SPATIAL PREDICTION OF HEAVY METAL POLLUTION FOR SOILS IN COIMBATORE, INDIA BASED ON ANN AND KRIGING MODEL

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Abstract

The concentration of five soil heavy metals (Cr, Pb, and As) was measured in 121 sampling sites in Coimbatore, Tamil Nadu, India regions known as centres of pollution due to the chemical and metallurgical activities. The soil samples were collected from locations where the ground is not sliding and the probability of alluvial deposits is small. The concentration of heavy metals was measured by using Atomic Absorption spectrometer. Kriging and ANN techniques were used to develop the model to predict the constituents of the heavy metal in the soils. In some locations, the concentration for the investigated heavy metals exceeds the concentration admitted by the guideline. The highest concentration of lead (8.9 ppm) was found in Ukkadam Lake. The highest concentration of chromium was found in Ganapathi (3.6 ppm). The highest concentration of Arsenic (5.4 ppm) was found in Sidco Industrial Estate. The maximum admitted concentrations in the sensitive areas revealed to be exceed from five to twenty times.

Keywords: Kriging, ANN, Soil Pollution, Heavy metals (Cr, Pb, and As), Coimbatore

1. Introduction

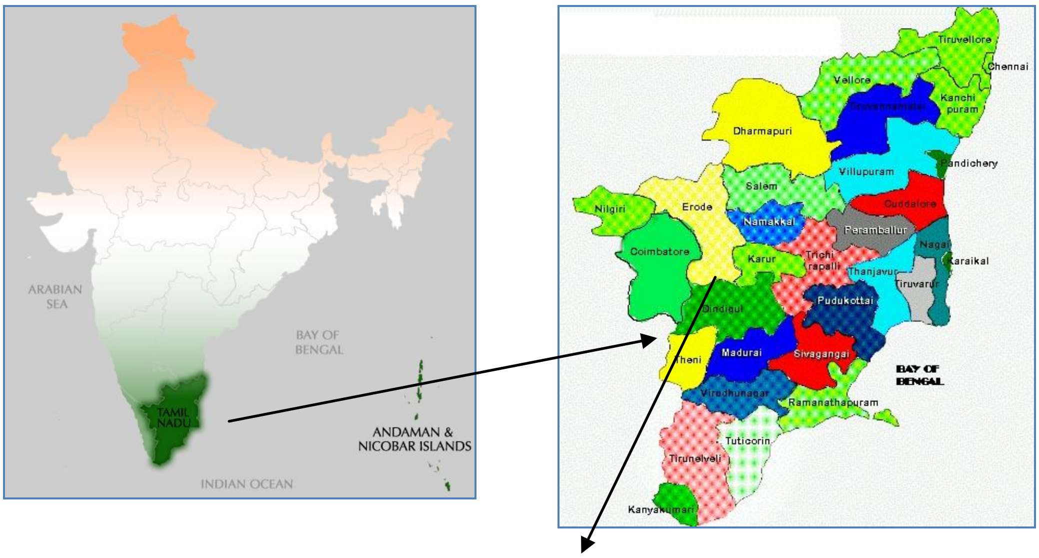
Heavy metal contamination of soil results mainly due to as mining [1], smelting procedures [2] and agriculture [3] as well as natural activities. Chemical and metallurgical industries are the most important sources of heavy metal contamination in the environment [4]. There are so many metal-based industries located in Coimbatore in an unorganized manner and is the second largest industrial centre in Tamil Nadu, India. The major industries include textile, dyeing, electroplating, motor and pump set, foundry and metal casting industries. According to the present situation, about 4500 textiles, 1200 electroplating industries, 300 dyeing units and 100 foundries are present in and around Coimbatore.

The metals are classified as "heavy metals" if they have a specific gravity of more than 5 g/cm^3. There are more than sixty heavy metals. Heavy metals get accumulated in soils and plants causing negative influence on photosynthesis, gaseous exchange, and nutrient absorption of plants resulting reductions in plant growth, dry matter accumulation and yield [5, 6]. In small concentrations, the traces of the heavy metals in plants or animals are not toxic [7]. Lead, cadmium and mercury are exceptions; they are toxic even in very low concentrations [8].

The main goal of the present research was to assess the heavy metals distribution in some Coimbatore areas, known as chemical or metallurgy industry centres.

2. Study Area

The study area (Figure-1) is located in the southern part in the state of Tamil Nadu, India



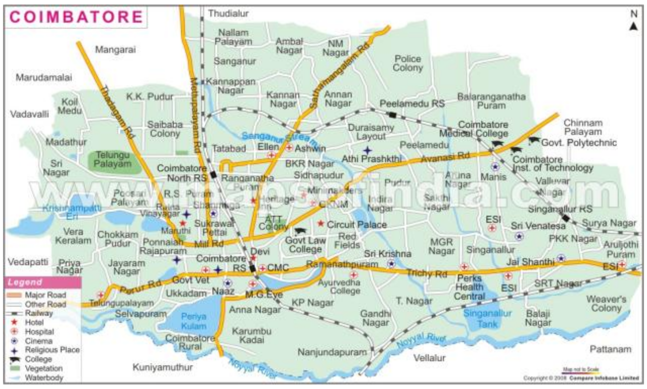


Figure-1-**Location map of study area**

121 locations were selected in the study area to collect the soil samples for analysis. To avoid contamination of the sample was thoroughly clean, black polythene bag was used in the collection of soil samples. To clean black polythene bags were dried at lower temperature. The soil samples were collected at random by digging the soil to about 1 meter at the specific refuse dumps.

3. Material and methods

The collected soil samples were air-dried and sieved into coarse and fine fractions. Well-mixed samples of 2 g each were taken in 250 ml glass beakers and digested with 8 ml of aqua regia on a sand bath for 2 hours. After evaporation to near dryness, the samples were dissolved with 10 mL of 2% nitric acid, filtered and then diluted to 50 mL with distilled water.

Heavy metal concentrations of each fraction were analyzed by Atomic Absorption Spectro photometry. Atomization and Quality assurance was guaranteed through double determinations and use of blanks for correction of background and other sources of error.

The GLOBEC Kriging Software Package – EasyKrig3.0 was used for creating the prediction model [9]. The prediction models are depicted in Fig. 2 to 4. The soils with potential risk of heavy metal pollution were located in isolated spots mainly in the northern part of the study region.

An artificial Neural Network technique is used to develop a model to predict the constituents of the heavy metal in the soils [10] such as lead, chromium, arsenic. The developed neural network model consist of 2 input neurons for latitude and longitude, 6 hidden layers consisting of 10 to 20 neurons in each layer for training the data and 1 neuron to predict the constituents of the heavy metal in the soils. The architecture of the model is depicted in Fig. 5 to 7.

4. Result and discussion

4.1 Kriging Model

The heavy metal from various localities including wetland soil sample were collected, analyzed and the results were reported. The metals analyzed were Cr, Pb and As. Lead Pb concentration varies from 0 to 8.9 ppm with a maximum 8.9 ppm at Ukkadam Lake. Reason for maximum Pb at Ukkadam Lake is due to discharging of sewage water into lake. Cr concentration ranged between 0 - 3.6 ppm. Maximum concentration was in Ganapathy because of the concentration of foundry industry. As ranged between 0 – 5.4 Maximum at Sidco Industrial Estate and Singanallur because of the concentration of electroplating industry. It is observed that maximum heavy metal pollution near the industrial, traffic junction and the legendary 'go-slow' of automobiles is the order of the day and in localities of large population concentration and relatively small areas under poor conditions of sanitation.

Kriging model was used to predict the heavy metal at the unknown point. From the model of heavy metals we can conclude that the residential areas are uncontaminated with Cr and moderately contaminated with Pb. Heavy metal accumulation in few prominent wetlands of 10 localities was analyzed. Pb is maximum in Velangulam Lake Ukkadam, and at the Sungam Lake.

4.2 ANN Model

The feed forward three layered back propagation network architecture is used to develop ANN model. The input layer consist of two nodes which represents latitude and longitude which used to predict the response and the output layer consist of one node which represents the constituents of the heavy metal in the soils such as lead, chromium, arsenic. The number of hidden layer and neurons in the hidden layer has been determined by training several networks.

The surveyed, predicted and error percentage of heavy metal is tabulated in table1.

4.3 Comparison of Kriging Model and ANN Model

Unlike an ANN model where spatial variability of particular metal deposition is captured through the nonlinear input – output mapping via a set of connection weights, kriging uses nearby sample points to predict the particular metal concentration at a particular location. Kriging and ANNs thus work in different frameworks. ANN resembles a parametric nonlinear global fitting model, whereas kriging works like a nonparametric local fitting model that restricts the mapping of the model to a local neighborhood of data points.

In kriging, the prediction of an unknown value at a location is obtained by linearly weighting the data points near to that particular location using the variogram structure of the attribute. In the present study, several kriging techniques—simple kriging (SK), ordinary kriging (OK), kriging with drift function (KD) and kriging with an external drift function (KED)—were used. Although the basic mechanisms of these techniques are the same, there are some fundamental differences. For example, unlike SK, OK and KD, the KED technique used the particular metal variable as secondary information to predict particular metal. Therefore, secondary information of the particular metal variability to detect particular metal is easily incorporated in the kriging model.

For Kriging, training and calibration datasets were merged to form a single dataset, based on which a kriging model was developed. The kriging models were tested on the same prediction datasets as those used for the ANN models.

The neural network model was developed and tested on the prediction dataset. The performance of the kriging techniques was also evaluated on the same prediction dataset as used in the ANN. The following test statistics were used to assess model performance. Mean error is a measure of bias, which also shows on average whether a model underestimates or overestimates the grades. A negative sign indicates overestimation and a positive sign indicates underestimation. Mean absolute error measures the mean absolute deviation of actual minus predicted values, which is a measure of accuracy.

4.3.1 Kriging interpolation

The use of Geostatistics in general and Kriging in particular was a useful tool to estimate the pollutants distribution in a contaminated site and also to give both the advantages and disadvantages associated with the use of Kriging.

Advantages of Kriging

- Kriging is an exact interpolator (if the control point coincides with a grid node).
- Relative index of the reliability of estimation in different regions.
- Good indicator of data geometry.
- Smaller nugget (or sill) gives a smaller kriging variance.
- Minimizes the Mean Square Error.
- Can use a spatial model to control the interpolation process.
- A robust technique (i.e., small changes in kriging parameters equals small changes in the results).

Disadvantages of Kriging

- Kriging tends to produce smooth images of reality (like all interpolation techniques). In doing so, short scale variability is poorly reproduced, while it underestimates extremes (high or low values).
- It also requires the specification of a spatial covariance model, which may be difficult to infer from sparse data.
- Kriging consumes much more computing time than conventional gridding techniques, requiring numerous simultaneous equations to be solved for each grid node estimated. The preliminary processes of generating variograms and designing search neighborhoods in support of the kriging effort also require much effort. Therefore, kriging probably is not normally performed on a routine basis; rather it is best used on projects that can justify the need for the highest quality estimate of a structural surface (or other reservoir attribute), and which are supported by plenty of good data.

4.3.2 Artificial Neural Network

Advantages of ANN Model

- A neural network can perform tasks that a linear program can not.
- When an element of the neural network fails, it can continue without any problem by their parallel nature.
- A neural network learns and does not need to be reprogrammed.
- It can be implemented in any application.
- It can be implemented without any problem.

Disadvantages of ANN Model

- The neural network needs training to operate.
- The architecture of a neural network is different from the architecture of microprocessors therefore needs to be emulated.
- Requires high processing time for large neural networks.

5.Conclusion

- Monitoring of heavy metal has been done through efficient way to access the qualitative and quantitative differences in metal concentration at distinct location and at local.

- Under the present ecological condition the heavy metal load is significant in Ukkadam Lake, Ganapathy and Goundampalayam dumping site.
- Many metal based industries like electroplating, foundries, casting, textile and dyeing industries apart from huge amount of sewage water production are the main sources of heavy metals contamination in Coimbatore, Tamil Nadu.
- The highest concentrations of heavy metals in these industrially polluted areas are not only problem with respect to plant nutrition and food chain contamination but also causes a direct health hazards to human and animals, which is still in need of an effective and affordable technological solution.

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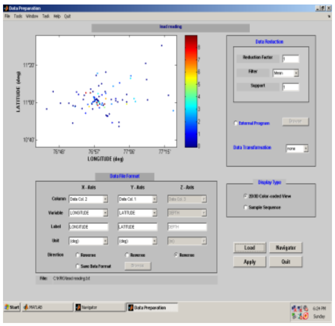
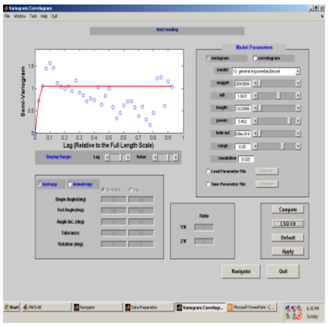
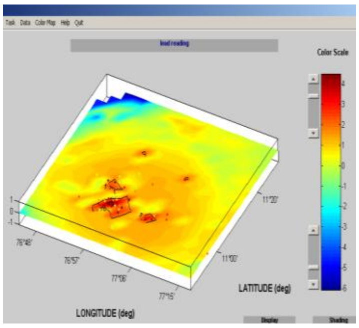


Data Preparation

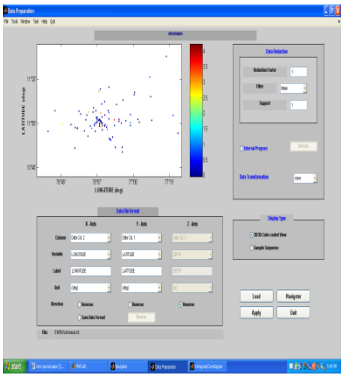


Variogram



Concentration Map

Fig. 2. Kriging model for Lead



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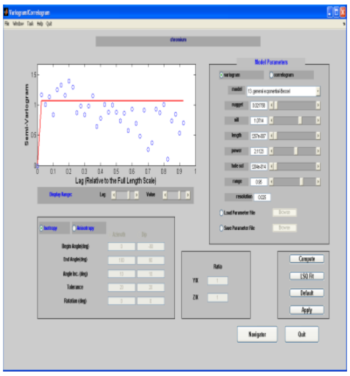
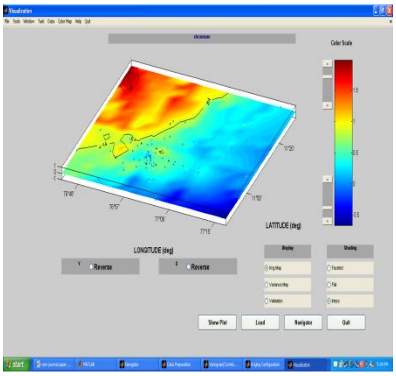
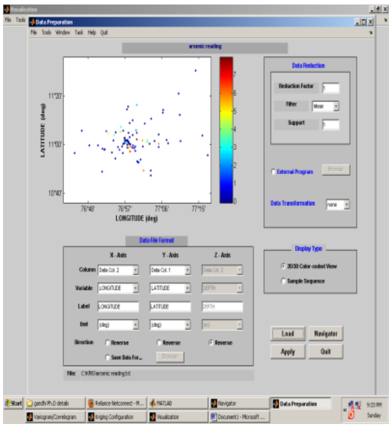


Variogram



Concentration Map

Fig. 3. Kriging model for Chromium



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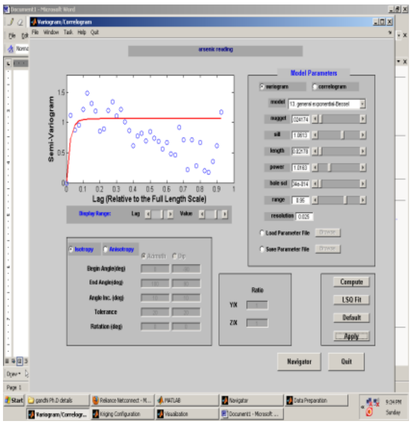
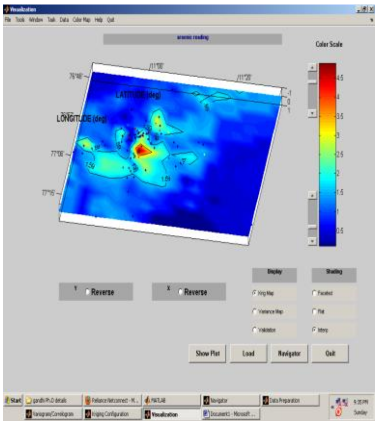


Variogram



Concentration Map

Fig. 4. Kriging model for Arsenic

Table – 1											
S.no	**Station**		**Output (Pb)**		**Error %**	**Output(Cr)**		**Error %**	**Output(As)**		**Error %**
	Latitude	**Longitude**	**Surveyed**	**Predicted**		**Surveyed**	**Predicted**		**Surveyed**	**Predicted**	
1	10º	77 º 0’27.39”E	0.579	0.5858	-	0.65	0.6566	-	1.39	1.4041	-
2	10º	77º 0' 15.12”E	0.12	0.1222	-	0.56	0.5483	2.0863	0.967	0.9855	-
3	11º	77º 1’51.76”E	0.032	0.0316	1.3125	0.41	0.4228	-	0.541	0.5544	-
4	11º 05’22”N	76º 52’31”E	0.41	0.4183	-	0.341	0.3506	-	0.321	0.3113	3.0137
5	11º	76º 8’39.81”E	2.44	2.5243	-	3.5	3.3944	3.0165	0.349	0.3529	-
6	11º 01’9.92”N	76º 57’45.09”E	2.12	2.0970	1.0847	3.62	3.5566	1.7523	0.321	0.3281	-
7	11º 03’28.2”N	76º 9’31.38”E	0.76	0.7445	-	2.341	2.4338	2.9355	0.211	0.2157	2.0692
8	11º 01’4.77”N	76º 57’56.82E	2.89	2.9295	-	0.23	0.2369	-	0.191	0.1931	-
9	11º 0’2.82”N	76º 58’5.38”E	3.2	3.1685	0.9831	0.0231	0.0233	-	0.876	0.9029	-
10	11º 15’25.01N	76º 57’49.84”E	2.39	2.3316	2.4446	0.015	0.0149	0.8998	0.0275	0.0269	2.1236
11	11º 14’0.84’’N	77º 06’22.97”E	1.234	1.2812	-	0.012	0.0124	-	0.006	0.0062	-
12	11º	76º 8’57.01”E	0.89	0.8889	0.1236	0.032	0.0320	0.1236	0.045	0.0445	1.0231
13	11º	77º 06’14.99”E	0.432	0.4416	-	0.012	0.0122	-	0.023	0.0225	2.0351
14	11º 10’26.6”N	77º 03’28.78”E	1.45	1.4116	2.6449	0.019	0.0186	2.2669	0.0468	0.0478	-
15	11 º 02’44.”N	76º 56’48.97”E	7.3	7.5914	-	0.02	0.0206	-	0.0102	0.0099	3.1129
16	11 º 0’40.26”N	76º 57’12.45”E	1.237	1.2631	-	0.43	0.4424	-	0.0184	0.0188	-
17	11 º 1’34.79”N	76º 57’2.86”E	0.31	0.3160	2.0351	0.02	0.0194	-	0.0348	0.0341	-
18	11 º 1’33.79”N	76 º 57’29.6”E	1.34	1.3684	-	0.45	0.4641	-	0.0098	0.0095	2.6449
19	11 º 9’	76 º 58’54.88”	0.01	0.0097	3.1129	0.008	0.0079	1.0029	0.069	0.0718	-
20	11 º 1’02”N	76 º 6’06.43”E	0.012	0.0122	-	0	0.0000	0	0.005	0.0051	-
21	11 º 0’3.42”N	77 º 03’2.44”E	0.023	0.0228	1.0435	0	0.0000	0	0.002	0.0020	2.4135
22	11º 0’28.75”N	76 º 57’3.31”E	6.02	6.1405	-	0.067	0.0692	-	0.003	0.0029	2.9917
23	11 º 0’34.57”N	76 º 57’9.89”E	0.004	0.0041	-	0.56	0.5746	-	5.68	5.8805	-
24	11 º 0’57.56”N	76 º 57’49.84”E	0.001	0.0010	0	3.568	3.4966	2.0001	6.12	6.0596	0.9871
25	10	77 º 01’24.24”E	2.15	2.1237	1.2247	0.025	0.0242	3.0047	0.014	0.0138	1.2247
26	10	76 º 58’20.89”E	0	0.0000	0	0.001	0.0010	0	0.025	0.0245	1.9233
27	11 º 1’30.5”N	77 º 01’18.94”E	0	0.0000	0	0.78	0.7600	2.5642	4.67	4.7163	-
28	10	76 º 58’21.89”E	0	0.0000	0	0.612	0.6351	-	3.98	3.9419	0.9561

29	10 º	76 º 59’19.7”E	0	0.0000	0	0.003	0.0029	3.1281	0.001	0.0010	0
30	10	76 º 57’37.89”E	0.001	0.0010	0	0.009	0.0092	-	4.89	4.9926	-
31	11 º 56’37”N	76 º 56’18.44”E	0.002	0.0019	2.9981	0.004	0.0038	3.9001	0	0.0000	0
32	11	76 º 56’49”E	0	0.0000	0	0.001	0.0010	0	0.45	0.4455	0.9991
33	11	76 º 57’11.59”E	0.002	0.0020	0	2.98	3.0490	-	6.65	6.8052	-
34	11 º2’44”N	76 º 56’48.44”E	1.82	1.8747	-	1.002	1.0321	-	0.011	0.0113	-
35	11 º 5’0.4”N	76 º 56’0.67”E	8.376	8.2838	1.1012	0.029	0.0281	3.0012	0.007	0.0068	2.3112
36	11 º 3’48.26”N	76 º 58’58.73”E	0.89	0.8711	2.1236	0.012	0.0119	1.1236	0.004	0.0041	-
37	11 º 4’12.48”N	76 º 52’56.2”E	0.568	0.5795	-	0.022	0.0227	-	0.0679	0.0697	-
38	11 º 8’27.19”N	76 º 01’1.92”E	0	0.0000	0	0.081	0.0802	0.9876	0.026	0.0257	0.9765
39	11 º 12’0.84’’N	77 º10’22.97”E	0	0.0000	0	0.004	0.0040	0	0.002	0.0020	0.8891
40	11 º 14’19.4”N	76 º 57’31.78”E	0.231	0.2334	-	0.065	0.0657	-	0.456	0.4608	-
41	10 º 57’4.86”	76 º 58’16.9”E	1.15	1.1740	-	0.005	0.0051	-	7.93	8.0955	-
42	10 º 59’37.95”	76 º 57’38.86”E	8.56	8.4460	1.3312	0.087	0.0842	3.1612	7.63	7.5284	1.3312
43	11 º 02’13.0”	76 º 57’1.92”E	2.58	2.6575	-	0.003	0.0031	-	0.029	0.0299	-
44	10º56’30.36’’N	76 º53’52.93”E	0.002	0.0020	0	0.09	0.0870	3.2927	0	0.0000	0
45	11 º 2’37.32”N	76 º 57’2.86”E	0.78	0.7879	-	0.0011	0.0011	0	0.002	0.0020	1.0351
46	11 º 1’28.98”N	76 º54’14.26”E	0.011	0.0112	-	0.007	0.0073	-	5.89	5.9980	-
47	11 º 0’35.43”N	76 º 57’0.20”E	0.021	0.0215	-	0.002	0.0021	-	1.34	1.3224	1.3125
48	11 º 0’40.26”N	76 º 57’12.45”E	0.27	0.2619	3.0137	0.05	0.0485	2.9637	1.002	1.0223	-
49	11 º 4’43.63”N	77 º 0’7.11”E	1.59	1.6076	-	0.028	0.0290	-	1.28	1.3242	-
50	11 º 1’52.76”N	76 º59’.59.32”E	6.14	6.2764	-	0.001	0.0010	0	0.0826	0.0817	1.0847
51	10º	76 º 59’3.67”E	1.59	1.5571	2.0692	4.2	4.1064	2.2292	0.155	0.1580	-
52	10º	76 º 58’20.89”E	4.12	4.1658	-	3.21	3.2821	-	3.76	3.8114	-
53	10 º 53’2.99”N	77 º 00’3.42"E	0.135	0.1392	-	0.013	0.0134	-	0.505	0.5000	0.9831
54	10 º 49’4.8”N	77 º 01’35”E	0.89	0.8711	2.1236	0.067	0.0657	2.0136	0.098	0.0956	2.4446
55	11 º 05’22”N	76 º 52’31”E	0.546	0.5516	-	0.013	0.0135	-	0.088	0.0889	-
56	11 º 01’4.77”N	76 º 57’56.82E	0.134	0.1299	3.0746	0.043	0.0418	2.7346	1.2	1.1631	3.0746
57	10º	76 º 52’5.6E	1	1.0222	-	0.12	0.1212	-	0.056	0.0572	-
58	11 º 4’35.16”N	76 º 57’56.82E	3.21	3.1688	1.2835	0.021	0.0202	3.8352	0.056	0.0542	3.1831
59	11 º 3’46.24”E	76 º 54’28”E	0	0.0000	0	0.004	0.0039	2.9132	0.001	0.0010	0

60	10º	76 º 51’35.3E	0	0.0000	0	2.98	2.8807	3.3312	0	0.0000	0
61	11 º 0’21.67”N	77 º 07’32.80E	2.87	2.8093	2.1135	0.04	0.0391	2.3511	0.561	0.5666	-
62	10º	77 º 17’10.87E	2.134	2.1885	-	0.987	1.0220	-	0.78	0.7877	-
63	11 º 0’40.26”N	76 º 57’12.45”E	0.112	0.1143	-	2.87	3.0116	-	5.45	5.5586	-
64	10º	76 º 58’53.64E	2.34	2.2954	1.9043	2.98	2.9063	2.4743	0.78	0.7653	1.8829
65	11 º 8’29.54”N	77 º 1’51.76”E	2.23	2.2816	-	0.023	0.0236	-	0.076	0.0783	-
66	10 º 54’7.31’’N	76 º 59’45.55”E	1.2	1.1780	1.8333	0.1	0.0972	2.8223	0.78	0.7879	-
67	11 º 4’54.83”N	76 º54.5’0.3”E	8.2	8.1245	0.9212	0.025	0.0245	2.1299	0.98	0.9997	-
68	10 º 58’40.3”N	76 º 57’38.56”E	2.89	2.9187	-	0.034	0.0351	-	0.38	0.3862	-
69	10º	76 º 59’36.02”E	5.12	4.9663	3.0021	0.076	0.0743	2.2245	0.72	0.7323	-
70	10 º 57’4.86”N	76 º58’16.99”E	4.56	4.6103	-	2.89	2.8966	-	4.567	4.4299	3.0018
71	10 º 59’01”N	76º 57’36.62”E	8.912	9.0110	-	0.92	0.9211	-	1.23	1.2437	-
72	10º	76º57’54.92”E	7.654	7.4840	2.2213	0.675	0.6538	3.1367	0.987	0.9651	2.2213
73	10º	76 º 59’ 0.95”E	9.27	8.9816	3.1111	1.04	1.0180	2.1109	7.56	7.3248	3.1111
74	10º	76 º55’19.88”E	1.543	1.5585	-	0.067	0.0691	-	6.67	6.7371	-
75	11º	77 º 1’12.9”E	1.67	1.6865	-	0.054	0.0529	2.0611	5.89	5.9482	-
76	11 º 1’48.88”N	77º 07’12.11”E	2.982	3.0414	-	0.54	0.5508	-	6.78	6.9152	-
77	11 º 0’5.88”N	76 º 56’46.10”E	3.5	3.4341	1.8829	0.89	0.8712	2.1129	2.12	2.0801	1.8829
78	10º	76º56.5’21.13”E	2.38	2.4515	-	0.387	0.3986	-	3.12	3.2137	-
79	11 º 0’40.26”N	76 º 57’12.45”E	1.87	1.8889	-	0.245	0.2475	-	1.23	1.2424	-
80	11 º 00’10.6”N	76 º 56’38.04”E	0.98	0.9997	-	0.17	0.1734	-	0.45	0.4590	-
81	10º	76º 56.5'	2.3	2.3376	-	0.19	0.1966	-	0.012	0.0117	2.1135
82	10º	76º 55’41.65”E	5.82	5.9196	-	0.034	0.0347	-	0.005	0.0051	-
83	10º	77º 5’18.69”E	5.42	5.2573	3.0018	2.345	2.2702	3.1886	3.89	3.9713	-
84	11 º 1’24.75”N	76 º 57’25.22”E	0	0.0000	0	0.005	0.0049	1.9932	0.345	0.3384	1.9043
85	11 º 4’00.39”N	77º 5’18.69”E	0.002	0.0020	0	0	0.0000	0	0.789	0.8073	-
86	11 º 0’12.55”N	77 º 4’18.33”E	0	0.0000	0	0	0.0000	0	0.003	0.0029	1.8333
87	11	77º 5’18.69”E	0	0.0000	0	0.002	0.0021	-	0.002	0.0020	0
88	11	76 º 59’47”E	0.002	0.0020	0	0.005	0.0051	-	0.001	0.0010	0
89	11 º 7’3.86”N	76 º 56’7.2”E	0.19	0.1861	2.0526	0.389	0.3750	3.5926	2.53	2.4384	3.6216
90	10º56’22.66”N	76 º 44’47.8”E	0	0.0000	0	0.007	0.0068	2.4412	0.008	0.0081	-

91	10º	76 º 50’31.36”E	0	0.0000	0	0	0.0000	0	0	0.0000	0
92	10	76º 48’ 15.77”E	0	0.0000	0	0	0.0000	0	0.005	0.0050	0.8823
93	11 º 0’48.17”N	77 º 2’29.9”E	0.678	0.6984	-	0.832	0.8499	-	0.0535	0.0546	-
94	11 º 1’49.17”N	77 º 2’ 29.9”E	0.654	0.6382	2.4153	0.567	0.5491	3.1535	0.798	0.7883	1.2153
95	11 º 1’18.08”N	77 º 10’39”E	0.003	0.0029	1.9981	0	0.0000	0	0.566	0.5604	0.9981
96	10	76º 44’47.8”E	0.002	0.0020	0	0	0.0000	0	0	0.0000	0
97	10	76º 56’23.85”E	0.001	0.0010	0	0.008	0.0082	-	0	0.0000	0
98	11 º 4’00.39”N	77º 5’18.69”E	0	0.0000	0	0.021	0.0218	-	0	0.0000	0
99	11 º 5’37.47”N	76º 46' 31”E	0.0001	0.0001	0	0.001	0.0010	0	0	0.0000	0
100	11 º 0’48.17”N	77º 2’29.9”E	0	0.0000	0	0	0.0000	0	0	0.0000	0
101	11	76º 59’56.74”E	0	0.0000	0	0	0.0000	0	0	0.0000	0
102	11	77º 10’7.07”E	0.003	0.0029	1.8812	0	0.0000	0	0	0.0000	0
103	11	77º 15’57.97”E	0	0.0000	0	0	0.0000	0	0	0.0000	0
104	11	77º 04’14.34”E	0.005	0.0051	-	0.002	0.0019	3.1456	0.002	0.0020	0
105	11	77º 05’33.98”E	0.003	0.0031	-	0.001	0.0010	0	0.001	0.0010	0
106	10	76º 51’28.61”E	0	0.0000	0	0	0.0000	0	0	0.0000	0
107	11º	77º 14’14.49”E	0	0.0000	0	0.003	0.0031	-	0	0.0000	0
108	11º	76º 58’9.86”E	0.054	0.0546	-	0	0.0000	0	0	0.0000	0
109	10º	76º 52 ' 9.32”E	0.001	0.0010	0	0.001	0.0010	0	0	0.0000	0
110	10º 56 23.48”N	76º 56’35.4”E	0	0.0000	0	0.002	0.0021	-	0	0.0000	0
111	11º 00 39.45”N	76º 58’3.6”E	0.053	0.0543	-	0.002	0.0019	3.1577	0.002	0.0020	0
112	10º 53 43.69”N	76 º53'35.4”E	0	0.0000	0	0	0.0000	0	0	0.0000	0
113	10º 49 7.88”N	77º 03’19.65”E	0.002	0.0020	0	0.001	0.0010	0	0.001	0.0010	0
114	10º 47 4.09”N	77º 03’31.03”E	0.023	0.0225	2.2985	0.104	0.1028	1.1976	0.202	0.1994	1.2977
115	11º 01'41.52”N	76º 57’40.6”E	0.031	0.0304	1.9888	0.002	0.0019	3.6712	0.032	0.0317	1.0891
116	11º 01’24.7”N	76º 57’25.27”E	0.057	0.0583	-	0.003	0.0031	-	0.011	0.0112	-
117	11º	76º 56’41.27”E	0.006	0.0062	-	0.001	0.0010	0	0.021	0.0212	-
118	11 º 02’54.9”N	76º 58’14.1”E	0	0.0000	0	0	0.0000	0	0	0.0000	0
119	11 º 07’6.69”N	77º 02’32.6”E	0.071	0.0703	0.9876	0	0.0000	0	0	0.0000	0
120	11º	77 º 04’47.64”E	0	0.0000	0	0	0.0000	0	0	0.0000	0
121	11º 12’ 5.7”N	77 º 4.39’ 30”E	0.032	0.0316	1.1111	0.001	0.0010	0	0	0.0000	0