

Estimation of Daily Temperature & Rainfall Using Inverse Distance Weightage (IDW) Method & Inter-Relationship with Water Quality & Adaptive Behaviors

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ABSTRACT - Do changes in micro-climate or weather have any effect on the manner in which we treat water for consumption? A research study by NEERMAN attempts to answer the question by combination of large scale field surveys, GIS analysis, and advanced econometric models. The field survey conducted data from over 9300 panel households from 242 villages from 4 districts of Maharashtra in summer and monsoon reason in 2005 and 2007 and collected information on socio-economics, disease prevalence, drinking water quality (E.Coli contamination in CFU/100 ml), and household water safety behaviors. Secondary data on rainfall and temperature was collected from 10 Indian Meteorology Department (IMD) weather stations and 103 blocks (Tehsil) rain gauge. Inverse Distance Weightage (IDW) method was used in ArcGIS to estimate daily weather condition (quantitative) of all the surveyed villages by spatial extrapolation of weather data. The data was then merged with the primary household data on basis of location of the village and the date of survey. Such GIS database was then analyzed in STATA - a statistical software – using regression models to assess the effect of temperature and rainfall on water safety related behaviors.

Keywords: climate change, e-coli contamination, inverse distance weighting, health & behavioral data, water quality

1.0 Introduction:

Climate data is normally collected on a periodic basis, if the sample locations (here survey villages) are very large. However, for a research study, which needed climate data on a daily basis, for same large number of survey villages, actual recording of data was not possible. Hence spatial interpolation technique in GIS was used for obtaining, handling & interpretation of data.

Various spatial interpolation techniques have been employed in related fields. Such techniques can be divided into:

1.1 Geographical statistics :Kriging

1.2 *Non-geographical statistics* : Nearest neighbor (NN), Thiessen polygons, Splines and local trend surfaces, Global / local polynomial, Trend surface analysis, Radial basic function (RBF), inverse distance weighting (IDW), and geographically weighted regression^[1]

GIS used in combination with other analysis tools can be an effective method for a wide range of research- from studies to Policy analysis. In this paper, potential of GIS is tapped to obtain a huge amount of data, which is further analyzed using regression & other statistical tools.

the inter-relationship studies. An on-site estimation of daily temperature and Rainfall, for all the 242 surveyed villages, was practically impossible. Hence, using reference data from the IMD & MahaHP met stations, daily readings were obtained.

Results obtained by NEERMAN have been used in the paper, to highlight the use of data.

2.0 Materials and Methods:

This interpolation method estimates a point using the nearest sample points, which are weighted by a power factor n , their distance from the interpolation station has the lowest weight. The influence of the closer the weights should be method is

$$P_i = \frac{\sum_{j=1}^G P_j / D_{ij}^n}{\sum_{j=1}^G 1 / D_{ij}^n}$$

Where;

P_i = value at the location i

P_j = value at the location j

D_{ij} = Distance from i to j

G = number of sampled locations

GIS based IDW method proved to be efficient in generating the climatic data.

2.1 Data for GIS Application

Climate data was collected from Indian Meteorological Department (IMD)&MahaHP (Hydrology Project, Water resource department, Government of Maharashtra). The study was conducted in 4 sample districts of Maharashtra state viz. Buldhana, Nashik, Osmanabad, Sangli.

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Temperature and rainfall data was a significant aspect of

Major difficulties were faced during data collection, due to long procedures & lack of availability of complete data. As per the software requirement, a minimum of 10 met-station data was to be used as input. Data for the month of August for Osmanabad station was not available. Hence data of Bhatsanagar station was used (entire data of Bhatsanagar too wasn't available, hence a combination of both the station data were to be made use of).

A few met stations, due to some technical issues, did not record data of a few random days. For such days, the readings were taken as an average of the preceding & succeeding days. The entire met station data was tabulated as a .csv file, & converted to ArcGIS 10 compatible shape (*.shp) file. This was the input file for the interpolation process. These were:

- Tmax 2005: maximum temperature readings for 2005
- Tmax 2007: maximum temperature readings for 2007
- Tmin 2005: minimum temperature readings for 2005
- Tmin 2007: minimum temperature readings for 2007
- RF 2005: Rainfall for 2005
- RF 2007: Rainfall for 2007

2.2 Field Survey Data:

242 villages were surveyed for health & behavioral data. Field survey was conducted for 2 seasons (summer & monsoon) during 2005 & 2007 by NEERMAN. Locations of these villages were marked using GPS, and data provided by them. Using the latitude- longitude for each village, a shape file was created viz. "village data".

3.0 Processing:

Activating the 'Geostatistical Analysis' Extension, the 'Geostatistical Analysis Wizard' tool was used, to create IDW raster layer file. This layer file was further used, for predicting day wise temperature & RF, creating vector files for villages. One file was created for each date, from 1st March to 15th October for the years 2005 & 2007. 228 files were thus created per year per parameter (228 files * 2 years * 3 parameters).

The predictions for all dates were then collectively saved in a single file to be submitted to NEERMAN, for their studies & further analysis.

This was done using inbuilt function (Geostatistical Analysis- Extension) in ArcGIS 10.

Further the GIS data was used to study climatic effects on water quality & adaptive behavior by NEERMAN. Following 6 variables were created: (0)

- Average rainfall (mm) over date of survey & previous day
- Average maximum temperature (°C) over date of survey & previous day
- Average rainfall (mm) over date of survey & previous 3 days
- Average maximum temperature (°C) over date of survey & previous 3 days
- Average rainfall (mm) over date of survey & previous 6 days
- Average maximum temperature (°C) over date of survey & previous 6 days

Here, it should be noted, that GIS played a very important role to obtain (more precisely, predict) climatic data on a daily basis at a large number of sample points. An actual

Parameters considered for field survey included:

Water filtering (W+F)

Safe handling techniques of water (viz. tap/ ladel to remove water) (SH)

Water quality (WQ)

Since water quality was a qualitative parameter, water was tested for presence of e-coli, a quantitative approach, to determine the presence of fecal contamination.

4.0 Results:

Table 1 indicates summary of climate data of met stations. Table 2 indicates summary of data obtained by IDW method using GIS. The predicted data shows a high standard deviation ranging from 4°C to 5°C. This is an indication of fluctuations in the daily climate data, during the survey dates.

NEERMAN analysis further indicated a co-relation climatic conditions & water quality & human adaptation. Their studies highlighted that an increase in temperature decreases WF.

An increase in rainfall is associated with increase in WF & SH.

A part of the analysis results taken from the paper of Climate change & human behavior answers 2 important queries, which would highlight importance of GIS in other fields, analysis & policy decisions:

Do households change their averting behaviors in response to climate?⁽⁰⁾

Yes, we find evidence that likelihood of filtering decreases and the likelihood of safe water handling increases with increase in current temperature. However, the reduction is quitesmall in magnitude. Increase in rainfall increases the likelihood of filtering and safer watertransfers. In case of substantial rainfall (say 100 mm), the behaviors will change substantially aswell. However, neither filtering nor safer water transfer were shown to have any effect on watercontamination at home. Therefore, even if households may modestly change their behaviors inresponse to current weather, these behaviors may not be adequate enough for the households toadopt to climate, and arguably by extension, to climate change.

What are the marginal effects of climate on drinking water quality at home?⁽⁰⁾

Increase of 1 degree Celsius in daily maximum temperature is associated with 4.7 percentreduction in e coli contamination at home. Rainfall has no effect on water quality production.However, as argued before this effect may be because of the reduction in temperature typicallyassociated with increased rainfall.

5.0 Discussion:

The research paper was one of the first of its kind attempt to indicate direct relationship between climate on a daily basis and water quality & in turn human behavior. Hence it lacked practical application to some extent. However, the studies did show relationship (obtained statistically).

measurement at all these sample points would have not been possible.

GIS can be of great help in other such studies. A normal

statistical analysis would be more effective when GIS technology is integrated with it. It is of immense help to policy makers

The IDW method in GIS method used for spatial extrapolation too has a few flaws viz: it requires a minimum input data of ten points (met stations). An input of less than 10 stations would give unstable results. Hence some more studies should be done so as to identify the flaw & rectify the same in the software/ system specifications.

Acknowledgments

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Fig. 1: IDW Layer in ArcGIS

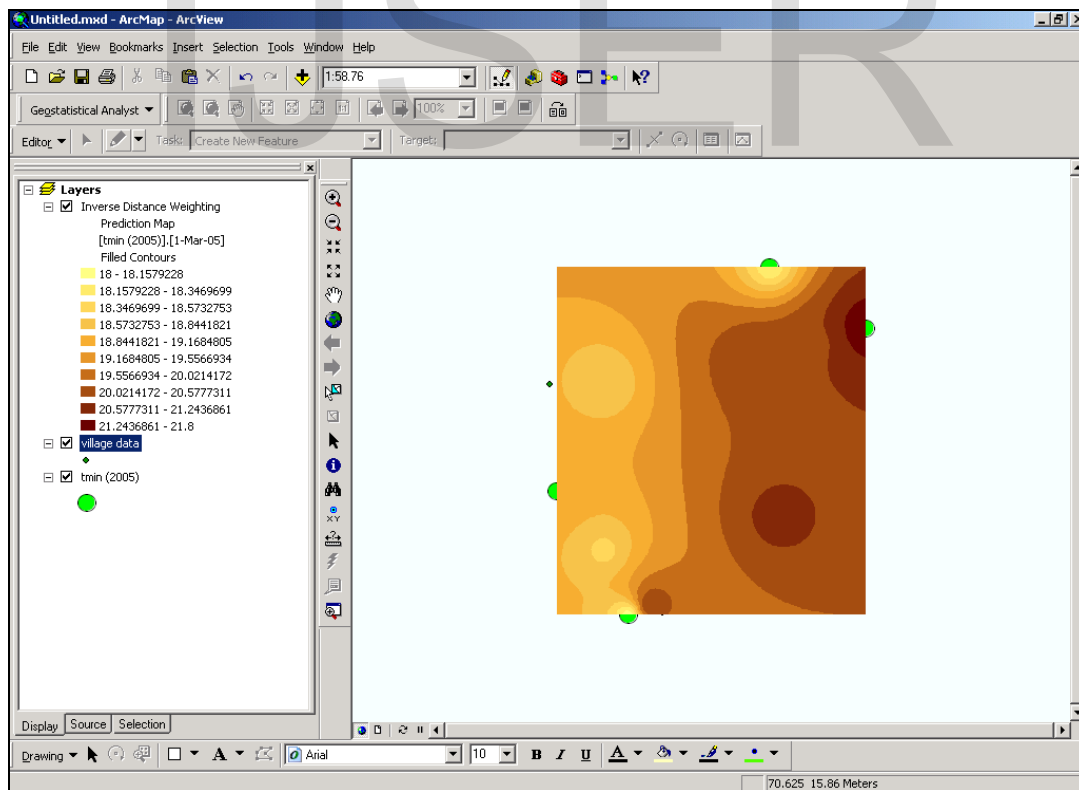
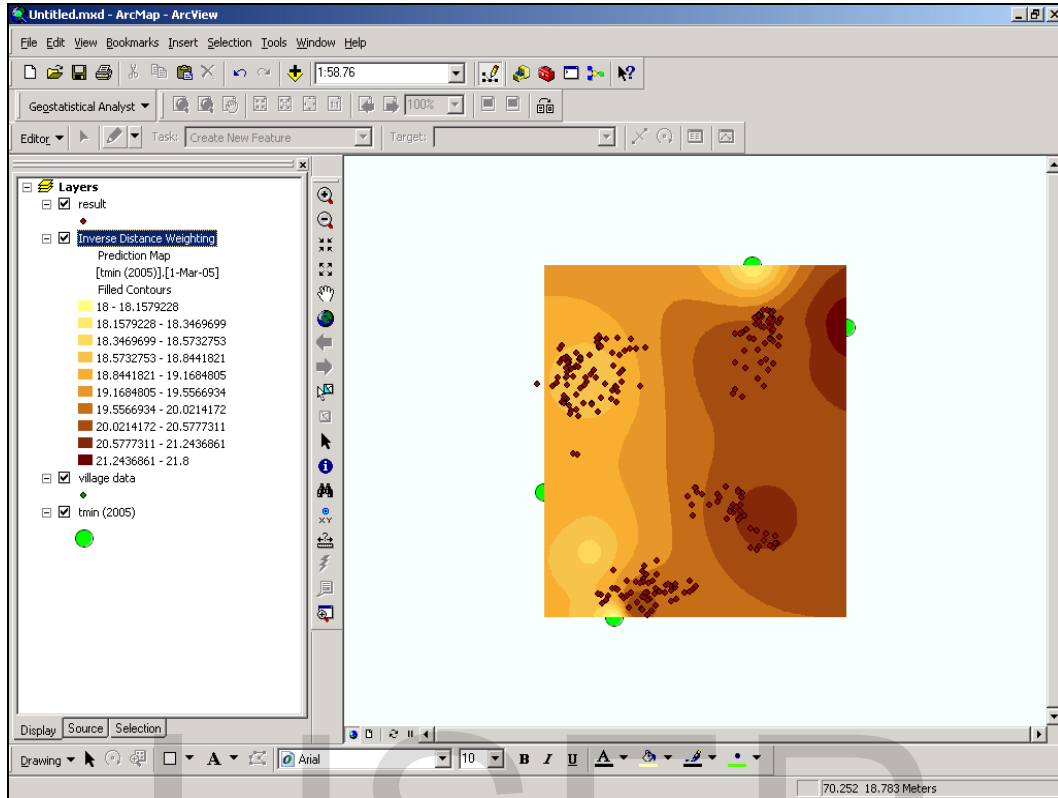


Fig. 2 : Prediction of climate data for 242 survey villages



Dist_Cd	Distname	Block_Cd	Blkname	Villcode	Villname	Date_Rnd1	Date_Rnd2	Date_Rnd3	Date_Rnd4	Included	Predicted
20	NASHIK	1	SURGANA	2458000	UMBARDE	25-May-05	26-Sep-05	27-May-07	19-Sep-07	Yes	18.797734
20	NASHIK	1	SURGANA	2450700	HADKAI CHOND	19-May-05	30-Sep-05	6-Jun-07	22-Sep-07	Yes	18.883244
20	NASHIK	1	SURGANA	2459600	SHRIBHUVAN	23-May-05	26-Sep-05	9-Jun-07	26-Sep-07	Yes	18.773243
20	NASHIK	1	SURGANA	2461100	SARAD	26-May-05	4-Sep-05	27-May-07	3-Sep-07	Yes	18.719242
20	NASHIK	1	SURGANA	2461200	GHAGBARI	18-May-05	5-Oct-05	7-Jun-07	28-Sep-07	Yes	18.705551
20	NASHIK	1	SURGANA	2469100	MASTEMAN	8-May-05	10-Sep-05	30-May-07	12-Sep-07	Yes	18.742289
20	NASHIK	2	KULWAN	2472300	KANASHI	19-May-05	2-Oct-05	10-Jun-07	22-Sep-07	Yes	18.740076
20	NASHIK	4	BAGLAN	2491200	JAMOTI	17-May-05	19-Sep-05	25-May-07	18-Sep-07	Yes	18.932398
20	NASHIK	4	BAGLAN	2492100	KHARAD	14-May-05	20-Sep-05	4-Jun-07	21-Sep-07	Yes	18.932674
20	NASHIK	4	BAGLAN	2496600	TEMBHE	21-May-05	16-Sep-05	19-May-07	13-Sep-07	Yes	19.060553
20	NASHIK	4	BAGLAN	2501300	BHAWADE	8-May-05	2-Sep-05	5-Jun-07	5-Sep-07	Yes	18.88161

Table 1: Climate Data Summary- Input Data (Met Stations)

Variable	Stn name	Akola		Amravati		Buldhana		Khandwa		Osmanabad	
	District	Akola		Amravati		Buldana		East Nimar		Osmanabad	
	Year	2005	2007	2005	2007	2005	2007	2005	2007	2005	2007
Tmax	Mean	36.5	36.5	32.9	32.7	33.5	33.7	35.4	35.6	33.5	32.9
	SD	5.3	4.9	5.9	5.8	4.8	4.5	5.1	5.0	5.0	5.3
	Max	46.0	45.8	46.0	43.5	43.0	42.3	45.1	45.1	46.7	42.4
	Min	23.4	23.3	23.0	23.5	23.0	23.0	25.1	24.1	23.0	24.0
Tmin	Mean	24.3	24.6	23.1	22.1	23.3	23.5	22.3	19.3	22.5	23.5
	SD	3.2	3.1	2.9	2.6	2.4	2.7	3.4	3.2	2.2	1.9
	Max	32.4	31.8	32.0	31.0	30.5	37.0	30.2	26.2	28.7	29.4
	Min	14.4	15.6	17.4	15.3	17.0	16.2	14.6	11.2	15.8	16.6

Variable	Stn name	Ozar		Sangli		Parali		Wadange (R.T)		Pali	
	District	Nashik		Sangli		Satara		Kolhapur		Raigad	
	Year	2005	2007	2005	2007	2005	2007	2005	2007	2005	2007
Tmax	Mean	32.5	32.2	32.7	32.9	28.3	27.7	28.3	28.8	31.0	30.6
	SD	4.9	4.3	4.9	4.7	4.5	4.0	4.1	4.4	4.2	3.9
	Max	40.8	41.5	42.7	41.3	36.5	37.0	36.0	38.0	40.0	40.0
	Min	23.5	23.4	23.6	23.7	21.5	22.0	22.0	22.5	24.0	24.0
Tmin	Mean	20.8	20.9	20.6	20.5	22.0	22.5	21.0	19.3	23.7	24.1
	SD	2.5	2.5	1.8	1.8	1.8	1.7	1.6	1.6	2.9	2.4
	Max	25.6	26.2	29.4	23.8	26.0	27.0	24.0	23.0	29.0	29.5
	Min	13.0	12.7	9.7	13.1	16.0	16.5	15.0	13.0	14.5	15.5

Table 2: Climate Data Summary- Predicted Data (Survey Districts)

Variable	Districts	Buldhana		Nashik		Osmanabad		Sangli	
	Year	2005	2007	2005	2007	2005	2007	2005	2007
Tmax	mean	34.7	34.7	32.5	32.1	33.1	32.8	31.3	31.4
	SD	4.9	4.7	4.7	4.3	4.8	4.7	4.6	4.5
	max	45.2	44.8	41.6	41.5	46.3	42.2	42.4	41.1
	min	23.1	23.1	23.5	23.4	23.1	24.8	22.8	23.3
Tmin	mean	23.4	23.1	21.2	21.3	22.3	22.9	21.0	20.7
	SD	2.5	2.6	2.3	2.4	2.0	1.8	1.6	1.6
	max	31.4	36.7	26.7	26.9	28.5	29.2	29.1	24.5
	min	15.2	14.9	13.0	12.7	15.9	16.2	10.2	13.3
RF	mean	4.1	0.2	18.0	6.4	6.6	7.8	9.2	6.7
	SD	7.5	0.8	31.9	14.8	10.3	14.6	14.0	10.8
	max	78.9	22.0	298.4	231.3	120.1	168.2	181.7	100.2
	min	0	0	0	0	0	0	0	0

Table 3 : Distance of Survey villages from the Met stations

Village	Akola	Amravati	Buldhana	Khandwa	Osmanabad	Ozar	Pali	Parali	Sangli	Wadange (R.T.)
Umbarde	349.9	426.5	263.0	312.5	376.9	52.6	199.6	286.3	380.1	386.0
Hadkaichond	354.3	430.1	268.5	310.3	391.5	68.6	215.7	303.8	397.8	403.7
Shribhuvan	332.7	409.1	246.1	295.0	366.9	46.5	207.9	289.6	380.6	388.1
Sarad	329.2	406.1	242.0	295.5	358.1	36.7	200.2	280.3	370.9	378.6
Ghagbari	327.4	404.4	240.1	294.7	355.3	34.0	198.8	278.2	368.5	376.3
Masteman	344.6	421.6	257.2	311.1	366.6	42.1	191.8	276.6	369.8	376.1
Kanashi	312.9	389.5	226.0	278.6	349.9	38.7	210.7	285.8	373.4	382.7
Jamoti	297.4	372.7	212.7	254.0	356.8	65.3	239.3	311.2	395.7	406.4
Kharad	299.4	374.6	214.8	255.4	358.9	65.8	239.6	312.1	397.0	407.6
Tembhe	270.4	345.7	186.0	229.8	338.9	75.9	250.2	313.6	392.9	405.9
Bhawade	301.3	377.0	216.0	260.2	355.2	58.6	232.3	305.0	390.3	400.7
Arai	279.7	356.3	193.1	247.9	329.2	53.5	227.4	291.7	372.7	384.9
Dhandri	268.9	345.7	182.0	240.1	319.5	58.7	229.9	290.1	368.8	381.9
Kasti	252.5	328.9	166.4	222.3	315.1	76.1	245.0	300.8	376.1	390.5
Nandurtek	278.3	355.8	190.4	255.7	313.5	42.5	212.1	273.2	353.5	365.8
Daregaon	266.2	344.0	178.0	248.8	300.1	51.5	213.8	269.3	346.6	360.0
Nanashi	343.4	420.8	255.6	313.6	359.6	35.1	183.4	267.5	360.6	366.9
Tilloli	396.7	474.5	308.5	368.5	390.8	80.7	158.2	257.7	358.4	359.5
Eklahare	322.2	400.3	233.8	302.5	329.6	5.7	173.4	247.9	337.2	345.4
Vanare	336.2	413.5	248.5	306.0	355.9	31.4	188.0	269.8	361.6	368.6
Jaulakedindori	323.4	401.3	235.1	301.4	334.2	9.5	177.3	252.9	342.5	350.6
Tirdhe	349.9	427.4	261.9	320.8	362.1	38.6	178.3	264.2	358.4	364.1
Bilkas	363.8	441.5	275.6	336.0	368.2	49.1	168.3	258.4	354.8	359.1
Jambhulmal	352.9	430.6	264.7	326.5	359.1	38.3	170.0	256.6	351.4	356.7
Pahine	356.7	435.0	268.0	341.4	340.8	43.2	140.2	225.6	321.3	325.9
Kharoli	361.0	439.4	272.4	345.8	343.2	47.6	137.3	224.3	320.7	324.9
Samundi	360.5	438.9	271.9	344.7	344.2	46.5	139.3	226.3	322.6	326.9
Alwand	364.6	443.0	276.0	350.0	344.4	51.8	133.8	221.9	318.9	322.7
Zarwadbk	362.9	441.3	274.3	348.9	342.2	50.7	133.2	220.6	317.3	321.3
Naikwadi	374.7	452.6	288.8	386.1	299.6	107.7	70.9	145.3	243.3	246.1
Dari	368.8	446.6	283.2	381.9	292.6	107.2	74.7	143.2	239.7	243.4
Belgaondhaga	340.7	419.0	252.1	325.7	331.1	27.6	150.3	229.7	322.5	328.9
Lohashingwe	334.1	412.6	245.6	325.4	315.7	33.1	142.0	216.1	307.3	314.4
Rayambe	356.2	434.6	267.6	344.7	333.2	47.4	131.4	215.3	310.9	315.5
Mogare	346.2	424.7	257.8	338.8	319.8	45.3	129.7	207.8	301.4	307.2
Balayduri	355.4	433.9	267.0	347.2	326.7	51.7	124.7	206.9	302.3	307.1
Khadked	346.0	424.5	257.8	342.2	312.9	52.4	122.7	198.6	292.0	297.8
Panchale	292.1	370.6	203.7	289.5	284.4	40.3	168.9	224.1	305.3	316.9
Pimpale	316.5	395.1	228.5	316.4	290.7	44.8	142.6	204.2	290.6	299.9
Mirgaon	285.6	364.1	197.4	286.4	275.6	49.1	170.7	221.4	300.4	312.8
Shivadi	295.3	373.5	206.7	281.6	305.7	22.5	183.0	245.9	329.2	340.1
Golegaon	280.3	358.6	191.7	271.0	291.6	38.7	189.2	244.9	324.4	336.8
Rui	286.8	365.2	198.2	279.4	290.9	35.5	180.6	237.2	317.9	329.8
Deshmane bk.	280.0	358.4	191.4	272.2	288.8	40.2	187.3	242.1	321.3	333.8
Kolamkh.	245.6	324.0	157.0	245.4	264.7	74.6	211.2	252.1	322.1	337.9
Khadakmal	347.9	424.6	261.0	310.7	375.3	51.2	199.9	286.0	379.5	385.7
Taharabad	288.4	363.7	203.7	246.3	350.0	66.9	241.7	310.7	393.6	405.1
Dangsaundane	299.4	375.6	213.4	261.9	348.1	51.2	225.6	297.1	382.1	392.6
Sawatawadi	251.4	326.8	167.0	213.6	326.3	87.0	258.3	315.7	391.1	405.5
Khedgaon	314.6	392.3	226.4	291.4	331.6	11.7	185.8	258.8	346.7	355.7
Ambegaon	341.9	419.6	253.7	316.5	350.7	27.7	173.5	256.2	349.2	355.5
Kachurli	360.4	438.7	271.8	342.7	347.6	45.0	144.0	231.4	327.7	332.0
Tandulwadi	277.6	344.2	217.8	350.5	116.0	221.5	216.7	167.4	179.8	207.3
Wangegavhan	296.2	359.5	241.7	375.4	104.0	248.2	227.2	163.4	159.2	189.0
Antarwali	259.4	325.8	201.1	334.5	108.1	221.1	229.7	185.1	197.2	225.2

Tintraj	261.4	327.9	202.7	336.0	109.5	220.4	227.7	182.9	195.4	223.3
Indapur	250.8	312.0	202.9	337.6	74.8	251.6	261.6	209.1	205.8	236.5
Terkheda	253.3	313.5	207.2	342.0	69.1	257.9	265.7	210.9	204.3	235.4
Adsulwadi	235.4	296.0	190.3	325.0	70.6	254.1	273.7	224.6	221.8	252.7
Hingangaon	231.5	288.1	194.0	328.0	52.7	273.2	293.6	241.0	230.8	262.7
Shiradhon	233.4	288.6	198.0	331.8	46.4	279.6	298.6	244.2	231.3	263.5
Nipani	239.3	294.2	204.0	337.8	42.7	282.3	297.7	241.2	226.3	258.7
Borwanti	234.7	291.1	197.0	331.1	51.1	274.1	292.6	238.9	227.9	259.9
Kamegaon	254.4	310.5	215.3	349.7	47.7	278.8	285.2	225.4	209.3	241.7
Shingoli	264.6	319.7	226.3	360.6	44.6	286.0	286.1	222.2	201.6	234.4
Padoli	263.5	315.3	231.1	364.6	27.1	302.1	303.5	237.5	211.0	244.5
Hinglajwadi	255.3	310.3	218.1	352.3	41.9	284.6	290.4	229.2	210.7	243.4
Alni	260.1	316.4	220.4	354.9	48.9	279.8	282.6	221.0	203.7	236.1
Junoni	276.3	332.2	235.8	370.5	53.0	285.5	278.2	211.3	188.9	221.7
Ambewadi	268.3	320.8	234.0	367.9	33.0	299.5	297.9	231.0	204.5	237.9
Ansurda	271.8	324.4	237.0	371.0	35.2	300.0	296.3	228.4	201.0	234.5
Sindgaon	306.2	352.7	278.5	411.3	47.8	341.3	322.0	241.7	193.6	228.2
Karanjgaon	278.8	325.3	253.2	385.4	20.3	330.2	325.3	252.6	214.2	248.5
Kadamapur	281.9	321.8	265.5	394.8	33.9	357.6	355.3	280.6	235.7	270.3
Thorliwadi	292.5	331.2	276.9	406.1	44.7	366.9	360.3	282.9	233.7	268.3
Hippargarao	292.8	332.2	276.3	405.8	43.1	364.6	357.4	279.9	231.0	265.6
Diggi	300.2	340.1	282.5	412.5	47.8	366.1	355.0	275.6	224.5	259.1
Jakekurwadi	291.2	334.3	269.6	400.7	33.9	349.1	339.9	263.1	217.3	251.9
Belamb	301.5	345.7	277.5	409.4	42.9	349.2	334.1	254.7	206.2	240.8
Alur	307.2	351.8	282.1	414.4	48.3	349.8	331.5	250.6	200.4	235.1
Sirasi	470.3	537.3	404.2	531.1	266.9	309.8	172.4	64.3	55.4	38.6
Khed	470.8	537.0	406.2	534.1	262.8	317.3	182.5	73.4	45.6	28.6
Sagaon	479.1	545.4	414.0	541.5	271.3	321.8	183.4	76.2	51.5	28.4
Tambave	452.7	519.1	387.9	515.8	247.7	302.2	174.3	62.9	44.8	42.0
Rethareharnaksha	449.2	515.1	385.3	513.9	241.8	304.0	179.3	67.7	38.9	41.0
Dudhari	449.4	515.7	385.0	513.2	243.7	301.7	175.9	64.3	42.4	42.8
Banewadi	448.6	514.5	384.8	513.5	240.9	304.2	179.9	68.3	38.2	41.1
Retharedharan	465.0	531.3	400.4	528.3	257.9	312.5	179.9	69.8	44.4	32.2
Shirgaon	452.9	517.9	390.4	519.8	240.5	313.8	190.1	78.5	28.4	33.3
Nagrle	472.7	540.1	406.0	532.4	271.1	308.5	169.1	62.3	60.4	42.2
Turchi	440.9	505.1	380.2	510.5	225.5	312.4	196.6	85.4	23.1	43.5
Ankalkhop	453.0	517.5	391.3	521.1	238.5	317.4	194.9	83.3	23.4	31.9
Burungwadi	447.7	512.0	386.4	516.4	232.7	315.2	195.7	84.1	22.2	36.9
Dhawaleshwar	430.6	496.2	367.7	497.0	223.2	294.6	180.1	69.8	41.1	56.1
Ghotibk	423.2	487.7	362.3	492.7	210.9	298.5	190.8	81.9	38.0	61.3
Khanapur	414.3	478.2	354.5	485.5	200.2	297.1	195.7	88.7	43.4	70.3
Mohi	417.6	481.2	358.1	489.2	202.0	301.0	198.3	90.5	39.6	67.2
Palashi	414.0	477.0	355.8	487.5	195.5	304.1	205.0	98.1	41.6	71.8
Banurgad	408.6	471.0	351.3	483.4	188.4	304.3	209.2	103.6	46.9	78.3
Umbargaon	380.7	444.6	321.7	453.4	170.9	277.7	196.4	100.3	75.6	103.9
Shetphale	398.3	460.9	341.1	473.3	179.7	297.4	207.8	105.0	57.1	88.1
Zare	397.5	462.5	336.4	467.0	190.6	279.4	185.6	84.0	62.4	87.2
Gharniki	405.0	469.7	344.0	474.6	196.0	285.3	187.4	83.1	54.9	79.6
Kharsundi	405.7	469.6	346.0	477.2	192.6	291.8	195.2	90.5	51.5	78.9
Siddhewadi	422.1	486.0	362.0	492.8	207.4	301.6	195.9	87.2	36.5	62.5
Wadgaon	426.4	488.6	369.2	501.1	203.5	317.3	213.5	104.3	29.2	61.9
Vajrachaunde	429.4	491.8	371.6	503.3	207.4	317.2	211.3	101.6	26.1	58.1
Yogewadi	436.6	499.0	378.7	510.3	214.0	322.0	212.7	102.1	18.9	51.3
Samdoli	460.0	523.2	400.5	531.2	238.9	332.5	210.9	99.3	10.0	26.3
Kavalapur	447.6	510.2	389.2	520.5	225.0	328.0	213.1	101.7	8.2	40.2
Salgare	436.7	496.6	382.7	515.6	204.7	338.9	235.3	125.2	30.3	64.2
Takali	451.6	513.1	394.8	526.7	224.4	338.3	224.5	113.0	9.1	42.7
Bolwad	451.9	513.3	395.3	527.4	224.2	339.5	225.9	114.4	10.2	43.4

Narwad	455.2	515.6	400.3	532.8	223.6	348.9	236.5	125.0	19.7	48.9
Lingnur	446.6	506.6	392.2	525.0	214.4	344.9	236.8	125.8	24.3	56.6
Shindewadi	433.4	494.7	377.4	509.7	206.5	327.7	222.6	112.6	24.7	59.2
Kerewadi	415.9	477.3	360.1	492.7	190.6	316.0	219.2	112.0	41.0	74.6
Dhalewadi	416.3	476.9	361.8	494.8	187.9	321.7	226.4	119.2	43.3	77.6
Moghamwadi	416.3	476.9	361.8	494.8	187.9	321.7	226.4	119.2	43.3	77.6
Alkud (m)	436.2	498.1	379.0	510.9	211.7	324.9	216.9	106.4	19.8	53.5
Haroli	436.6	498.1	380.3	512.5	210.1	328.9	221.8	111.4	21.1	55.6
Gulvanchi	404.0	464.3	350.4	483.6	175.4	316.3	228.0	123.4	55.8	89.9
Dorli	414.1	473.8	361.1	494.5	182.6	326.3	233.9	127.2	49.2	83.8
Walekhindi	400.6	460.2	348.2	481.7	169.6	318.9	233.6	129.8	61.6	95.9
Antral	399.5	458.1	348.8	482.6	165.0	324.8	241.9	138.4	67.1	101.7
Sonyal	391.0	446.5	345.4	480.0	147.6	338.6	265.3	163.8	90.1	124.6
Sanamadi	399.6	456.3	351.9	486.3	158.9	336.9	257.4	154.0	77.5	112.0
Madgyal	395.8	451.7	349.4	483.9	153.2	339.0	262.7	160.1	84.5	118.9
Nigadibk	384.5	439.7	339.5	474.1	140.5	336.5	266.9	167.0	96.5	131.0
Mallal	414.3	471.7	364.9	498.9	175.3	340.8	252.8	146.4	62.4	96.5
Basargi	420.5	478.6	369.9	503.7	183.2	340.7	248.4	140.9	53.9	88.0
Jadraboblad	381.8	438.5	334.5	469.0	142.3	326.1	255.6	156.4	90.8	125.4
Sonbardi	61.2	117.5	80.4	72.3	299.6	290.1	431.1	442.9	476.4	503.0
Kuvardeo	65.3	122.6	78.5	69.7	300.4	285.8	427.7	440.6	475.2	501.5
Bhingara	70.3	129.5	75.1	67.9	300.3	279.3	422.2	436.4	472.3	498.4
Raipur	71.9	134.6	68.0	71.8	295.4	271.9	414.4	428.8	465.4	491.2
Rasulpur	65.5	129.2	66.7	76.5	291.3	275.1	415.9	428.6	463.7	489.9
Islampur	73.3	139.0	61.5	76.4	290.5	265.4	407.4	421.9	458.8	484.5
Dadulgaon	68.3	137.4	53.7	85.4	281.5	263.3	402.6	415.2	450.9	476.9
Garpeth	69.1	132.4	67.1	74.1	293.3	273.0	414.7	428.4	464.3	490.3
Zadegaon	59.8	129.3	55.2	89.2	278.3	270.0	407.2	417.7	451.5	477.9
Chichari	58.6	113.6	82.8	73.9	299.8	293.9	434.2	445.3	478.1	504.8
Wasali	58.5	114.4	81.4	74.4	298.8	292.6	432.8	443.9	476.8	503.5
Nimkhed	58.0	112.6	83.4	74.3	299.9	294.8	435.0	446.0	478.6	505.3
Niwana	50.4	111.9	74.3	84.0	288.8	290.2	427.7	436.8	468.2	495.2
Nirod	49.1	111.8	72.9	85.9	286.8	289.6	426.5	435.2	466.4	493.4
Kavthal	47.1	114.4	65.8	91.5	279.7	284.6	420.0	427.9	458.8	485.8
Hingnavaijanath	27.8	102.3	66.6	111.9	263.7	292.8	421.3	423.6	449.8	477.7
Janori	41.9	113.5	60.6	100.4	270.7	283.1	415.7	421.6	451.3	478.5
Lasura bk.	41.1	116.3	53.9	108.6	261.7	278.9	409.0	413.5	442.3	469.7
Shirasgaonnile	40.6	116.8	52.4	111.5	258.7	278.3	407.3	411.3	439.7	467.1
Tintrav	35.5	112.2	55.9	114.7	257.0	282.7	410.5	413.1	440.2	467.9
Jawala bazar	71.7	147.2	30.9	106.4	261.0	248.6	382.9	393.1	428.1	454.1
Tighrapr.malkapur	78.9	151.4	41.2	93.8	274.3	247.5	386.7	400.5	438.1	463.6
Nimbari	84.7	158.6	35.1	99.7	270.0	239.3	378.1	392.3	430.8	456.1
Morkhedkh.	87.3	161.7	33.0	102.2	268.4	235.9	374.5	388.9	427.8	453.0
Borjawala	65.5	141.5	32.6	108.3	258.6	253.9	386.6	395.2	428.7	455.0
Mathani	48.3	125.7	42.5	115.8	252.4	269.2	397.4	401.5	430.7	457.9
Mandwa (forest)	52.2	130.2	40.2	138.8	229.4	267.3	387.1	385.8	411.3	439.1
Amdapur	61.6	139.5	33.2	142.9	224.3	258.8	377.7	376.7	403.1	430.7
Hanwatkhed	81.2	159.3	10.0	126.1	242.8	235.6	364.6	372.6	407.1	433.1
Umarkhed	98.4	176.9	11.3	144.0	229.0	219.2	344.1	351.3	386.8	412.5
Jambhora	116.3	192.4	48.7	183.4	189.8	217.6	323.9	320.9	350.3	377.0
Nimkhed	121.7	197.4	54.1	188.8	185.6	215.0	318.9	315.2	344.5	371.2
Khamgaon	113.4	187.1	58.1	192.0	177.7	230.3	330.2	322.0	346.7	374.3
Wadgaonjejan	80.6	152.2	56.1	177.1	190.4	261.4	365.6	355.6	375.4	404.1
Madakhed bk.	52.7	118.5	65.9	86.5	283.5	282.0	419.1	428.5	460.7	487.4
Karanwadi	65.2	132.6	58.7	82.9	284.4	269.0	408.4	420.6	455.7	481.8
Paturdakh.	40.5	103.5	75.9	92.6	283.4	296.0	430.7	437.3	466.5	493.9
Sagoda	48.2	117.3	61.5	93.6	276.6	280.9	415.8	423.7	454.8	481.8
Kalkhed	40.1	110.4	64.2	99.4	272.9	286.5	419.3	425.1	454.4	481.7

Hingnabhota	54.4	124.3	56.7	92.0	276.4	274.2	410.1	419.2	451.8	478.4
Wadgaonmali	78.9	154.0	41.9	165.5	201.4	252.4	362.3	356.7	380.5	408.4
Hanwatkhed	69.9	133.4	66.6	73.9	293.4	272.1	414.0	427.8	463.9	489.9
Borala bk.	53.7	117.7	68.9	83.9	286.5	283.9	421.6	431.4	463.8	490.6
Palaskhed	53.3	118.6	66.7	85.6	284.5	282.3	419.7	429.2	461.6	488.3
Madakhedkh.	52.7	118.5	65.9	86.5	283.5	282.0	419.1	428.5	460.7	487.4
Shivani(n.v.)	58.3	116.0	78.6	75.5	296.7	290.0	430.0	441.1	474.1	500.8
Wandgaonpr.adgaon	44.0	101.1	82.8	87.7	290.7	301.0	437.2	444.5	474.1	501.4
Changefal bk.	54.8	117.0	71.8	81.4	289.6	285.8	424.2	434.4	467.0	493.7
Bhilkhed	48.5	112.6	70.7	87.4	284.8	288.0	424.5	433.0	464.2	491.2
Lasurajahangir	28.5	106.6	60.4	122.5	251.6	288.4	413.3	413.4	438.3	466.4
Chinchkhedkh.	95.4	169.6	34.9	103.1	270.5	228.5	368.8	385.2	425.9	450.7
Sarola	60.2	138.4	28.8	123.6	243.4	256.6	383.3	387.5	417.7	444.7
Malegaon	59.0	134.2	47.4	155.1	213.6	268.9	382.0	376.5	398.8	427.1
Wagdeo	47.1	123.4	51.0	146.5	224.0	276.6	392.9	388.5	410.9	439.3
Bhankhed.	86.6	164.8	18.8	150.8	217.8	234.2	352.9	354.6	385.1	411.9
Mudhewadi	431.1	499.0	364.1	490.8	236.8	275.5	154.1	43.4	64.7	68.9
Navalwadi	400.3	460.3	347.2	480.6	171.0	315.9	230.0	126.3	60.2	94.3
Khumbhari	406.8	465.6	355.3	489.0	172.8	327.1	240.0	134.8	59.5	94.1
Kaslingwadi	396.5	455.4	345.2	479.0	163.4	320.7	238.8	136.0	68.1	102.6
Bukanwadi	251.3	305.4	216.0	349.9	37.3	288.0	296.2	235.6	216.4	249.3
Gad deodari	264.2	320.3	224.5	359.0	48.9	281.7	281.9	218.9	200.1	232.7
Kolewadi	258.8	312.2	224.0	357.9	34.3	293.0	296.9	233.4	211.0	244.1
Bendkal	279.0	327.4	250.5	383.4	23.8	322.1	316.1	243.9	207.7	241.9
Jawalgabet	281.8	324.8	261.1	391.9	25.6	345.5	341.1	266.8	224.2	258.7
Bendga	297.7	338.6	278.8	409.2	43.6	361.1	350.4	271.7	222.1	256.7
Guhijambhulpada	357.4	433.5	271.2	315.4	390.0	66.0	209.3	298.3	392.9	398.4
Palsan	328.0	404.8	241.0	293.2	359.2	39.0	203.4	283.3	373.6	381.4
Borgaon	328.0	404.8	241.0	293.2	359.2	39.0	203.4	283.3	373.6	381.4
Chikhali	328.1	405.0	241.0	294.2	358.0	37.1	201.4	281.3	371.6	379.5
Amdabarhe	355.1	431.9	268.0	318.8	378.4	53.7	194.9	283.0	377.7	383.1
Gahale	353.1	429.8	266.0	316.5	377.4	52.8	196.1	283.7	378.1	383.7
Galwad	345.2	422.0	258.0	309.8	370.5	46.2	196.5	281.7	374.9	381.2
Mankhed	344.5	421.5	257.1	310.7	367.3	42.7	192.8	277.6	370.7	377.1
Sambarkhal	347.4	424.3	260.1	312.9	370.2	45.6	193.2	279.0	372.5	378.6
Khadkidigar	358.4	435.4	271.1	323.2	378.4	53.9	190.5	279.5	374.8	379.9
Ambepada	346.5	423.6	259.2	312.9	368.2	43.6	191.4	276.9	370.3	376.5
Mailwade	298.5	373.6	214.1	253.7	359.7	68.0	241.8	314.1	398.8	409.5
Ajande	302.4	377.7	217.7	258.5	360.2	64.3	237.6	311.0	396.4	406.7
Bhildar	298.4	374.4	212.5	260.1	348.8	53.4	227.8	299.1	384.0	394.5
Kikwarikh.	297.4	373.3	211.6	258.8	348.9	54.6	229.1	300.2	384.8	395.5
Kikwari bk.	295.4	371.4	209.5	257.5	346.7	54.2	228.9	299.3	383.5	394.4
Palasdare	228.4	304.7	142.7	200.9	303.0	97.5	260.9	309.3	379.3	395.6
Sayanekh	243.5	320.0	157.4	214.9	309.5	83.3	249.9	302.7	376.0	391.1
Mesankhede bk.	267.5	345.4	179.2	250.8	299.3	49.9	211.6	267.1	344.6	358.0
Pimpalgaon-dhabli	271.9	349.9	183.6	255.8	300.1	45.1	206.9	263.5	341.9	354.9
Tetmala(n.v.)	346.0	423.2	258.4	314.3	364.4	39.8	186.7	271.8	365.2	371.4
Talyachapada	334.0	411.2	246.3	303.3	355.5	31.4	190.5	271.6	363.1	370.3
Vanjole	332.1	409.4	244.4	302.0	353.3	29.4	190.0	270.5	361.6	369.0
Dhakambe	326.1	404.2	237.6	307.8	329.1	9.7	167.6	243.0	333.0	340.9
Kalune	350.3	427.6	262.6	319.3	365.8	41.6	183.0	269.3	363.5	369.2
Hanumanthpada	350.8	428.5	262.6	324.2	358.0	36.5	171.4	257.3	351.7	357.2
Thanapada	366.9	444.8	278.6	341.7	365.6	50.7	160.1	250.9	348.0	351.8
Bhagohol	373.7	451.7	285.3	349.4	368.0	57.0	154.5	247.4	345.4	348.5
Holdarnagar	351.7	429.7	263.2	329.6	350.5	34.9	159.9	245.3	340.0	345.3
Matori	332.9	411.2	244.4	315.6	331.1	17.4	160.8	238.3	329.6	336.8
Bortembhe	357.5	436.0	269.1	350.4	325.8	55.6	120.6	203.1	298.9	303.4
Baragaon	306.9	385.4	218.4	300.2	298.5	27.9	161.5	224.4	309.6	319.5

Chandrapur	322.6	401.1	234.1	316.1	305.6	31.4	147.4	215.8	304.5	312.8
Khaparale	321.9	400.4	233.4	316.0	304.2	32.4	147.1	214.8	303.3	311.7
Mukhed	307.6	385.6	219.2	288.1	321.6	10.1	183.6	253.0	339.3	349.0
Adgaonrepal	271.2	349.5	182.6	261.0	289.6	46.3	198.7	252.2	329.7	343.0
Satyagaon	279.5	358.0	190.9	274.7	283.4	43.7	183.7	236.5	315.2	327.9
Sonegaon	260.5	320.7	213.7	348.5	70.6	258.8	262.0	205.0	197.1	228.3
Bedarwadi	263.7	329.4	206.5	340.0	104.9	226.0	230.6	183.0	192.4	220.8
Deolali	270.6	332.0	220.8	355.5	80.9	253.6	250.3	192.0	185.8	216.5
Burudwadi (n.v.)	261.7	326.2	207.0	341.1	96.3	233.9	238.6	188.7	193.8	222.9
Bhoinja	284.2	348.9	227.7	361.2	106.4	235.9	224.4	167.9	171.5	200.3
Jalgaon (galane)	260.6	337.2	174.2	230.7	317.9	68.0	238.3	296.4	373.4	387.1
Shivare	309.9	387.5	221.9	285.4	331.7	17.2	192.0	263.9	350.9	360.3
Kuchi	423.8	484.9	368.3	500.9	196.8	323.0	222.9	114.3	34.4	68.6



Krupali Vijaykar Vahalkar



Dr. G. V. Rao

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