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

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Research Article

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Abstract

Spatial variability of soil organic carbon status is necessary for enhancing crop and soil productivity. In this study, soil samples were collected from Koppal and Yadgir taluk in 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 Geo-wizard Kriging method. The results of the study indicated that, soil organic carbon content was medium in 37 per cent and high in 26 per cent of the total area (1,38,298 ha) in Koppal taluk. Whereas in Yadgir taluk, soil organic carbon 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 study showed a moderate spatial dependence with spherical model. Therefore, the study showed that, most of the soils were medium in fertility status. There is a need of integrated management for sustainable crop production.

Introduction

In India, low fertility of soils is the major constraint to achieving high productivity goals. Therefore, it is important to investigate the soil fertility status and it may provide valuable information relating crop research (Rajendra Hegde et al. 2021). Imbalanced and inadequate use of chemical fertilizers, improper irrigation and various cultural practices also deplete the soil quality rapidly (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 of the soils for assessing the kind and amount of fertilizers required for each of the crop intended to be grown (Mahendra Kumar et al. 2015). Balanced use of organics, fertilizers and biofertilizers plays an important role to maintain soil fertility in long run (Singh et al. 2014).

Soil organic carbon is the basis of soil fertility. It releases nutrients for plant growth, promotes the structure, biological and physical health of soil, and is a buffer against harmful substances. Increasing soil organic carbon improves soil health and fertility as well as helping to mitigate climate change. Many management practices that increase soil organic carbon 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 (Journel and Huijbregts 1978; Stenger et al. 2002). Most of the studies on spatial variability of soil attribute using geospatial techniques have been carried out in diverse temperate countries (Blackmore et al. 1998; Cambardella and Karlen 1999; Domsch and Wendroth 1997; Geypens et al. 1999; Heisel et al. 1999; Verhagen 1997). In the past three decades, the application of geostatistical methods by soil researchers primarily focused on predicting spatial variability along a transect (Schloeder et al. 2001) or at field-scale (Cambardella et al. 1994; Stenger et al. 2002).

Using geostatistics, GIS and remote sensing techniques for large area in Australia, McBratney et al. (2003) provided the comprehensive maps for soil properties. 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). A recent study (Tziachris et al. 2017) made a comparative study of interpolation techniques and confirmed that Kriging. The carbon content of soils is being depleted and affecting soil health. In order to take stock of situation about the status and spatial variability of soil organic carbon for making advisory on area basis, the present investigation was carried out in Kopal and Yadgir soils of Karnataka.

Materials And Methods

In the present study, Kopal and Yadgir districts were selected as study area in Northern dry zone and Northeastern dry zone of Karnataka (Figure 1 & Figure 2). Koppal district is located in between 15^0 08'67"-15^0 37'00" N latitudes and 75^0 53'4"-76^0 25'28" E longitudes, covering an area of 1,38,298 ha. The major parent material of the area is granite gneiss. The climate of the area is semi-arid and categorised as drought prone. The maximum temperature during summer was 45°C and the 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 period 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. Entire area is having red and black soils with loamy to clayey texture. The soil depth of the area was shallow to deep and gradient of land was very gently sloping to gently sloping.

Yadgir district is located in between 16^0 28'18"-16^0 57'05" N latitudes and 76^0 58'45"-77^0 28'32" E longitudes, covering an area of 1,71,060 ha. The major parent material of the area is granite gneiss. The climate of the area is semi-arid and categorised as drought prone. The summer season starts during the middle of February and continues up to the first week of June. The period from December to the middle of February is the coldest season. December is the coldest month with mean daily maximum and minimum temperatures being 29.5^0C and 10^0C respectively. During peak summer, temperature shoots up to 45^0C. It falls under semiarid tract of the state and is categorized as drought- prone with total annual rainfall of 866 mm. Of this, maximum of 652 mm is received during the south–west monsoon period from June to September; the north-east monsoon from October to early December contributes about 138 mm and the remaining 76 mm during the rest of the year. Entire area is having black soils with loamy to clayey texture. The soil depth of the area was deep to very deep and gradient of land was very gently sloping to gently sloping.

Surface composite soil samples collected in the year 2018 from farmer's field for fertility status (major and micronutrients) at 320 m grid interval in the study area and the sample location was recorded by GPS. The soil samples were air-dried, ground (0.2 mm) and organic carbon was analyzed as per procedure laid out by Walkley and Black (Nelson and Sommers 1975).

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 has been measured. By interpolating the values between these input points will be predicted from the surface menu of Arc GIS 10.4 Geo-wizard Kriging method for Interpolation and spherical model is used for Kriging. The generated map was reclassified based on rating of organic carbon status (<0.5% - Low, 0.5% to 0.75% - Medium and 0.75% - High) and area for each category of nutrient was calculated. Descriptive statistics and semivariogram parameters of soil properties were also calculated.

Results And Discussion

The distribution of organic carbon content 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 %) (Figure 3). The presence of organic carbon status in the soils of Yadgir taluk revealed that, low, medium and high in an area of about 22,621 ha (13%), 64,372 ha (38%) and 53,910 ha (31%), respectively (Figure 4).The reason for low organic carbon content in these soils may be attributed to the prevalence of arid condition, where the decomposition of organic matter occur at a faster rate coupled with little or no addition of organic manures, low vegetative cover on the fields and varied cropping pattern, thereby leaving less chances of accumulation of organic carbon in the soils (Dowuona et al. 1998; Nye and Stephans 1962). Baseline survey of households in Sujala-III Project area revealed that, the quantity of 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 are in confirmation with those reported by Patil et al. (2016, 2017a, 2017b, 2018a, 2018b, 2018c).

Descriptive statistics

The soil organic carbon (OC) content of Koppal and Yadgir taluk 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 S.D. of 0.36 and 0.42 per cent. The variance of 0.13 and 0.18 and C.V. of 52.64 and 57.21 per cent respectively (Table 1). The values were positively skewed and had positive kurtosis value. The soil organic carbon (OC) content was medium to high in majority of soil samples due to regular addition of organics in the form of FYM and compost. Similar results were obtained by Rajendra Hegde et al. (2021). According to Rao et al. (2008) higher clay content in soil was responsible for maximum organic carbon content in soils.

Variogram and model parameters (Geo-statistics)

The lag size and range of soil organic carbon of Koppal and Yadgir taluk was 627.71 and 90.28 m and 5043.69 and 608.96 m respectively with variogram expressed in exponential model fits the experimental semivariogram for soil nutrients with low RMSE values (Figure 5 and Figure 6) similar results were obtained by Rajendra Hegde et al. (2019). The spatially 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 neighboring 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 (fertilization and cultivation practices) and intrinsic factor (soil forming processes). This observation is in conformity with Reza et al. (2012).

The organic carbon status in soils is to be enhanced with following integrated approaches such as, application of recommended dose of FYM for each crop grown, green manuring using pre monsoon rainfall, 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 due to shedding of leaves at maturity, crop rotation with legume to increase organic carbon content of soil due to shedding of leaves at maturity and crop residue management using microbial consortium.

The suggested above practices will help in arresting land degradation, improving physical, chemical and biological properties and fertility status of soils to achieve sustainable production.

Conclusion

The soils of Koppal and Yadgir taluk in Karnataka were medium to high in organic carbon status. The descriptive statistics showed positively skewed with positive kurtosis value. The semivariogram were moderate spatial variability with spherical model. There is a need of integrated soil organic carbon management for sustainable crop production.

Declarations

Acknowledgement

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Conflict of interest

The authors declare no competing interests.

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Authors contribution

This work was carried out in collaboration among all authors. Author Rajendra Hegde approved the study. Author M.B. Mahendra Kumar designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author K. V. Niranjana corrected the manuscript and managed the analyses of the study. Author K. V. Seema prepared the maps in GIS environment. Author B. A. Dhanorkar managed the literature searches. All authors read and approved the final manuscript.

Availability of data and material

All relevant data are available on request.

Code availability

Not applicable.

Ethics approval

Not applicable.

Consent to participate

Not applicable.

Consent for publication

Not applicable.

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Tables

Table 1: Descriptive statistics of organic carbon status of Koppal and Yadgir taluks.

Location of study area (Taluk)	Mean	Minimum	Maximum	Standard Deviation	Variance	Kurtosis	Skewness	Coefficient of variation (%)
Koppal	0.68	0.01	2.91	0.36	0.13	2.57	1.05	52.64
Yadgir	0.73	0.01	4.08	0.42	0.18	3.60	1.34	57.21

Table 2: Semivariogram parameters of soil organic carbon.

Location of study area (Taluk)	Lag size (m)	Range (m)	Nugget (C_0)	Partial sill (C)	Sill (C_0 +C)	N:S ratio	Spatial dependence	Model	RMSE
Koppal	627.71	5043.69	0.09	0.03	0.12	0.75	moderate	Spherical	0.30
Yadgir	90.28	608.96	0.08	0.07	0.15	0.54	moderate	Spherical	0.85

Figures

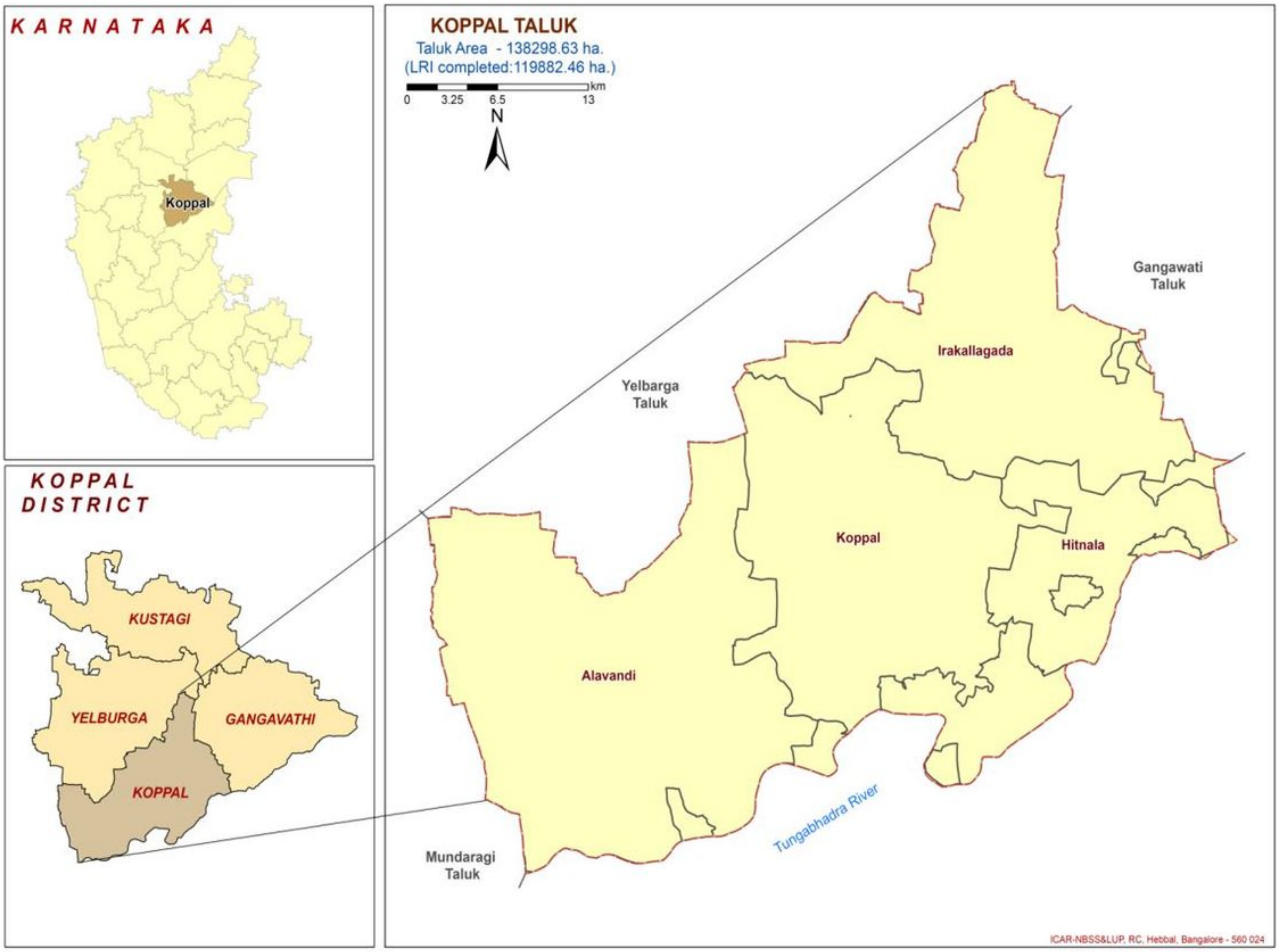

Figure 1

Location map of Koppal taluk.

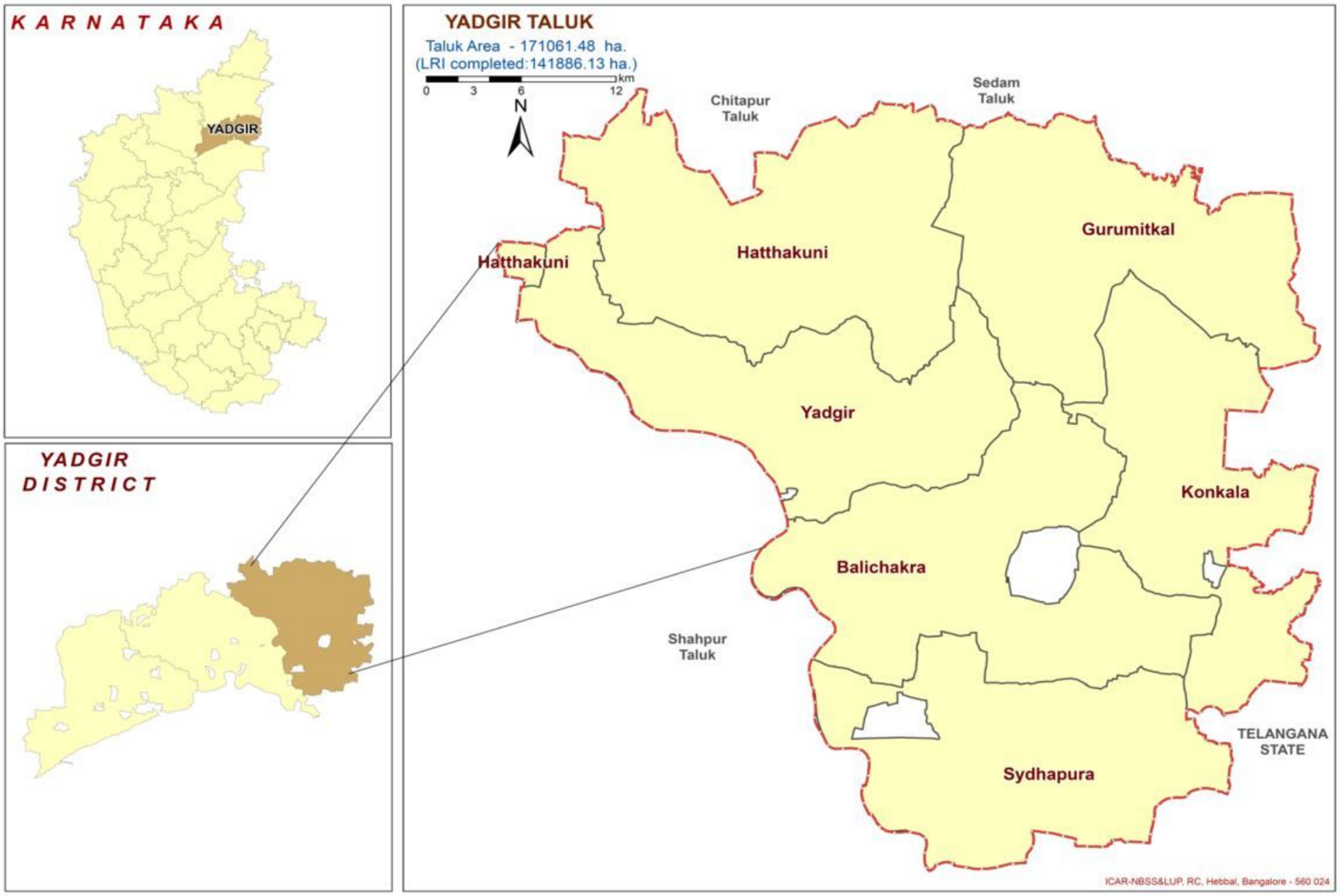

Figure 2

Location map of Yadgir taluk.

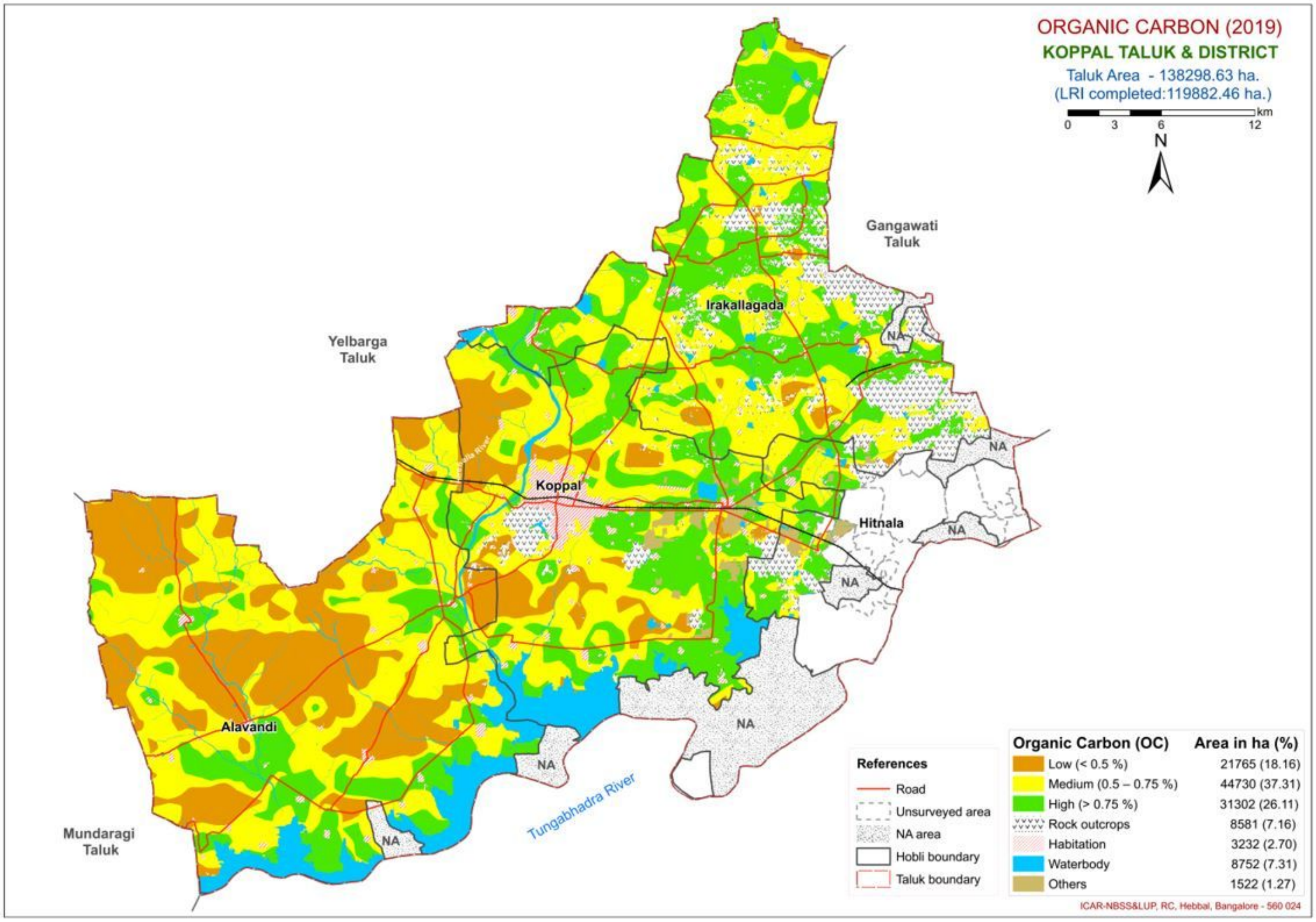

Figure 3

Soil organic carbon status of Koppal taluk.

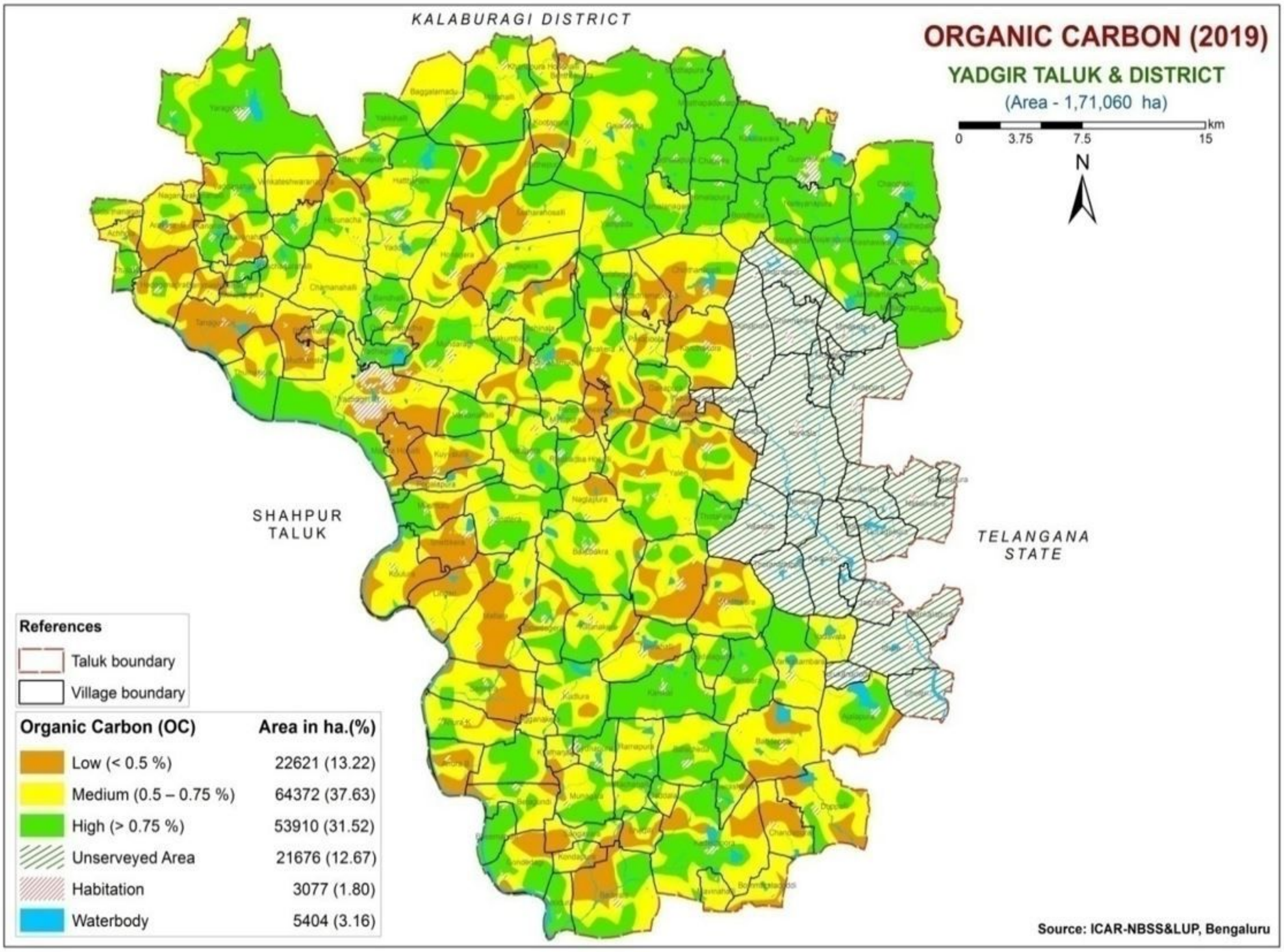

Figure 4

Soil organic carbon status of Yadgir taluk.

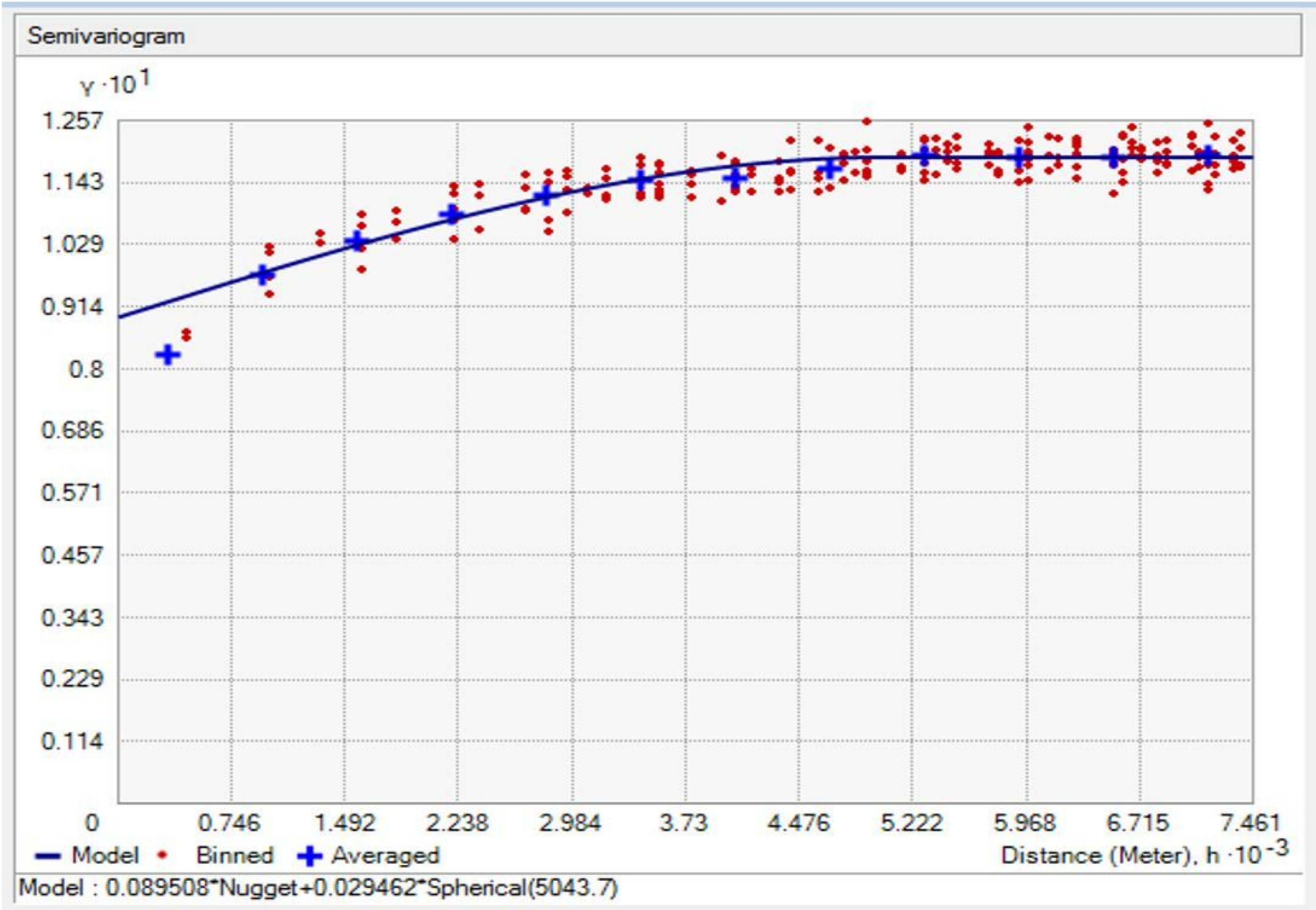

Figure 5

Semivariogram model of organic carbon of Koppal taluk.

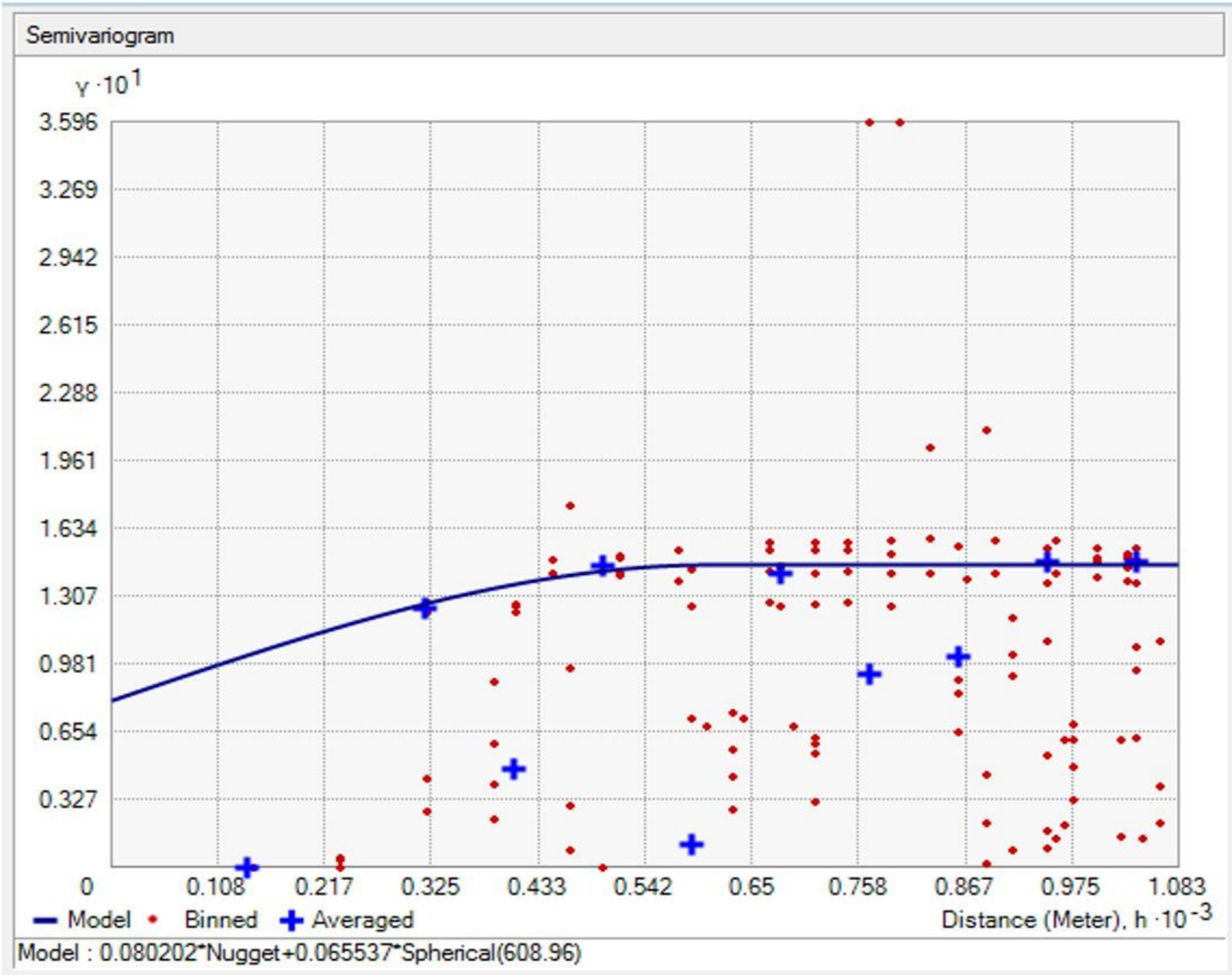

Figure 6

Semivariogram model of organic carbon of Yadgir taluk.