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Spatial Variability of Soil Fertility Parameters in Jirang Block of Ri-Bhoi District, Meghalaya

R. K. JENA*, V. P. DURAISAMI[1], R. SIVASAMY[1], R. SHANMUGASUNDARAM[1], R. KRISHNAN[1], S. PADUA, S. BANDYOPADHYAY, S. RAMACHANDRAN, P. RAY, P. DEB ROY, S. K. SINGH[2] AND S. K. RAY

ICAR-National Bureau of Soil Survey and Land Use Planning, Regional Centre, Jorhat 785 004, [1]Tamil Nadu Agricultural University, Coimbatore 641 003, [2]ICAR-National Bureau of Soil Survey and Land Use Planning, Amravati Road, Nagpur 440 033.

Abstract–*Spatial variability of soil fertility parameters is important to know the distribution of fertility status in a particular area. Surface soil samples from Jirang block, Ri-bhoi district of Meghalaya were analysed for soil reaction, organic carbon, available macro- and micronutrients status. The spatial variability maps were generated for soil parameters by regularised spline technique in ArcGIS 10.0. Soil pH varied from extremely acidic to moderately acidic. The maximum area of soil was under moderately acid (59.3% area) followed by extremely acid (27% area), very strongly acid (6.9% area) and strongly acid (6.9 % area). Soil organic carbon content varied from medium (40% area) to high (60% area). The available nitrogen content was high in 54.5 % area where as available phosphorus was medium in 67.8 % area. Available potassium content was low in 67.5 % area. The micronutrients status was sufficient. The multi-macronutrient map (N, P and K) showed 25.4% area was deficient in either all or more than one macronutrient which was classified as high prioritized zone. The multi-micronutrient map (Fe, Mn, Zn and Cu) showed maximum area under low prioritized zone (80.5% area).*

Key words : Spatial variability, Soil fertility parameters, Interpolation, Spline method, multinutrient deficient zone

Introduction

Soil characteristics are the outcome of the interplay of pedogenic factors and processes prevailing in a particular area. The hilly and mountainous regions are endowed with a wide range of environmental factors that exert an influence on spatial variability of soils. A review of those factors and processes that have contributed to soil formation is necessary for a better understanding of the soils of a particular area. In India, harsh climatic conditions, population pressure, land constraints, and the decline of

***Corresponding Author Email:** roomeshjena@gmail.com

traditional soil management practices have often reduced soil fertility (Stoorvogel and Smaling, 1990; Tandon, 1998; Henao and Baanante, 1999; Bumb and Baanante, 1996).The north eastern hilly region of india is characterised by heavy soil erosion, loss of soil fertility and deforestation causing acute environmental degradation and severe ecological imbalance (Sachchidananda, 1989). Shifting cultivation or slash & burn agriculture, locally known as *Jhum* cultivation, is the main form of agriculture in this region. In north east India, the average annual loss of top soil, organic carbon, P_2O_5 and K_2O due to shifting cultivation is to the extent of 40900, 702.9, 0.15 and 7.5 kgha^{-1}, respectively (ICAR, 1983). The repeated use of land with short *Jhum* cycle finally converts the *Jhum* fallows into degraded wastelands. In cultivated areas the imbalanced and indiscriminate use of fertilizers in intensive cropping system without adequate restorative practices may pose threats to sustainability of system, as high yielding varieties draw heavy amount of plant nutrients from soil and nutrient uptake often exceeds replenishment through fertilizers causing soil fertility deterioration at many places (Singh and Lal, 2011). Farmers usually apply fertilizers without considering the information on soil fertility status and nutrient requirement of the crop, which leads to either nutrient toxicity or deficiency (Ray *et al.,* 2000). In order to apply nutrients, based on soil fertility, it is necessary to know the location specific variability in nutrient supply to provide optimum doses of fertilizers as per the crop nutrient demand (Dobermann and Cassman, 2002). Geographic Information System (GIS) helps to generate such spatial variability maps (Sood *et al*., 2009). Information on spatial variability of soil fertility parameters for the Meghalaya Plateau is lacking. Therefore, the present study was undertaken with the objectives (1) to assess the nutritional status of the soils of Jirang block in Ri-Bhoi district of Meghalaya and (2) to map the spatial variability of soil fertility parameters for delineating the multi-nutrient deficient zones.

Materials and Methods

The present study was conducted in the Jirang (Community and Rural Development) block lies in the north west direction of the Ri-Bhoi district of Meghalaya between 25^o 47'17.16'' N to 26 ^{o}5' 22.56'' N latitude and 91^o 20'40.56'' E to 91 ^{o}51' 41.4'' E longitude. The total geographical area (TGA) of the block is 714 km^2 (71400 ha). The geology of the study area comprises mostly of (i) Gneiss with old inliers of Sela group and (ii) Granite rocks. The block occupies around 648.42 km^2 (90.8 % of TGA) under Gneiss with old inliers, sela group and 65.58 km^2 (9.2 % of TGA) under granite rocks on 1:600000 scale. The study area represents two agro-ecological sub-regions (AESR) of middle Brahamaputra plain, hot humid eco-subregion (15.2) with an area of 553.5 km^2

(77.5% of TGA) and under Meghalaya Plateau and Nagaland hill, warm to hot moist, humid to perhumid eco-subregion (17.1) with an area of 160.5 km^2 (22.5% of TGA). It is characterised by hot and moist summers and cool winters belonging to subtropical climate. The mean summer and winter temperatures are 26.4 ^oC and 13.8 ^oC, respectively. The average annual rainfall of the area is about 2395 mm.

Geo-referenced surface soil samples (0-15 cm) were collected from 248 locations in the study area representing different terrain situations. The collected soil samples were processed, passed through 2mm sieve and stored for laboratory analysis. Soil reaction was determined by using pH meter with glass electrode from soil:water in the ratio 1:2.5 (Jackson, 1973). Organic carbon was determined by chromic acid wet digestion method (Walkley and Black, 1934). The available nitrogen was estimated by alkaline $KMnO_4$ method (Subbiah and Asija, 1956). Available phosphorus and potassium were estimated by 0.03 N NH_4F and 0.025 N HCl reagents (Bray and Kurtz, 1945) and neutral normal ammonium acetate method (Jackson, 1973), respectively. Cationic micronutrients namely Zn, Fe, Cu and Mn were determined using the DTPA (diethylenetriaminepenta acetic acid) extraction method (Lindsay and Norvell, 1978).

Regularised spline interpolation technique for point data was used to create different layers for pH, organic carbon, available N, P, K, Fe, Mn, Zn and Cu in a GIS environment (Arc GIS 10.0 software) (Collins and Bolstad, 1996; Hutchinson, 1995).

The layers generated for macronutrients (N, P and K) and micronutrients (Fe, Mn, Zn and Cu) were used to define the priority areas for multinutrient management intervention. Initially the surfaces were classified into three classes *viz*., low, medium and high depending on their nutrient status. The low category was given

Table 1. *Categorization for the soils parameters studied*

Parameter	Categories		
	Low (1)	Medium (2)	High (3)
OC (%)	<0.4	0.4 – 0.75	>0.75
N (kg ha^{-1})	<280	280-560	>560
P_2O_5 (kg ha^{-1})	<34	34-68	>68
K_2O (kg ha^{-1})	<135	135-335	>335
Fe (mg kg^{-1})	<4.5	4.5-9.0	>9.0
Mn (mg kg^{-1})	<3.5	3.5-7.0	>7.0
Zn (mg kg^{-1})	<0.6	0.6-1.2	>1.2
Cu (mg kg^{-1})	<0.2	0.2-0.4	>0.4

a value 1 and similarly the medium and high categories were given a value of 2 and 3, respectively (Table 1) (Takkar, 2009; Brays and Kurtz, 1945).

After reclassification, two layers were generated by using the decision tree. Multi-macronutrient layer was generated by combining all the macronutrient layers (available N, P and K), whereas multi-micronutrient layer was generated by combining all the cationic micronutrient layers (Fe, Mn, Zn and Cu). All the macro- and micronutrient surface layers were combined into one using the decision tree given (Table 2, 3). All the layers were given equal weightage in the operation and the

Table 2. *Decision tree for multi macronutrient map (N, P and K).*

IF	All the layers have value 1	High priority area
ELSE IF	Two layers have value 1 and one layer has value 2	High priority area
ELSE IF	Two layers have value 2 and one layer has value 1	High priority area
ELSE IF	All the layers have value 2	Medium priority area
ELSE IF	One layer has value 1, other layer has value 2 and another layer has value 3	Medium priority area
ELSE IF	Two layers have value 2 and one layer has value 3	Medium priority area
ELSE IF	All the layers have value 3	Low priority area
ELSE IF	Two layers have value 3 and one layer has value 2	Low priority area

Table 3. *Decision tree for multi micronutrient map (Fe, Mn, Zn and Cu).*

IF	All the layers have value 1	High priority area
ELSE IF	Three layers have value 1 and one layer has value 2	High priority area
ELSE IF	Three layers have value 1 and one layer has value 3	High priority area
ELSE IF	Two layers have value 1 and other two layers have value 2	High priority area
ELSE IF	All the layers have value 2	Medium priority area
ELSE IF	Three layers have value 2 and one layer has value 1	Medium priority area
ELSE IF	Three layers have value 2 and one layer has value 3	Medium priority area
ELSE IF	Two layers have value 2, third layer has value 1 and fourth layer has value 3	Medium priority area
ELSE IF	One layer has value 2 and two layers have value 1 and fourth layer has value 3	Medium priority area
ELSE IF	Two layers have value 1 and other two layers have value 3	Medium priority area
ELSE IF	All the layers have value 3	Low priority area
ELSE IF	Three layers have value 3 and one layer has value 1	Low priority area
ELSE IF	Three layers have value 3 and one layer has value 2	Low priority area
ELSE IF	Two layers have value 3 and other two layers have value 2	Low priority area

value for each surface was evaluated in a raster environment.

Results and Discussion

Fertility status and their spatial distribution

The surface soils of the study area were extremely acid to moderately acid which ranged from 4.2 to 6 (Tables 4, 5, Fig.1a). The area under extremely acid (< 4.5) was 19207 ha (29.6 % of TGA) and under moderately acid was 42279 ha (59.3 % of TGA). The organic carbon in these soils ranged between 0.49 percent and 3.01 percent with an average value of 1.47% (Fig.1b). About 60 % of TGA was under high organic carbon content followed by medium organic carbon content (40 % of TGA). The soil available nitrogen content varied from 121 to 744 kg ha^{-1} with an average value of 351 kg ha^{-1} (Fig.1c). The area under low, medium and high available nitrogen content was 8.8 %, 36.7 % and 54.5 % of TGA, respectively. The mean available P (Bray's P) and K contents were 65 kg ha^{-1} and 190 kg ha^{-1}, respectively (Fig.1d). In case of available P majority of the area was under medium nutrient status (67.8 % of TGA) followed by high nutrient status (32.2 % of TGA) whereas available potassium status was low to high (Fig.1e). The area under low potassium content was the highest (67.5 % of TGA) followed by high (21.7 % of TGA) and medium available potassium (10.8 % of TGA). The mean available Fe, Mn, Zn and Cu contents were 105.1, 26.5, 2.03 and 4.7 mg kg^{-1}, respectively (Table 4) which indicated sufficient status of these micronutrients in

Table 5. *Spatial distribution of soil reaction.*

Soil reaction (pH)	Area (ha.)	% of TGA
Extremely acid (<4.5)	19207	26.9
Very strongly acid (4.5-5.0)	4969	6.9
Strongly acid (5.1-5.5)	4945	6.9
Moderately acid (5.6-6.0)	42279	59.3
Total area	71400	100

Table 4. *Descriptive statistics of soil parameters.*

Parameter	Mean	Range	SD
pH	5.01	4.2-6.0	0.33
OC (%)	1.47	0.49 – 3.01	0.46
N (kg ha^{-1})	350.6	121.4 – 744.4	90.1
P_2O_5 (kg ha^{-1})	65.05	44.9 – 234.8	26.9
K_2O (kg ha^{-1})	190.01	53.8 – 954.2	116.4
Fe (mg kg^{-1})	105.1	4.7– 154.42	25.8
Mn (mg kg^{-1})	26.5	3.55 – 91.48	17.4
Zn (mg kg^{-1})	2.03	0.60 –7.52	0.98
Cu (mg kg^{-1})	4.7	0.34 – 16.79	2.23

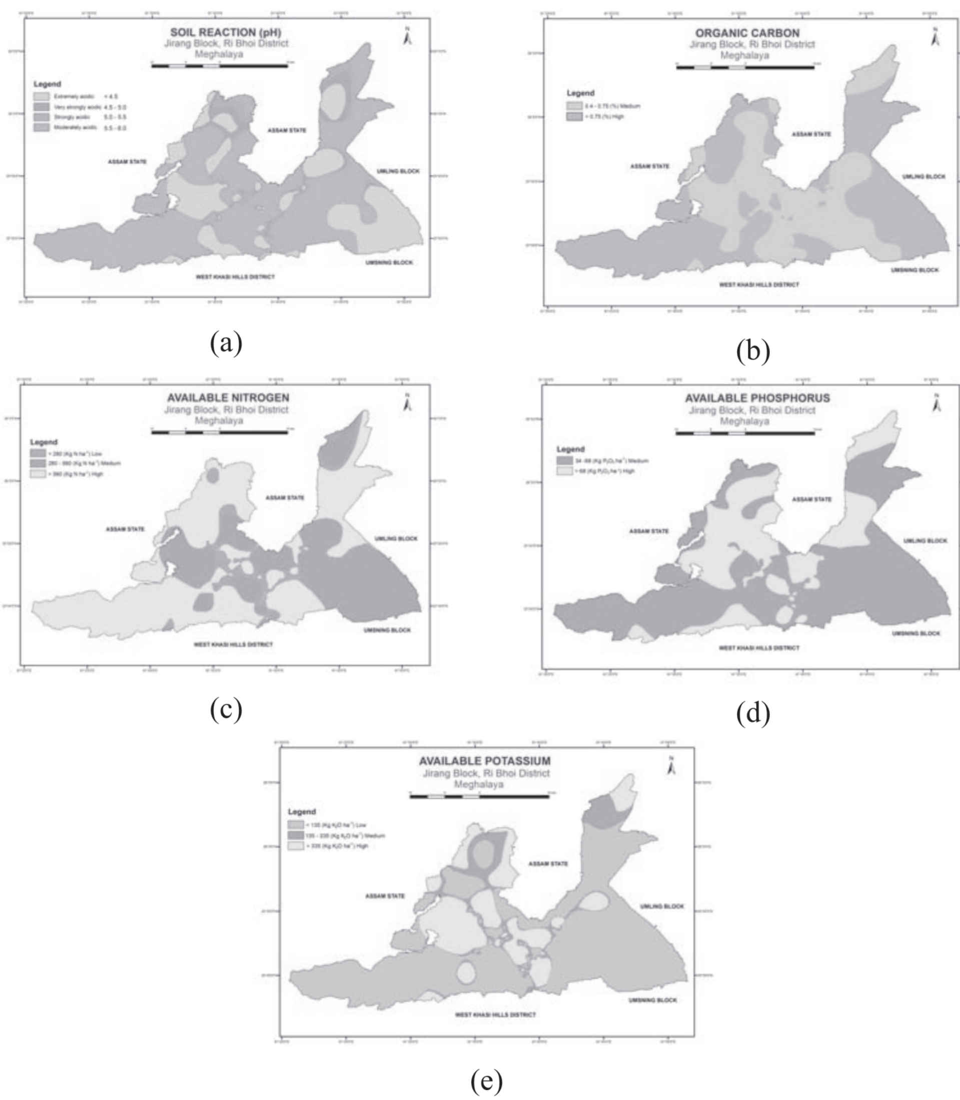

Fig. 1. *Spatial distribution of (a) soil reaction (pH), (b) organic carbon, (c) available nitrogen, (d) phosphorus and (e) potassium in Jirang block, Ri-Bhoi district.*

the study area (Fig. 2). Higher amounts of Zn and Cu may be due to high organic carbon content (Venkatesh *et al*., 2003).

It is observed that available N and K varied widely with standard deviation (SD) of 90.1 and 116.4, respectively from the mean value. In the high hills, due to abundant vegetation, high amount of N and K were present, whereas in valley areas the status was low to medium because of uptake of N and K by crops (Table 5, 6) which are not replenished by the addition of fertilizers.

Multi-nutrient deficiencies

The multi-nutrient map was generated by considering the macro- and micro-nutrients. As majority of the study area was high or medium in organic carbon content, it was not considered in multi-nutrient mapping. The multi-macronutrient map (Fig. 3) indicated that about 25.4 % of total geographical area (TGA) of the block had deficiency in either or all the macronutrients (N, P and K). This area needs to be given immediate attention in terms of nutrient management decision as the soils are already exhausted in terms of nutrient supplying capacity either due to intensive cropping or due to leaching (Havlin *et al*., 1999). Whereas 55.3% of TGA was under medium prioritized zone which need proper attention to reverse the trend of decline in soil fertility for crop production by judicious management of the resources, inspite of the fact that fertility status under this category was better compared to the areas under high priority class. The

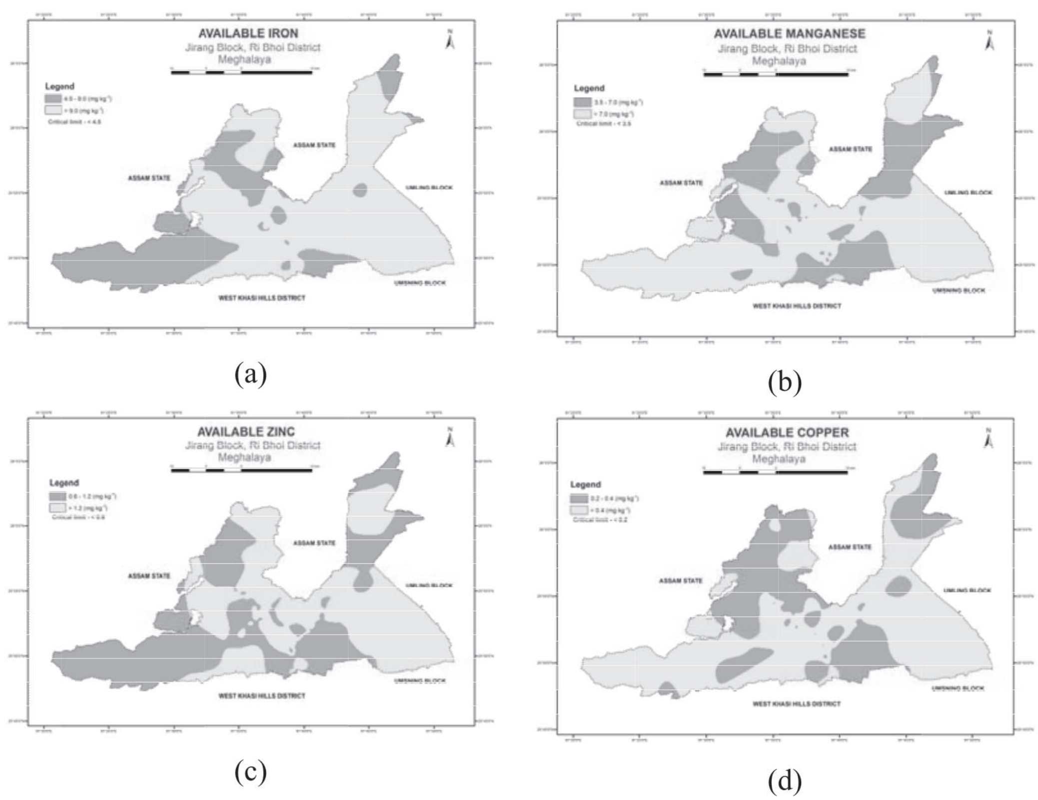

Fig. 2. *Spatial distribution of available (a) Fe, (b) Mn, (c) Zn and (d) Cu in Jirang block, Ri-Bhoi district.*

remaining area of the block was under high nutrient status category with regard to available N, P and K. The area under low prioritized zone was 19.3 % where excess application of fertilizers should be avoided, because over application of fertilizers induces neither substantially greater crop nutrient uptake nor significantly higher yields (Smaling and Braun, 1996). The multi-micronutrient map (Fig. 4) of the study area showed that around 80.5% of TGA was under low prioritized zone due to high content of cationic micronutrients followed by medium prioritized zone (19.5% of TGA) because all the cationic micronutrients are above the critical limit (Table 7).

The dataset developed in this study indicated that the major soils are extremely to moderately acid and the organic carbon content is generally not meagre. Slightly more than half of the soils are sufficient in available nitrogen and about two thirds of the soils are adequate in available phosphorus, whereas only one third of the soils are adequate in available potassium. The available micronutrients (Fe, Mn, Zn and Cu) are also in the sufficient range. Under such circumstances, the multi-macronutrient map developed using spline interpolation method resulted in a deficient zone or high prioritised zone only in 25% of the soils indicating inadequacy of either all or more than one macronutrient. On the

Table 6. *Spatial distribution of soil nutrient status.*

Parameters	Low Area in ha. (%)	Med. Area in ha. (%)	High Area in ha. (%)
N	6288 (8.8%)	26192 (36.7%)	38920 (54.5%)
P_2O_5	0 (0%)	48402 (67.8%)	22998 (32.2%)
K_2O	48208 (67.5%)	7669 (10.8%)	15523 (21.7%)
OC	0 (0%)	28535 (40%)	42865 (60%)
Fe	0 (0%)	24005 (33.6%)	47395 (66.4%)
Mn	0 (0%)	22597 (31.6%)	48803 (68.4%)
Cu	0 (0%)	25879 (36.2%)	45521 (63.8%)
Zn	0 (0%)	33985 (47.6%)	37415 (52.4%)

Table 7. *Spatial distribution of priority zones in Jirang block, Ri-Bhoi district.*

High priority Area in ha. (% of TGA)	Medium priority Area in ha. (% of TGA)	Low priority Area in ha. (% of TGA)
Macronutrient map		
18162 (25.4%)	39457 (55.3%)	13781 (19.3%)
Micronutrient map		
0 (0%)	13918 (19.5%)	57482 (80.5%)

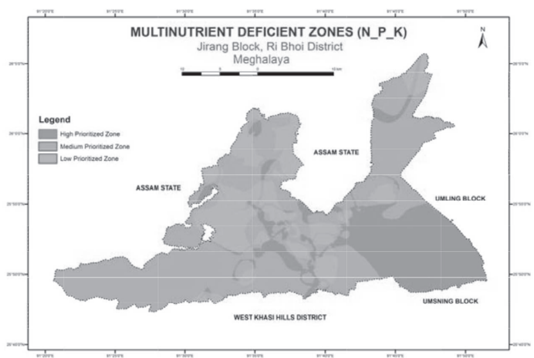

Fig. 3. *Spatial distribution of available (a) Fe, (b) Mn, (c) Zn and (d) Cu in Jirang block, Ri-Bhoi district.*

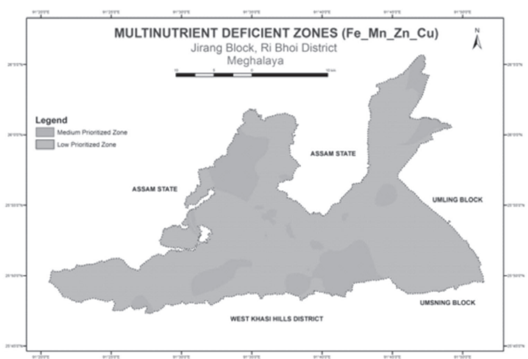

Fig. 4. *Multi-micronutrient map of Jirang block, Ri-Bhoi district*

other hand, for the micronutrients it was possible to carve out 20% area under medium prioritised zone. The higher organic content may be the reason for higher availability of micronutrients. The spline interpolation technique in the study area could invigorate the otherwise apparently insipient data which appeared to be mostly sufficient for growing even exhaustive crops. The users should thus ponder upon the results of the study, especially the high prioritised areas for monitoring purpose which would be much easier due to the development of minimum dataset instead of the difficulty of handling multiple data.

Conclusions

Spline interpolation technique can be effectively used to represent spatially the various soil fertility parameters namely pH, organic carbon, available N, P, K, Fe, Zn, Cu and Mn. The decision tree used in the methodology of this study is very simple and flexible. The study showed that in Jirang block of Ri-Bhoi district high priority areas need immediate attention in terms of nutrient management decision and the medium priority areas need proper attention to reverse the trend of decline in soil fertility by judicious management of the resources. Multinutrient deficiency maps based on weightage may guide as a nutrient decision support tool and prevent gratuitous use of fertilizer and amendments, and thereby increase nutrient use efficiency in soils. This is expected to help researchers, planners as well as farmers to take proper decisions in managing soils.

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