A Spatial Distribution of Organic Carbon status in Koppal and Yadgir Taluks of Karnataka, India using GIS and Geostatistics

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ABSTRACT

Spatial distribution of Soil Organic Carbon (SOC) status is necessary for enhancing crop and soil productivity. In this study, soil samples were collected from Koppal and Yadgir taluks (Northern dry zone and Northeastern dry zone) of Karnataka at 320 m grid interval at 0-15 cm depth and assessed for organic carbon and map was prepared under GIS using Arc GIS 10.4 Geowizard Kriging method. The results of the study showed that, SOC was medium in 37 per cent and high in 26 per cent of the total area (1,38,298 ha) in Koppal taluks. Whereas, in Yadgir taluks, SOC status was medium in 38 per cent and high in 31 per cent of the total area (1,71,060 ha). The descriptive statistics were positively skewed with positive kurtosis value. The spatial variability showed a moderate spatial dependence with spherical model in both the taluks. Therefore, the study showed that, most of the soils were medium in SOC status. There is a need of integrated nutrient management with additional emphasis for enhancing SOC for sustainable crop production.

INTRODUCTION

In India, fertility constraints are limiting the optimum crop productivity. Therefore, it is important to investigate the fertility status of soils which provide valuable information for managing soil health and crop productivity (Rajendra Hegde et al., 2021). Inadequate and imbalanced use of chemical fertilizers, improper irrigation and faulty cultural practices also deplete the soil quality (Medhe et al., 2012). Several studies have assessed the soil fertility status for recommending optimum soil management practices, crops and cropping systems to ensure sustainable yields in the rainfed regions (Prabhavathi et al., 2013). Hence, it is necessary to know the fertility status particularly Soil Organic Carbon (SOC) status of the soils for assessing the kind and amount of fertilizers and manures required for each of the crop intended to be grown (Mahendra Kumar et al., 2015). Balanced use of organic, chemical fertilizers and biofertilizers is a must to maintain soil fertility in long run (Singh et al., 2014).

Soil organic matter is a primary source of plant mineral nutrition and an essential part of the terrestrial soil carbon pool. SOC has important role in water and nutrient retention in soils, optimizing soil water and air relationships, soil structure, etc. The content and dynamics of soil organic matter directly impact the global carbon cycle (Ping et al., 2021). Soil nutrition loss is associated with the condition of land degradation, which affects the health of soil carbon pool (Smith, 2008). Therefore, it is necessary to carry out soil and water conservation measures to promote soil carbon recovery and accumulation (Lal, 2004). SOC is the basis of soil fertility. It releases nutrients particularly micronutrients for plant growth, promotes the structure, biological and physical health of the soil, and is a buffer against harmful substances. Increasing SOC improves soil health and fertility as well as help to mitigate climate change. Many management practices that increase SOC also improve crop and pasture yields.

The spatial variability of soil properties can be measured and quantified at a given scale with regular sampling technique for designing sustainable land management practices (Stenger et al., 2002). In India, majority of soil maps were prepared by conventional methods on smaller scale. Due to initiation of detailed surveys in drought prone areas of Karnataka along with grid survey, the modern spatial prediction techniques were employed in spatial variability of soil properties (Mali et al., 2016; Pal et al., 2014; Saha et al., 2012). The carbon content of soils is being depleted and affecting soil health. Universally, SOC is critical for agriculture and environmental ecology, and its content directly affects the function and sustainable utilization of soil ecosystems (Junyao Li et al., 2020). The spatial distribution characteristics of SOC content are affected by many environmental cofactors and their variability has different characteristics at different scales. In this context, the present study was undertaken to evaluate the soil organic carbon status in Kopal and Yadgir soils of Karnataka using GIS and Geostatistical methods.

MATERIALS AND METHODS

The study was conducted in the Kopal and Yadgir taluks (Northern dry zone and Northeastern dry zone) of Karnataka, India (Figs.1 & 2). The Koppal taluk is located in between 15°08'67" to 15°37'00" N latitudes and 75°53'4" to 76°25'28" E longitudes, covering an area of 1,38,298 ha. The major parent material is granite gneiss. The climate is semi-arid and categorised as drought prone. The maximum summer temperature recorded was 45°C and minimum temperature was 16°C in winter. Mean maximum temperature was 39°C and mean minimum temperature was 23°C. It falls under semiarid tract of the state and is categorized as drought-prone with total annual rainfall of 662 mm, of this, a maximum of 424 mm precipitation takes place during south–west monsoon from June to September, north-east monsoon contributes about 161 mm and prevails from October to early December and the remaining 77 mm received during the rest of the year. The entire area was having red and black soils with loamy to clayey texture. The soil depth was shallow to deep with very gently to gently sloping land.
Yadgir taluk, spread over an area of 1,71,060 ha, lies in between 16°28'18" to 16°57'05" N latitudes and 76°58'45" to 77°28'32" E longitudes. The granite gneiss is major parent material. The climate is semi-arid and categorized as drought prone. The summer season starts from middle of February and continues up to first week of June. The coldest season starts from December to middle of February. December is the coldest month with mean daily maximum and minimum temperature of 29.5°C and 10°C, respectively. During summer, temperature reaches up to 45°C. It falls under semi-arid tract of the state and is categorized as drought-prone with total annual rainfall of 866 mm, of this, maximum of 652 mm received during south–west monsoon from June to September; the north-east monsoon from October to early December contributes about 138 mm and the remaining 76 mm during rest of the year. The soils of entire area are black with loamy to clayey texture. The depth of the soil is deep to very deep with very gently to gently sloping land.

The surface soil samples were collected from farmer’s field in the year 2018 for fertility status (major and micronutrients) at 320 m grid interval and the sample location was recorded with GPS. The collected samples were air-dried, ground and analyzed for organic carbon by
following the wet oxidation digestion method (Walkley and Black, 1934).

The geostatistical methods were used for data analysis. The interpolation predicts values for cells in a raster from a limited number of sample data points. It can be used to predict unknown values for any geographic point data such as elevation, rainfall, chemical concentrations and so on. A point layer in which each symbol in the point layer represents a location where the samples have been measured. Interpolating the values between these input points will be predicted from the surface menu of Arc GIS 10.4 Geo-wizard method for interpolation and spherical model was used for Kriging. The generated map was reclassified based on ratings of organic carbon (Low - <0.50%, Medium - 0.50% to 0.75% and High - >0.75%) and area of occurrence for each category of nutrient was calculated. Then, descriptive statistics and semivariogram parameters were calculated in the excel sheet.

RESULTS AND DISCUSSION

The organic carbon status in the soils of Koppal taluk was low in 21,765 ha (18%), medium in 44,730 ha (37%) and high in an area of about 31,302 ha (26%) (Fig.3). The organic carbon content in the soils of Yadgir taluk revealed that, low, medium and high in an area of

![Fig.3. Soil organic carbon status of Koppal taluks.](image1)

![Fig.4. Soil organic carbon status of Yadgir taluks.](image2)
about 22,621 ha (13%), 64,372 ha (38%) and 53,910 ha (31%), respectively (Fig.4). The reason for low organic carbon content in the soils was due to prevalence of arid condition, where the decomposition of organic matter occurs at a faster rate coupled with limited addition of organic manures, low vegetative cover and varied cropping pattern, thereby leaving less chances of accumulation of organic carbon in the soils (Dowuona et al., 1998). The baseline survey of households in Sujala-III Project area revealed that, the quantity of Farm Yard Manure (FYM) applied by the farmers is less than one tonne per hectare at an interval of 3-4 years. Intensive cropping is also one of the reasons for low organic carbon content in soils. The results were in conformity with the findings of Patil et al. (2016, 2017, 2018).

**Descriptive Statistics**

The organic carbon content in the soils of Koppal and Yadgir taluks ranged from 0.01 to 2.91 and 0.01 to 4.08 per cent with a mean of 0.68 and 0.73 per cent respectively and standard deviation of 0.36 and 0.42. The variance of 0.13 and 0.18 and coefficient of variation of 52.64 and 57.21 per cent respectively (Table 1). The values were positively skewed and had positive kurtosis value. The organic carbon content was medium to high in most of the soil samples due to regular addition of organics in the form of FYM and compost. Similar results were obtained by Hegde et al. (2021). According to Rao et al. (2008) higher clay in the soils was responsible for maximum organic carbon content in the soils.

**Variogram and Model Parameters**

The lag size and range of soil organic carbon of Koppal and Yadgir taluks were 627.71 and 90.28 m and 5043.69 and 608.96 m respectively with variogram expressed in exponential model. This model fits the experimental semivariogram for soil nutrients with low RMSE values (Figs.5 & 6). Similar results were obtained by Hegde et al. (2019). The spatial dependence was moderate in both the taluks with nugget of 0.09 and 0.08, partial sill of 0.03 and 0.07, and sill of 0.12 and 0.15 respectively. The Nugget to Sill ratio (N:S ratio) of 0.75 and 0.54 respectively (Table 2). It had low nugget effect, which suggests that random variance of variable is low in the study area. This means that near and away samples have similar and different values, respectively. In other words, a small nugget indicated a spatial discontinuity between neighbouring points and showed weak spatial dependence at the same grid points.

The variogram of soil organic carbon was described by spherical model. The soil organic carbon showed moderate spatial variability which might be attributed to extrinsic factors like fertilization and cultivation practices and intrinsic factor like soil forming processes. This is in conformity with Reza et al. (2012).

Organic carbon status in soils can be enhanced with following measures. Integrated approaches such as, application of recommended dose of FYM, green manure, growing of sunhemp as an intercrop and incorporation to soil at flowering stage in wider row spaced crops like maize, cotton, sunflower, fruit and plantation crops, growing of legume as an intercrop to increase organic carbon content of soil. Crop rotation with legume and crop residue management using microbial consortium. These practices will also help in arresting land degradation, improving physical, chemical and biological properties and fertility status of soils to achieve sustainable production.

| Location of study area (Taluks) | Mean | Min. | Max. | Std. Dev. | Variance | Kurtosis | Skewness | Coeff. of variation (%) |
|-------------------------------|------|------|------|-----------|----------|----------|----------|------------------------|
| Koppal                        | 0.68 | 0.01 | 2.91 | 0.13      | 0.18     | 3.60     | 1.34     | 52.64                  |
| Yadgir                        | 0.73 | 0.01 | 4.08 | 0.18      | 0.36     | 1.05     | 1.34     | 57.21                  |

| Location of study area (Taluks) | Lag size (m) | Range (m) | Nugget (C0) | Partial sill (C0) | Sill (C0+C) | N:S ratio | Spatial dependence | Model | RMSE |
|-------------------------------|-------------|-----------|-------------|------------------|-------------|-----------|--------------------|-------|------|
| Koppal                        | 627.71      | 5043.69   | 0.09        | 0.03             | 0.12        | 0.75      | mod. Spher.       | 0.30  |      |
| Yadgir                        | 90.28       | 608.96    | 0.08        | 0.07             | 0.15        | 0.54      | mod. Spher.       | 0.85  |      |

mod. - moderate; Spher. - Spheroidal

Fig.5. Semivariogram model of organic carbon of Koppal taluks.
CONCLUSION

The soils of Koppal and Yadgir taluks were medium to high in organic carbon status. The descriptive statistics were positively skewed with positive kurtosis value. The semivariograms were expressed in exponential model with low RMSE values in soils. The spatial dependence was moderate with spherical model in both the taluks. Most of the soils in these taluks were medium in fertility status. There is a need of integrated nutrient management and interventions to incorporate additional quantities of organic manures.

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Fig.6. Semivariogram model of organic carbon of Yadgir taluks.
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