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Mapping the Extent of Free Calcium Carbonate in the Soils of Madurai District, Tamil Nadu and Its influence on Micronutrient Availablity Using GIS Techniques

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An extensive study was conducted to delineate the calcareous soils in Madurai district of Tamil Nadu, India. A total of 1724 geo referenced surface soil samples have been collected from all the 13 blocks of the district and analyzed for free $CaCO_3$ content. The observations showed minimum lime content (0.75 %) only in a few samples. Most of the samples showed moderate levels of calcareousness *i.e.* 5 to 10 %. Calcareous lands are spread in patches in Madurai district. Some of the blocks *viz;* Madurai East, Madurai West, Kottampatty, Sedapatty, Kallikudi, Chellampatty, Usilampatty and Alanganallur blocks possess non calcareous soils. Thirupparankundram (6.00%), Melur (6.00 %), T. Kallupatti (8.00 %), Thirumangalam (6.00 %) and Vadipatti (6.00 %) blocks showed moderate level of lime. However, according to Piper (1966) classification, the average calcareousness of each block was found to be in non calcareousness (3.07 %) category.

Key words: Madurai district, Calcareous soil, Mapping, GIS technique.

Calcareous soils are typically alkali soils, which may contain one to 25 % $CaCO_3$ by weight, with near neutral pH in the range of near neutral 7.6 to 8.4. As early in 1998, the Central Soil Salinity Research Institute, Karnal declared that the approximate salt affected soil in Tamil Nadu and India was 0.47 M ha and 742.1 M ha, respectively (Sharma, 1998).

Soil lime content refers to the free $CaCO_3$ available. Normally lime is applied for the reclamation of acid soils. Such soils generally are known to have 100% base saturation and the exchange complex is dominated by calcium. Ca+ ions from $CaCO_3$ tend to replace H+ and Al+ ions from the exchange sites; thus results in bringing down the soil acidity. But, with the presence of excessive lime, the growth of plants is very much affected due to the reduction in phosphorous and potassium availability. Moreover, high -OH ion concentration will not favour root development. Growth inhibition may appear with tip swelling brought about by hydration.

Nutrient management in calcareous soils, also differs because of the effect of soil pH on soil nutrient availability,such changes in chemical reactions may affect the fixation or loss of almost all nutrients. Both native and applied P is tied up in highly insoluble Ca and Mg phosphates, rendering the added P only sparingly available for plant uptake. Iron, Zinc, Manganese and Copper deficiencies are common in soils that have a high $CaCO_3$ due to reduced solubility at alkaline pH values. Dehydrating properties of boron,acts as a protective agent for excess -OH ion concentration, thus resulting in boron deficiency. Occurrence of scab in root crops will be common due to Bo deficiency. In view of documenting and delineating calcareous soils in Madurai district, Tamil Nadu, geo-referenced mapping has been done and the results are discussed.

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Material and Methods

Area of delineation

The Madurai district of Tamil Nadu extends over an area of 3741.73 km^2. It is geograhically bounded by Dindugul and Thiruchirapalli district in the North, Sivagangai district in the East, Virudunagar district in the South and Theni district in the West. It lies between 78.12° E longitude and 9.93° N latitude (Fig 1). The average annual rainfall of 832 mm makes the district fall under a semi arid climate. There are two cropping seasons *viz*. Kuruvai (June-July) and Samba (August). The present study area comprises of 13 blocks and 431 panchayat villages in the district.

Soil sampling, processing and analysis

The soil samples were collected by a systematic survey covering 4 samples per panchayat village. The samples were processed following standard methods of drying in shade and sieved through 2 mm mesh copper sieve. Physico-chemical properties of the samples were estimated following standard procedures. Organic carbon (Walkley and Black, 1934), free $CaCO_3$ (Piper, 1966), pH and EC (Jakson, 1973) were recorded. The soils of surved area have been grouped in to non calcareous (< 5 %), moderately calcareous (5 - 10 %) and strongly calcareous (10 – 15 %) categories following Piper (1966) classification.

Statistical and spatial analysis

The Pearson correlation coefficients were estimated for all possible paired combinations of the response variables to generate a correlation coefficient matrix. These statistical parameters were calculated with SPSS 16.0® software (SPSS Inc., Chicago, III., USA). In this research, the study area has been wrested from the base map, the GPS points and values (analytical results) were coupled. The locations of sampling sites were fed into the GIS environment and digitized using ArcGIS software; they were validated for digitization errors, polygonized and finally transformed in to thematic map by spatial interpolation method of kriging (Krige, 1951). Spherical, exponential and Gaussaian models were fitted to the empirical semivariograms. The best-fit model with the smallest nugget values with minimum root mean square error (RMSE) were selected for mapping the calcareousness.

Results and Discussion

Soil pH

The pH of the surface soils of different blocks in Madurai district varied widely from 5.50 to 9.11. However, majority of blocks had neutral pH. The range of pH values recorded were: Madurai East (5.57 - 9.11), (5.55 - 8.88) Madurai West, (6.31 - 8.53) Thirupparankundram, (5.52 - 8.90) Kottampatti, Melur (5.51 - 8.76), Sedapatty (6.01 - 8.35), T. Kallupatty (5.65 – 8.10), Kallikudi (5.94 – 8.40), Thirumangalam (5.82 – 8.40), Chellampatty (5.66 – 8.88), Usilampatty (6.23 – 8.82), Alanganallur (5.50 – 8.73) and Vadipatty (6.51 – 9.00) (Table. 1).

Electrical conductivity

The Electrical conductivity (EC) of the surface soils ranged from 0.10 to 1.06 dS m^{-1}, with an overall mean value of 0.20 dS m^{-1}. In general, almost all soils had very low level of salinity and posed no problem in the selection of crops. Over 95 % of the surface soils had low salinity level 0.30 dS m^{-1}. The mean EC values recorded were 0.23 dS m^{-1} in Chellampatty and Kallikudi; 0.20 dS m^{-1} in Madurai East, 0.25 dS m^{-1} in Madurai West, 0.21 dS m^{-1} in Melur, 0.21 dS m^{-1} in Usilampatty, 0.19 dS m^{-1} in Thirupparankundram, 0.17 dS m^{-1} in Kottampatti and 0.26 dS m^{-1} in Vadipatti blocks.

Organic carbon

The organic carbon content of surface soils in different blocks ranged from 0.03 to 0.50 %. Based on low (< 0.50 %), medium (0.50 – 0.75 %) and high (> 0.75 %) status, all blocks fall under low levels of

Table 1. Range and mean values of soil physico chemical properties, free calcium carbonate and micronutrients

Block	pH	EC (dS m^{-1})	Organic carbon (%)	Free $CaCo_3$ (%)	DTPA-Cu	DTPA-Zn	DTPA-Mn	DTPA-Fe	HWS-B
Madurai East	5.57-9.11	0.10-0.86 (0.20)	0.03-0.49 (0.25)	0.75-5.00 (2.76)	0.52-20.94 (2.89)	0.80-11.00 (1.23)	1.22-28.62 (18.64)	0.92-81.32 (35.52)	0.10-3.80 (1.69)
Madurai West	5.55-8.88	0.10-0.90 (0.25)	0.05-0.44 (0.24)	1.00-4.00 (2.88)	0.51-4.19 (1.44)	0.80-10.42 (1.41)	1.80-34.56 (15.03)	3.77-82.10 (34.57)	0.10-5.80 (2.04)
Thirupparankundram	6.31-8.53	0.10-1.00 (0.19)	0.03-0.45 (0.20)	1.00-6.00 (2.61)	0.06-21.02 (2.18)	0.80-9.42 (1.23)	1.26-24.29 (6.85)	1.11-17.18 (11.84)	0.10-4.00 (1.51)
Kottampatti	5.52-8.90	0.10-0.90 (0.17)	0.03-0.50 (0.26)	1.00-4.00 (2.15)	0.20-8.14 (1.95)	0.80-2.65 (0.98)	0.81-22.87 (7.10)	1.84-79.37 (14.15)	0.20-3.50 (1.32)
Melur	5.51-8.76	0.10-1.00 (0.21)	0.05-0.44 (0.22)	0.75-6.00 (3.80)	0.20-24.37 (1.05)	0.80-5.86 (1.10)	1.33-18.46 (10.75)	1.06-66.14 (8.67)	0.20-2.89 (1.49)
Sedapatti	6.01-8.35	0.10-0.98 (0.18)	0.03-0.44 (0.23)	0.75-4.00 (2.54)	0.41-8.39 (2.01)	0.80-5.40 (1.22)	1.27-32.67 (15.15)	1.08-31.45 (18.11)	0.20-3.00 (1.86)
T. Kallupatti	5.65-8.10	0.10-1.06 (0.17)	0.03-0.45 (0.26)	1.00-8.00 (3.86)	0.11-22.26 (1.50)	0.80-8.10 (1.37)	1.52-33.87 (15.92)	4.29-20.07 (13.50)	0.10-3.50 (1.21)
Kallikudi	5.94-8.40	0.10-0.93 (0.23)	0.03-0.45 (0.20)	0.75-5.00 (2.81)	0.05-26.40 (1.26)	0.80-9.40 (1.25)	1.20-34.78 (11.12)	4.40-19.93 (14.25)	0.20-2.87 (1.30)
Thirumangalam	5.82-8.40	0.10-0.84 (0.17)	0.03-0.45 (0.23)	1.00-6.00 (3.23)	0.05-6.55 (0.91)	0.80-5.19 (1.18)	1.34-34.91 (6.87)	6.70-21.98 (14.35)	0.40-3.60 (1.69)
Chellampatty	5.66-8.88	0.10-0.90 (0.23)	0.03-0.44 (0.19)	1.00-5.00 (3.22)	0.06-8.40 (1.39)	0.82-4.55 (1.12)	1.12-35.42 (12.32)	2.32-27.32 (13.64)	0.10-4.00 (1.59)
Usilampatty	6.23-8.82	0.10-0.84 (0.21)	0.03-0.45 (0.20)	1.00-5.00 (2.75)	0.05-6.59 (1.14)	0.81-5.70 (1.38)	1.26-28.23 (11.74)	11.14-18.54 (17.72)	0.20-3.60 (1.48)
Alanganallur	5.50-8.73	0.10-0.73 (0.15)	0.03-0.44 (0.28)	1.00-4.00 (3.38)	0.15-5.22 (0.93)	0.80-8.20 (1.14)	2.38-31.33 (7.35)	2.29-81.18 (16.55)	0.20-4.00 (1.71)
Vadipatti	6.51-9.00	0.10-0.90 (0.26)	0.03-0.44 (0.24)	1.00-6.00 (3.98)	0.08-3.61 (1.54)	0.80-3.68 (0.99)	1.11-14.10 (6.90)	2.16-76.47 (25.31)	0.10-3.00 (1.48)

Numerals in parentheses indicate the mean of particular block

organic carbon with an overall mean value of 0.23%. Alanganallur block had the highest mean value of 0.28 % of organic carbon followed by Kottampatti, T. Kallupatti blocks with 0.26 % and Madurai East with 0.25 %.Other blocks like Madurai West (0.24 %), Thirupparankundram (0.20 %), Sedapatti (0.23 %) and Chellampatty (0.19 %) blocks also recorded similar values.

Free calcium carbonate

The lime content in the surface soils was found to be in the range of 0.75 to 8.00 % with an average of 3.07 %. Among all the blocks, the lowest mean value for $CaCO_3$ of 0.75 % was registered in Madurai East, Melur, Sedapatty and Kallikudi, with a mean values of 2.76, 3.80, 2.54 and 2.81 %, respectively.

Whereas, T. Kallipatti block showed the highest calcium carbonate content of 8.00 % with the mean of 3.86 %. The maximum and minimum $CaCO_3$ content of the remaining blocks *viz*. Madurai West, Thirupparankundram, Kottampatty, Thirumangalam, Chellampatty, Usilampatty, Alanganallur and Vadipatty recorded were: 1.00 – 4.00 %, 1.00 – 6.00 %, 1.00 – 4.00 %,1.00 – 6.00 %, 1.00 - 6.00 %, 1.00 - 5.00 %, 1.00 - 4.00 %, 1.00 - 6.00 % with an overall block average of 3.23 , 3.22 , 2.75 , 3.38 and 3.98 %, respectively.

Table 2. Correlation between the soil physico chemical properties and free calcium carbonate

Soil properties	pH	EC	OC	$CaCO_3$	DTPA-Cu	DTPA-Zn	DTPA-Mn	DTPA-Fe	HWS - B
pH	1	0.002	-0.039	0.012	0.008	0.021	-0.024	-0.035	0.009
EC		1	-0.026	0.092*	-0.007	-0.012	-0.099*	-0.05	0.085
OC			1	-0.030	-0.063	0.440**	0.073*	0.047	0.046
$CaCO_3$				1	-0.040	-0.051	-0.061	-0.062	0.070
DTPA-Cu					1	0.090*	1.000	0.074*	-0.061
DTPA-Zn						1	0.051	0.039	-0.009
DTPA-Mn							1	0.148**	-0.035
DTPA-Fe								1	-0.070
HWS - B									1

*Correlation is significant at 0.05 level. **Correlation is significant at 0.01 level.

In general, free $CaCO_3$ is contributed from kankar nodules, limestone, sandstone and fluvial deposits. the possible reason attributed is the incipient charnockite formation reported along certain major joint / fracture systems within garnetiferous quartzo-feldspathic granulite, near Melur in Madurai District. The source may be from the post Pliocene rocks represented by calcareous mud, clay, sandy clay and gritty sandstone noticed in the Kambam valley in Madurai District. Such crystalline lime stones of

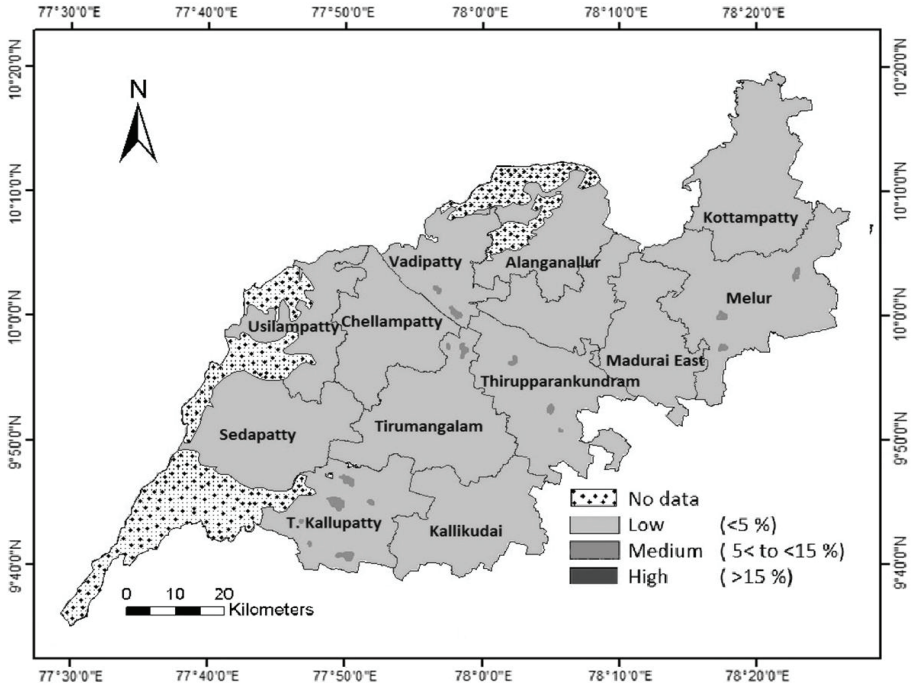

Fig. 1 Spatial distribution of free $CaCO_3$ in the soils of Madurai district

Precambrian age are mainly distributed in parts of Madurai (Srinivasan and Rajeshdurai, 2010) district, which may be responsible for the consistently moderate lime content throughout the district, and its surroundings.In the entire Madurai district almost 20 % calcareous soils were found to be relatively alkaline.

Correlation coefficient between soil physio-chemical properties and free $CaCO_3$

The results of the study are presented in Table 2. The correlation studies revealed that the EC (r = 0.092*) is positively correlated with the soil free $CaCO_3$ content, denoting that EC is highly influenced by $CaCO_3$ content, this means that the increase of free $CaCO_3$ content in soil would favour an increase in EC and vice versa. $CaCO_3$ and $CaCO_3$ induced EC are also found to be negatively correlated with DTPA-Cu, Zn, Mn (r = -0.099*), Fe, by forming insoluble carbonates. In general all the cationic micronutrients except boron are found to be negatively correlated with the $CaCO_3$ content. In addition to this the organic carbon content, is positively significant with DTPA-Zn (r = 0.440**) and Mn (r = 0.073*), says that presence of organic carbon will tend to increase the availability of these nutrients; DTPA-Cu is significantly correlated with Zn (r = 0.090*); Fe (r = 0.074*) and DTPA-Mn is also found to be highly significant with Fe (r = 0.148**).

A similar significant negative correlation was also noticed in the correlation studies of Thiruvallur district. The decrease of micronutrient availability with increase in free $CaCO_3$ was found and the $CaCO_3$ not only plays an important role in the adsorption of soluble zinc, but also with increase in CO_3^{2-} content in soil, which helps to precipitate the soluble Zn as $ZnCO_3$. The oxidation of Fe^{2+} to Fe^{3+} oxides or replacement by calcium carbonate and fixation of Mn by adsorption on the surface of calcium carbonate particles (Choudhary et al. 2012; Premnath, 2016). It may be concluded that liming decreases the micronutrients content of the soil.

Similar kind of mapping work was carried out by Shukla et al. (2015) in Hariyana and Wagh *et al*.(2016) in Nagpur, where they reported that increased soil calcareousness due to the presence of $CaCO_3$ would limit the availability of DTPA extractable micronutrients like Fe, Mn and Cu in soil by precipitation.

Conclusion

On comparing results obtained with the critical limits (0-5 % - Non calcareous; 5 -10 % - Moderately calcareous and 10 - 15% - Strongly calcareous), the free $CaCO_3$ content (0.75 – 8.00 %) present in the soils of Madurai district are classified in to non-calcareous to moderately calcareous category. It is also evident that an increase in $CaCO_3$ content would increase the EC in the soil.

It is concluded that EC and $CaCO_3$ are the most influential properties that determine in the availability of micronutrients in the soil. To increase the availability of the micronutrients, the $CaCO_3$ content should be moderated. In calcareous soils, pH of the whole soil is controlled mainly by $CaCO_3$ content. Manipulation of soil texture (clay content) is also impractical in the field. Perhaps the practical ways of improving the availablity of micronutrients are to try lower the pH of microsites near the plant roots by applying the acidifying fertilizer granules or manures, and growing plant cultivars capable of extracting more soil micronutrients either by themselves or in association with other organisms.

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