviation of 0.10, CV of 15.31% and values ranged between 0.58-0.77 (Table 3). Variation in OC in all the three sites might be due to the differences in topographical features, vegetation types, organic matter addition and climatic patterns prevailing in different sites of the study.

The available N was in the low range in all studied sites (Figure 1). It was 277 kg $ha^{-1}$ in watershed site-I (265.49-288.25 kg $ha^{-1}$) with SD of 11.41 and CV of 4.11%. Similarly, in watershed site-II, the mean value was 244.41 kg $ha^{-1}$ (230.53-255.11 kg $ha^{-1}$) with SD of 12.60 and CV of 5.15%. While, in control site, the mean value was 234.64 kg $ha^{-1}$ (224.82-244.46 kg $ha^{-1}$) with SD of 13.89 and CV 5.92% (Table 3). The available P, K and S were also recorded higher in watershed site-I, followed by watershed site-II and control site. The available P was in low range in watershed site-II (Figure 1 and Table 3) and control site, and medium in watershed site-I. Variations might be due to coarse texture of soils having less amount of organic matter. It had mean value in watershed site-I as 12.78 kg $ha^{-1}$ (12.57-12.91 kg $ha^{-1}$), SD of 0.19 and CV 1.45%. The available K was in medium category (Table 3) in studied watershed sites. This might be due to non-application of fertilizer and also, fixation of K in soils. It was 193.65 kg $ha^{-1}$ (189.24-199.74 kg $ha^{-1}$) with SD of 5.45 and CV of 2.81% in watershed site-I. The available S was recorded in low range in all studied sites. Low and medium level of available S could be due to lack of S addition and continuous removal of S by crops (Venkatesh and Satynarayana, 1999). It was 4.16 mg $kg^{-1}$ (3.34-5.37 mg $kg^{-1}$) in watershed site-I with SD of 1.07 and CV of 25.75%. The high value of CV suggests large variation of available S spatially.

### Available micronutrients

The available micronutrients in soil especially B and Zn were found to be low in the studied sites (Table 4). The availability of B in soil is very low, mostly less than 0.3 ppm. The reason might be the soil conditions and low organic matter in soils of SAT region. More of the leaching loss in sandy soils is also a reason for less B availability in soil and subsequently to crops. Satyavathi and Reddy (2004) also reported that Zn

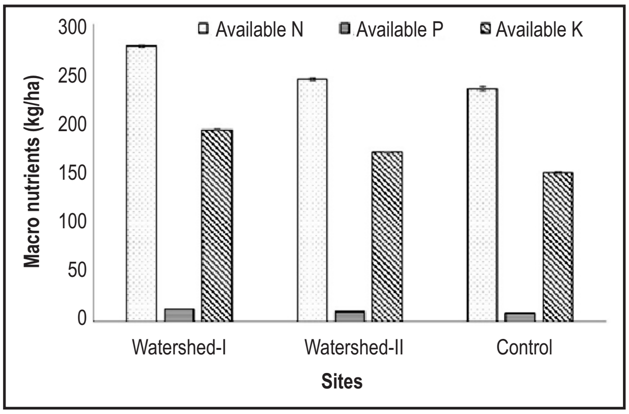


**Fig. 1. Major nutrients (N, P and K) status in soil of watersheds in Bundelkhand.**

**Table 3. Chemical properties of soils of different watersheds in Bundelkhand.**

| Statistics | Soil pH (1:2.5) | Soil EC (dS $m^{-1}$) | Organic carbon (%) | Available N (kg $ha^{-1}$) | Available P (kg $ha^{-1}$) | Available K (kg $ha^{-1}$) | Available S (ppm) |
|---|---|---|---|---|---|---|---|
| **Watershed site-I** | | | | | | | |
| Average | 7.62 | 0.13 | 0.66 | 277.35 | 12.78 | 193.65 | 4.16 |
| SD | 0.12 | 0.01 | 0.10 | 11.41 | 0.19 | 5.45 | 1.07 |
| CV (%) | 1.58 | 11.12 | 15.31 | 4.11 | 1.45 | 2.81 | 25.75 |
| Range | 7.50-7.74 | 0.12-0.15 | 0.58-0.77 | 265.49-288.25 | 12.57-12.91 | 189.24-199.74 | 3.34-5.37 |
| **Watershed site-II** | | | | | | | |
| Average | 7.98 | 0.16 | 0.44 | 244.41 | 10.41 | 170.88 | 3.49 |
| SD | 0.15 | 0.02 | 0.03 | 12.60 | 0.37 | 6.72 | 0.34 |
| CV (%) | 1.88 | 11.12 | 7.91 | 5.15 | 3.60 | 3.93 | 9.69 |
| Range | 7.81-8.09 | 0.14-0.17 | 0.42-0.48 | 230.53-255.11 | 10.04-10.79 | 163.14-175.19 | 3.12-3.78 |
| **Control site** | | | | | | | |
| Average | 7.75 | 0.17 | 0.38 | 234.64 | 9.26 | 150.10 | 3.13 |
| SD | 0.17 | 0.02 | 0.06 | 13.89 | 0.23 | 7.83 | 0.08 |
| CV (%) | 2.18 | 12.11 | 15.78 | 5.92 | 2.52 | 5.22 | 2.44 |
| Range | 7.63-7.87 | 0.15-0.18 | 0.34-0.43 | 224.82-244.46 | 9.09-9.42 | 144.56-155.63 | 3.08-3.18 |

**Table 4. Status of soil micronutrients in different watersheds of Bundelkhand.**

| Statistics | Boron (ppm) | Zinc (ppm) | Copper (ppm) | Iron (ppm) | Manganese (ppm) |
|---|---|---|---|---|---|
| **Watershed site-I** | | | | | |
| Average | 0.26 | 0.51 | 0.35 | 5.65 | 7.44 |
| SD | 0.07 | 0.13 | 0.09 | 0.76 | 2.64 |
| CV (%) | 25.33 | 26.55 | 26.62 | 13.43 | 35.46 |
| Range | 0.22-0.34 | 0.41-0.66 | 0.25-0.44 | 5.11-6.52 | 4.40-9.15 |
| **Watershed site-II** | | | | | |
| Average | 0.32 | 0.38 | 0.27 | 5.41 | 5.75 |
| SD | 0.04 | 0.01 | 0.05 | 0.66 | 1.06 |
| CV (%) | 13.28 | 3.17 | 17.58 | 12.26 | 18.41 |
| Range | 0.27-0.35 | 0.36-0.38 | 0.23-0.32 | 4.81-6.13 | 4.90-6.94 |
| **Control site** | | | | | |
| Average | 0.29 | 0.40 | 0.34 | 4.91 | 5.41 |
| SD | 0.04 | 0.03 | 0.09 | 1.20 | 0.01 |
| CV (%) | 14.12 | 6.90 | 28.02 | 24.51 | 0.17 |
| Range | 0.26-0.31 | 0.38-0.42 | 0.27-0.40 | 4.06-5.76 | 5.40-5.42 |

content in soils decreased with increase in pH. The Zn might have been precipitated and their decreased mobility and solubility may reduce their availability (Patil *et al*., 2006). Level of Cu, Fe and Mn were more than sufficient in studied sites. The high values of CV in watershed site-I suggests high variation of micronutrients spatially in the sampled areas. The soil available B was 0.26 ppm in watershed site-I, followed by 0.32 ppm in watershed site-II and 0.29 ppm in control site. Similarly, the level of Zn in watershed site-I was 0.51 ppm, followed by 0.38 ppm in watershed site-II and 0.40 ppm in control site. The available Cu, Fe and Mn were 0.35, 5.65 and 7.44 ppm, respectively in watershed site-I, followed by value of 0.27, 5.41 and 5.75 ppm in watershed site-II and 0.34, 4.91 and 5.41 ppm in control site.

## 4. CONCLUSION

The present study, conducted to determine soil fertility status of two watershed sites, suggests that the soils were mostly slightly to moderately alkaline in nature. The organic carbon status ranged from low to medium and available N mostly in low category. The soil available P was low to medium, available K was in medium range and available S was in low category. Regarding available micronutrients, B and Zn were in low category, and level of Cu, Fe and Mn was in sufficient range. The assessment revealed that watershed site-I had better soil fertility status as compared to watershed site-II and control. Thus, the fertility status data confirms that organic carbon, N, P, S, B and Zn were major soil fertility constraints. The results of this study very aptly suggest improvement of nutrient status over time as compared to control sites. Bundelkhand region is characterized with very peculiar, geological and climatic conditions, led to low water availability, sparse vegetation, degradation thus, making the SAT region of the area as the main hotspot for water scarcity. At this crucial juncture, we have to explore ways and forms for much more efficient utilization of natural resources. Agroforestry based watershed interventions has the potential not only to make the availability of water at the very doorsteps but also able to increase water recharge, reduce runoff, increase percolation, improved diversity, enhance livelihood security and overall ecosystem functioning. Thus, more and more of such work concerned with agroforestry based watershed interventions needs to be scaled up and promulgated for environmental and social sustainability.

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