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Assesment of soil physico-chemical quality indicators in rice soils of Cuddalore district of Tamil Nadu, India

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Abstract
An assessment soil quality indicators study was conducted in rice growing block of cuddalore district viruthachalam. The present investigation entitled "Assessment of soil quality Indicators under nutrient management systems in different rice growing districts of Tamil Nadu "was carried out during 2018 with the objectives: To assess the soil physico- chemical and biological quality parameters in rice soils of Tamil Nadu and To compare soil quality indexing methods viz., Principal component analysis, Minimum data set and Indicator scoring method and To develop soil quality indices for formulating soil and crop management strategies. To fulfil these objectives a total of (34) soil samples were collected from Cuddalore district Viruthachalam block and TNAU research stations.

Keywords: Physico-chemical quality indicator, soil quality, principal component analysis

Introduction
Globally, the area of rice (*Oryza sativa* L.) production has increased from 148 Mha in 2002 to 164 Mha in 2011 (FAOSTAT2013). Asia is the main continent where this expansion has been reported. Food and nutritional security in Asian countries depend largely upon rice, because it is the source of 15% of protein and 21% of energy intake for the population (Depa *et al*. 2011) [11]. However, productivity of rice in lowland cultivated areas is low because of declining soil fertility (Haefele *et al*. 2014) [19], degradation of soil structure (Das *et al*. 2014a) [9], and unreliable water resources, lack of resources and wide spread poverty (Das *et al*. 2014b) [10]
Assessing the quality of soil resources has been stimulated by increasing awareness that it is an important component of the earth's biosphere, functioning not only in the production of food and fiber but also in ecosystems services and the maintenance of local, regional, and global ecological balance (Glanz, 1995) [17]. Soil quality primarily describes the combination of physical, chemical, and biological characteristics that enables soils to perform a wide range of ecological functions (Karlen *et al*., 1997) [22]. The functions largely include, sustaining biological activity and diversity; regulating and partitioning water and solute flow; filtering, buffering, degrading, immobilizing, and detoxifying organic and inorganic toxic materials; storing and cycling nutrients in soil-plant-atmospheric continuum and providing support of socio-economic treasures. Another way we can tell the quality of a soil is an assessment of how it performs all of its functions now and how those functions are being persuaded in future. This capacity of the soil to function can be assessed by physical, chemical and/or biological properties, which in this context are known as soil quality indicators (Wander and Bollero, 1999) [39]. Perceptions of what constitutes a good soil vary. They depend on individual priorities with respect to soil function, intended land use and interest of the observer (Doran and Parkin, 1994, Shukla *et al*., 2006) [15, 33]. Soil quality changes with time can indicate whether the soil condition is sustainable or not (Arshad and Martin, 2002, Doran, 2002) [3, 14]. Maintaining soil quality at a desirable level is a very complex issue due to climatic, soil, plant, and human factors and their interactions and it is especially challenging in lowland rice cropping systems because of puddling practices in soil preparation (Chaudhury *et al*., 2005) [8].

Materials and Methods
Study area
The areas under intensive rice cultivation (>1.0 lakh ha) in Tamil Nadu were selected for the study. In Tamil Nadu production intensive rice producing districts were identified. Two sampling grids (10x10 sq.km) were used, with sampling depth of 10-15cm soil sampling was carried out in locations which were subjected to various management strategies.

The composite soil samples were analyzed for soil quality parameters. Keeping there in view, the soil quality indicators of rice soils were assessed.

The study was conducted in Virudhachalam block of Cuddalore district, Tamil Nadu and TNAU research station in this district. The general geological formation of the district is simple with metamorphic rocks belonging to the gneiss family. Resting on these are the three great groups of sedimentary rocks belonging to different geological periods and overlaying each other in regular succession from the coast on the east to the hills on the west.

The area receives total rainfall of 1104 mm. It includes both the south west (373 mm) and north east (731 mm) monsoons. The maximum recorded temperature of the district is 36.8 °C while minimum temperature is 19.9 °C

The soils of the district can be divided into three main classes namely, the black soil, the red ferruginous and the arenaceous. The black soil prevails largely in the Chidambaram, Vriddhachalam and Cuddalore Taluks. The arenaceous occurs chiefly near the coast in the Chidambaram and Cuddalore. Black clay is the most fertile kind of soil, the loam is the next best and the red sand and arenaceous soils are the poorest.

The major crops cultivated in Cuddalore district are paddy, sugarcane, maize, black gram, green gram and groundnut.

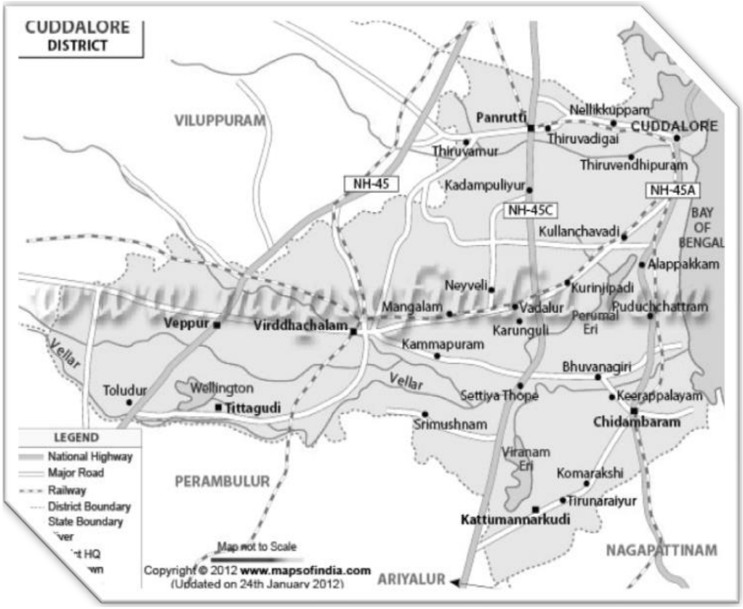

Fig 1: Cuddalore district of Tamil Nadu

Physicochemical indicators included pH, EC was determined in 1:2 soil water suspensions using a combined pH meter (Jackson, 1973) [20] and cation exchange capacity of soil was determined by using Neutral Normal Ammonium Acetate (Bower *et al*., 1952) [5]. Biological properties measured in terms of organic carbon by chromic acid wet digestion method (Walkely and Black, 1934). Soil available nitrogen was determined by Alkalaine potassium permanganate method (Subbaiah and Asija 1956) [38], soil available phosphorus by 0.5M $NaHCO_3$ (pH-8.5) extractable (Olsen *et al*., 1954) [30], Soil available potassium was determined by Flame photometric method (1NNH$_4$OAC extractable) (Standford and English, 1949) [37], soil available micronutrients, zinc, Fe was determined by DTPA Extraction, (Lindsey and Norvell, 1978) [27] Soil available boron extracted by Hot water (Bremmer, 1965) [7]

Statistical analysis: All the Statistical Analysis described in this chapter were performed using the softwares STATISTICA 10.0 and SPSS 20.0.

Results and Discussion

Soil physico-chemical quality indicators of Cuddalore district

The pH of the rice soils of Viruthachalam block varied from 5.11 to 7.98. The low pH value (5.11) might be the result of well drained and lack of calcareousness in this soil. These findings were in corroboration with the conclusion of Nair and Koshy (1987) [29]. High pH value of (7.98) in Viruthachalam block could be due to the high base saturation, restricted leaching and high $CaCO_3$ content. This high pH would affect the availability of secondary nutrients such as Ca and Mg as well as micronutrients.

Management practices of mechanical farming registered the lowest pH of 7.16. Wide variations in soil reactions may be attributed to the nature of parent material, leaching, topograpic position, presence of $CaCO_3$ concentration**,** base saturation per cent (BSP) and Na content in soil. A similar result was reported by Sihi *et al*. (2017) [35]

In Viruthachalam block of Cuddalore district, electrical conductivity of the soil samples ranged from 0.01 to 0.31 dS m^{-1}. Organic rice cultivation recorded the lowest EC value of 0.10 dS m^{-1}. Highest EC value of 0.31 dS m^{-1} would be due to the foraging of nutrient ions by the vegetation in the surface soils. These observation are in the agreement with the findings of Renukadevi (2008) and Shaikh and Gachande (2013) [36]

The organic carbon of the rice soils of Viruthachalam block varied from 1.1 to 6.3 g kg^{-1}. Organic carbon content of 1.1 g kg^{-1} registered to be the lowest value in this block. This could be because of erosion, leaching and rapid oxidation of organic matter. Among the nutrient management practices of INM registered the highest organic carbon content of 9.9 g $kg^{-1.}$ This result is in line with Jayanathi *et al.* (2003) and Chen *et al*. (2018) who reported that INM practice increases organic carbon content in rice soils

The exchangeable properties of the soils were mostly influenced by the content and quality of clay and predominance of cations associated with colloidal complex. The cation exchange capacity varied from 20.00 to 56.00 cmol $(p)^+$ kg^{-1}. Wide variation in CEC was observed and it was due to the difference in mineral composition, clay content, p^H and organic carbon content of soils.

The low CEC value could be due to the sandy texture of the soil, poor clay content, low base saturation, low organic matter and leaching of added nutrient cations. Management practice of organic farming registered the highest CEC value of 81.00 cmol $(p)^+$ kg^{-1}. This is in accordance with Araujo (2017) and Verma *et al.* (2010) who observed that release of cations with the decomposition of organic matter would have increased the CEC and due to more exchange sites on humus

Table 1: Physico -Chemical Quality Indicators of Cuddalore District

Site. No	Name of the location	Soil $p^{H\,1}$(1:2.5 soil : water)	Electical Conductivity (dSm^{-1})	Organic carbon ($g\ kg^{-1}$)	Cation Exchange Capacity ($cmol(p^+)\ kg^{-1}$)
1	Viruthachalam	7.32	0.22	5.3	47.00
2	Kuppanatham	7.56	0.24	6.3	38.00
3	Kovilanur	6.83	0.36	5.4	46.00
4	M.Patti	5.43	0.14	3.2	41.00
5	Manavalanallur	7.11	0.15	5.7	43.00
6	Mathur	7.81	0.07	3.3	42.00
7	Narumanam	7.21	0.12	4.7	39.00
8	Chinnaparur	7.04	0.19	3.6	36.00
9	Eadaiyur	5.11	0.22	3.8	34.00
10	Gopurapuram	5.15	0.24	3.4	45.00
11	Karnatham	5.17	0.21	3.0	52.00
12	Chinnakandiyankuppan	5.21	0.25	4.1	55.00
13	Ka.Elamangalam	5.25	0.27	4.5	37.00
14	Kattiyanallur	5.38	0.23	4.2	33.00
15	Earumanur	5.55	0.29	1.9	44.00
16	Kovilanur	5.76	0.31	1.5	42.00
17	Komangalam	5.79	0.32	1.6	25.00
18	Paravalur	5.90	0.28	1.3	30.00
19	Puliyur	5.80	0.30	1.1	28.00
20	Rajendirapatinam	6.21	0.35	2.3	29.00
21	Sathiyavadi	6.35	0.33	2.2	26.00
22	Pthukooraipettai	6.38	0.36	2.5	27.00
23	Peralaiyur	6.15	0.39	2.6	24.00
24	Mu.Agaram	6.46	0.38	2.8	20.00
25	Vetakudi	6.55	0.40	3.9	46.00
26	Thottikuppam	6.48	0.47	4.2	45.00
27	Siruvambar	7.42	0.51	4.5	48.00
28	Thoravalur	7.10	0.45	4.7	39.00
29	Sembalakurichi	7.98	0.58	4.9	56.00
30	Puthukooraipetai	8.20	0.53	5.1	52.00
31	Rupanarayananallur	8.23	0.56	5.2	51.00
	Range	5.11-7.98	0.07-0.58	1.1-6.3	20.00-56.00
	Mean	6.44	0.31	4.7	39.00
	Standerd Deviation	0.82	0.10	0.4	9.00

Soil Fertility and its spatial variability

Present agricultural systems are explosive of nutrients through intensive tillage, monocropping, less recycling and burning of crop residues The availability of macro and micronutrients to plants is influenced by several soil characteristics. The deficiency of micronutrients along with macronutrients N,P,K and S were reported in recent years due to intensive cropping, loss of top soil by erosion, losses of micronutrients through leaching, excess liming of acid soils, less application of FYM compared to chemical fertilizers, growing high nutrient demanding modern crop cultivars and use of marginal lands for crop production (Behera and Shukla, 2013) [6]

Available N was deficient with values less than 250 kg ha^{-1}. The acute deficiency of N could be associated to low OC content, increased rate of mineralization and insufficient application of fertilizers. Similar results were reported by Kalesswari *et al*. (2012). Nutrient management practice of organic farming registered the highest available N of 310 kg ha^{-1}. This result was in accordance with Manjunatha *et al.* (2013) and Krishna kumar *et al*. (2013) [34] who reported that available N was found to be increased from fifth to fifteen years of organic farming practice.

Olsen – P was found to be low to high status. The deficiency of P was caused by fixation of P by iron and aluminium under acidic conditions and alkaline $CaCO_3$ in neutral and alkaline conditions. However the relatively better availability of P may be due to dissolution of precipitated forms of P. INM registered the highest Olsen - P content of 29.00 kg ha^{-1}. This result corroborate with the findings of Ghosh *et al.* (2012) [18] and Kalesswari *et al*. (2007).

Available potassium was found to be medium to high status. Adequate available K in these soils could be attributed to K rich minerals like illite and feldspars, more intensive weathering, release of labile K from organic residues, application of K fertilizers. (Pal and Murhopadhyay, 1992, Kalesswari *et al*. (2012). INM practice registered the highest available K of 360 kg $ha^{-1.}$ This result confirmed with the observation of Khanda *et al.* (2005) [26] and Xu *et al*. 2010 who reported that, increasing the application of K may be useful for increasing crop yields, including those of the high productivity paddy soils.

Table 2: Available Nitrogen, Available Phosphorus, Available Potassium status of Cuddalore district

Site. No	Name of the location	Available Nitrogen (kg ha^{-1})	Available Phosphorus (kg ha^{-1})	Available Potassium (kg ha^{-1})
1	Viruthachalam	120	15.00	247
2	Kuppanatham	100	27.00	262
3	Kovilanur	110	34.00	252
4	M.Patti	105	22.00	181
5	Manavalanallur	120	23.00	246
6	Mathur	125	19.00	212
7	Narumanam	128	12.00	209
8	Chinnaparur	130	26.00	242
9	Eadaiyur	135	11.00	126
10	Gopurapuram	134	13.00	132
11	Karnatham	140	16.00	134
12	Chinnakandiyankuppan	146	18.00	136
13	Ka.Elamangalam	150	20.00	145
14	Kattiyanallur	155	22.00	150
15	Earumanur	160	14.00	180
16	Kovilanur	180	24.00	188
17	Komangalam	190	25.00	210
18	Paravalur	185	26.00	222
19	Puliyur	195	27.00	166
20	Rajendirapatinam	200	16.00	168
21	Sathiyavadi	210	15.00	165
22	Pthukooraipettai	205	17.00	170
23	Peralaiyur	220	18.00	175
24	Mu.Agaram	215	20.00	250
25	Vetakudi	230	21.00	258
26	Thottikuppam	250	29.00	280
27	Siruvambar	188	25.00	288
28	Thoravalur	240	33.00	290
29	Sembalakurichi	235	31.00	296
30	Puthukooraipetai	199	30.00	310
31	Rupanarayananallur	196	32.00	314
	Range	100-250	11.00-34.00	126-310
	Mean	170	21.00	209
	Standerd Deviation	44.0	6.00	55.0

The micronutrient status of the study area was grouped in to deficient / sufficient. DTPA Zinc content ranged from 1.75 to 9.98 mg kg^{-1}. Zinc deficiency may be associated with coarse texture, high p^{H} (formation of insoluble reaction products of Zn), less amount of organic matter and high clay contents. This was in line with the findings of Anil sood *et al.* (2009), Kalesswari *et al*. (2012). Among the management practices, aerobic rice farming registered the highest available Zn. This is in accordance with the findings of Panwan *et al* (2010).

DTPA - Fe varied from 7.89 to 30.5 mg kg^{-1}. Coarse texture and low organic matter content are the prominent factors that affect iron availability in varying extent and intensity. This was supported by the findings of Katyal and Rattan (2003) [24], Kalesswari *et al*. (2012). Nutrient management practice of INM registered the highest available iron (Fe) of 39.7 mg kg$^{-1.}$ Similar findings was reported by Dhaliwal *et al.* (2013)

Table 3: Physico-Chemical Quality Indicators of ICAR-KVK, Viruthachalam

Management Strategies	P^{H}	Ec	OC	CEC	N	P	K	TN	ZN (mg kg^{-1})	FE (mg kg^{-1})	B(mg kg^{-1})
SRI Method	7.54	0.22	9.4	79.0	280	24	350	1.29	10.1	35.4	0.81
Organic Farming	7.59	0.10	9.2	81.0	310	28	355	1.23	11.2	37.4	0.83
INM practice	7.96	0.15	9.9	78.0	290	29	360	1.28	13.3	39.7	0.86
Aerobic Rice	8.20	0.20	9.1	75.0	285	27	354	1.34	12.2	33.5	0.82
Conventional Farming	7.23	0.37	8.9	58.0	294	26	350	1.24	9.2	36.8	0.75
Mechanical Farming	7.16	0.32	9.5	66.0	298	25	344	1.21	8.2	35.3	0.80
RANGE	7.16-8.20	0.10-0.37	9.9-8.9	58.0-81.0	280-310	24-29	344-360	1.21-1.34	13.3-8.2	33.5-39.7	0.75-0.86
MEAN	7.61	0.22	9.3	72.0	292	26	352	1.26	10.7	36.3	0.81
Standard Deviation	0.40	0.10	0.3	8.0	10.0	1.7	5.0	0.04	1.9	2.12	0.03

Hot water soluble boron content of the soil samples ranged from 0.10 to 0.78 mg kg^{-1} in Cuddalore district. INM practice registered the highest available hot water soluble boron. Similar results was reported by Yaduvanshi (2001)

Table 3: Principal components, Eigen values and component matrix variables of Cuddalore district

Principal components	PC 1	PC 2	PC 3	PC 4	PC 5
Eigen values	13.166	52.663	52.663	3.748	14.991
%Variance	67.654	2.149	8.596	76.25	1.071
%Cumulative variance	4.284	80.534	0.899	3.597	84.131
Weightage factor	0.833	0.705	0.54	0.422	0.303
Bulk Density	-0.095	-0.342	-0.072	0.169	0.538
Particle Density	-0.145	0.079	-0.486	-0.117	0.173
Porosity	-0.035	0.301	-0.381	-0.395	-0.287
Sand	-0.075	-0.152	-0.248	0.441	-0.188
Silt	-0.181	0.282	0.193	-0.152	0.087
Clay	0.11	-0.266	0.241	-0.424	-0.285
AWC	-0.026	-0.353	-0.273	-0.372	-0.08
MWD	-0.264	0.052	0.093	0.071	0.059
Aggregate stability	-0.252	0.075	0.015	0.065	-0.097
P^H	-0.168	-0.182	0.341	0.054	-0.278
EC	-0.205	0.17	0.168	0.081	0.098
OC	-0.2	-0.293	0.057	-0.005	-0.132
CEC	-0.2	-0.273	-0.048	-0.026	-0.016
AN	-0.231	-0.15	0.243	-0.109	-0.055
AP	-0.136	-0.074	0.221	-0.415	0.472
AK	-0.255	0.142	-0.035	-0.028	-0.026
TN	-0.188	-0.259	-0.256	-0.029	0.122
Zn	-0.265	0.117	-0.018	0.017	0.007
Fe	-0.265	0.03	-0.114	-0.051	-0.051
Boron	-0.251	0.184	-0.052	0.023	0.03
MBC	-0.171	0.179	0.033	-0.171	0.02
MBN	-0.209	-0.199	-0.156	-0.007	-0.191
PMN	-0.26	0.136	0.062	0.077	-0.024
SRR	-0.251	-0.05	0.007	-0.031	0.033
DHA	-0.236	-0.053	0.062	0.142	-0.257

Table 4: Cuddalore District highly weighed parameters under Principal component Analysis

Highy weighed parameters	PC 1	PC 2	PC 3	PC 4	PC 5
	bulk density	particle density	porosity	WHC	sand

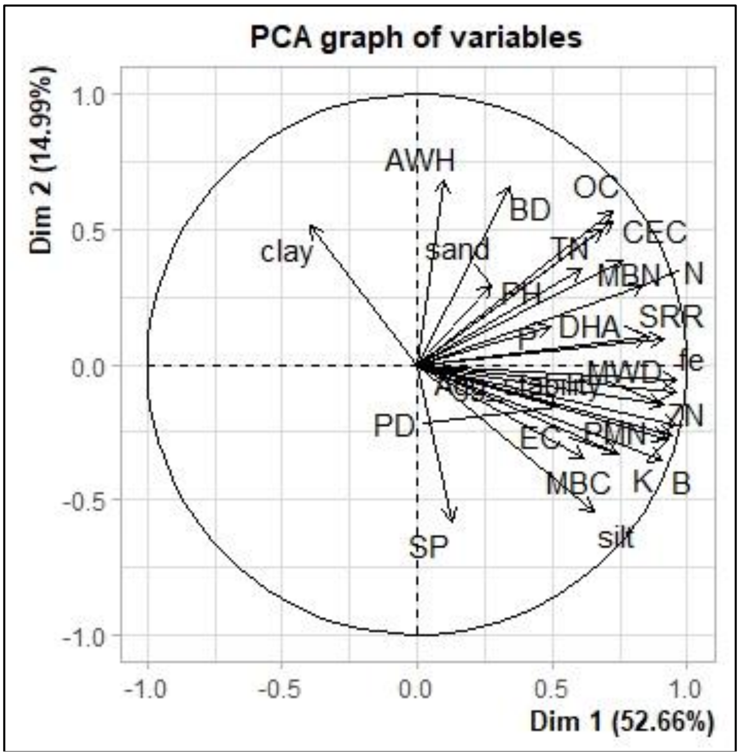

Fig 2: Cuddalore District soil physico-chemical indicators in PCA graph variables

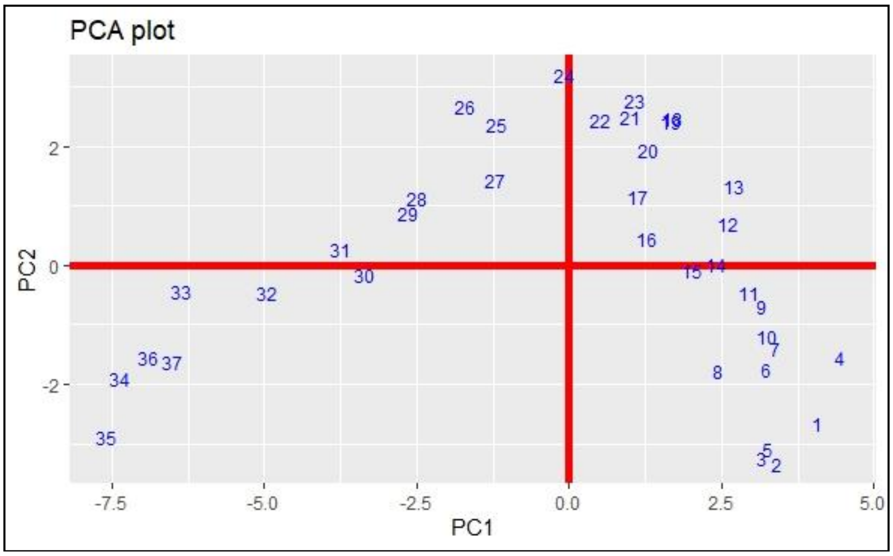

Fig 3: Cuddalore District soil physico-chemical indicators in PCA plot variables

Principal Component Analysis

The results obtained from PCA indicated five Principal Components (PCs) with eigen values greater than 1 (Table) and soil variables from each PC were considered for minimum soil data set MDS) The soil parameters selected from PC 1, PC2, PC3, PC4,PC5 were, P^{H,} EC, OC, CEC, Available Nitrogen, Available phosphorus, Available potassium, TN, Zn, Fe, Boron.

However, PCA Pt, PCA graph varibles showed higher variables between these parameters indicated available phosphorus which has the highest factor loading was retained in the MDS.

Conclusion

Soil quality index is a useful tool to assess soil health and well being. Few methods are available to estimate it. Among those PCA based scoring, ranking and weightage method gaining popularity. However, SQI assessment primarily depends on objectives of study or soil functions need to be addressed. Selection of MDS and its ranking play important role for determining SQI.Cuddalore district soil Physico-Chemical quality indicators soil Available phosphorus high under based on the Principal Component Analysis.

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