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RESEARCHARTICLE

SPATIAL DISTRIBUTION OF SETTLEMENT PATTERNS IN DHANKTUA DISTRICT, NEPAL

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ABSTRACT

This paper attempt to analyze the spatial distribution of settlement patterns in Dhankuta district, eastern hills, Nepal. Because geographers use the word spatial as an essential modifier in framing their questions and forming their concepts. But the spatial distribution of settlement patterns and their relations in a geographic space cannot easily be observed. In this context, Nowadays, geographers are interested to interpret such challenging matter in the landscape by employing various methods, tools and techniques. They have popularly used a point pattern method to identified spatial patterns of settlements on a map. This paper applies the nearest neighbor index computing with the help of both statistical techniques and ArcGIS software. It is very popular to detect locational arrangements of settlements, schools, hospitals and other service facilities in the study area. Settlements were identified from a map based on local level government units. Data were collected through automated and manual calculations. Both methods were used to calculate the index of the nearest neighbor and Index of dispersion through quadrat maps. The calculated nearest neighbor index of Dhankuta district (8.66) shows that the patterns of settlement in the Dhankuta district seemed dispersed. Whereas, the entire local level pattern is more random than dispersed (1.11-1.30). This indicates that the spatial patterns of settlement in the local levels of the Dhankuta district are randomly distributed. However, the Index of dispersion of this district result (1.32) indicates that the patterns tend towards the cluster. Similarly, the index of dispersion of the entire local levels seemed (1.06-1.46) dispersed.

INTRODUCTION

Geography is known as is a spatial science. It is concerned with the spatial behavior of people, with the spatial relationships that are observed between places on the earth's surface, and with the spatial processes that create or maintain those behaviors and relationships in terms of settlement patterns (Fellman *et al*., 2002). Geography is related to describing the spatial arrangement of features on the earth`s surface. As a geographer, we are particularly interested to examine the spatial distribution of various phenomena over the surface of the earth and of the process that generates them (Burt *et al*., 2009). Physical and human features, as well as resources, are unevenly distributed on the earth's surface. These features and resources make essential to the functioning of human societies. So, how these features are distributed on the landscape or surface of the earth is the subject matter of spatial. The arrangement, placement and perceptual structure of objects in the landscape are known as a spatial pattern. A technique of study about the arrangements of points, lines, areas and surfaces on a map as known as spatial analysis (Unwin 1981, quoted by Husain, 2009). Spatial analysis is quantitative technique which is based on the philosophy of positivism. The theoretical approach associated with the quantitative revolution in Anglo-American Geography in the 1960s which privileged spatial analysis.

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During this period many Geographers turned from the integrated, descriptive analysis to the specialized and quantitative analysis. To represent the selected spatial information of the earth, the map is the appropriate technique for the people to understand easily. It conveys the information of the earth`s surface representing the specific scale of an area of land or sea showing physical as well as cultural features. It is not possible to show the entire features existing on the earth`s surface on the map. Hence, a set of symbols is using to characterize and communicate information about real objects. There are different three types of symbols to represent the information namely: point, line and area symbols. First, point symbols are used to represent zero-dimensional features such as settlement, school, temple, building, spot height. The point symbol is used to show exactly where one thing is located on a map. Secondly, when the real object is long and shape is linear, line symbols are using to represent the features such as river, road, boundary, electric line, contour line. Finally, the object is not a specific point, rather a whole area, the area symbols are used to represent such as forest, urban areas, agricultural areas. This paper aims to analyze the distribution pattern of settlements, where points are used to represent settlements. A dot or point is the most commonly used symbol at quantitative mapping. Mostly, it is used to show the distribution of settlements in the map. The distribution of settlements is varying with great spatial variability and determined such as local amenities, economic factors, communications, food availability and production capacity of the land. As a result, the settlements are unevenly distributed across the various spatial scales (Zhang *et al*., 2014).

Spatial distribution of settlements can measure through various methods but mostly, nearest neighbor analysis and quadrat analysis are highly used because of its simplicity and ease of implementations for point pattern analysis. Beside it, Ripley`s 'K' function also other classical spatial point analysis method. It has widely used to distribute patterns of herbs (Peter, 1995). Point pattern analysis is a set of methods for the detection of patterns in maps that contain a set of locations. The pattern of distribution of a settlement is a fundamental characteristic but it is difficult to describe in precise and meaningful terms. Nearest neighbor analysis is a descriptive statistic that shows pattern of locating features by comparing graphically the observed nearest neighbor distance. It is not only examining the distance between two points but also it examines the closet point too. It is used to describe to know the proximity of points. This technique has used the analysis of the study of distribution such as settlements, schools, hospitals and other features which are represented by point (s) features. This provides the basis of measuring point pattern of an aerial/regional which would help in understanding the spatial processes of the distribution of human activities. In this paper, nearest neighbor analysis technique is used to analyze the settlement patterns. This paper attempts to measure the distribution of settlements according to the structure whether they are cluster, random or dispersed. Dacey introduced the technique of nearest neighbor analysis, which was developed originally by Clark and Evans (1954) for measuring spatial relationships among biological populations (Kariel, 1970). Other geographers who have used the technique for analyzing spatial distributions include Berry, 1959; King, 1962; Medvedkov, 1963 & 1966; Getis,1964; Birch, 1967; Peter, 1975 & Zhang, 2014. They all considered the nearest neighbor analysis as a tool to measure precisely the spatial distribution of a point features.

Many studies have been conducted to analyze the spatial patterns of human settlements focused on the area, density and shape of human settlements. However, the spatial characteristics of settlement location itself received little attention. So, the primary objective of this paper is to study the settlement pattern of the Dhanktua district, Nepal and discuss some aspects of nearest neighbor analysis. Settlements are represented by point features and it is difficult to perform precisely and correctly by manual computation. Hence, GIS tools have been used to calculate the nearest neighbor values of settlements. Recently, the development of GIS plays a significant role in the increment of spatial analysis tasks worldwide. This technology has also significantly increased geographer`s ability to work with large and complex spatial datasets.

METHODS AND MATERIALS

Study area: Dhankuta district has been purposively selected for the analysis of the distribution of settlement patterns. The study area lies in the province number 1, eastern hills of Nepal. The geographical location is extended from 26°53′ to 27°19′ northern latitude and 87°08′ to 87°33′ eastern longitude. Nowadays, the district has been restructured into 7 local government units including 3 Municipalities and 4 Rural Municipalities (Figure 1). Based on the Survey Department, Government of Nepal (1997) data source, 746 settlements were identified in this district (Figure2).

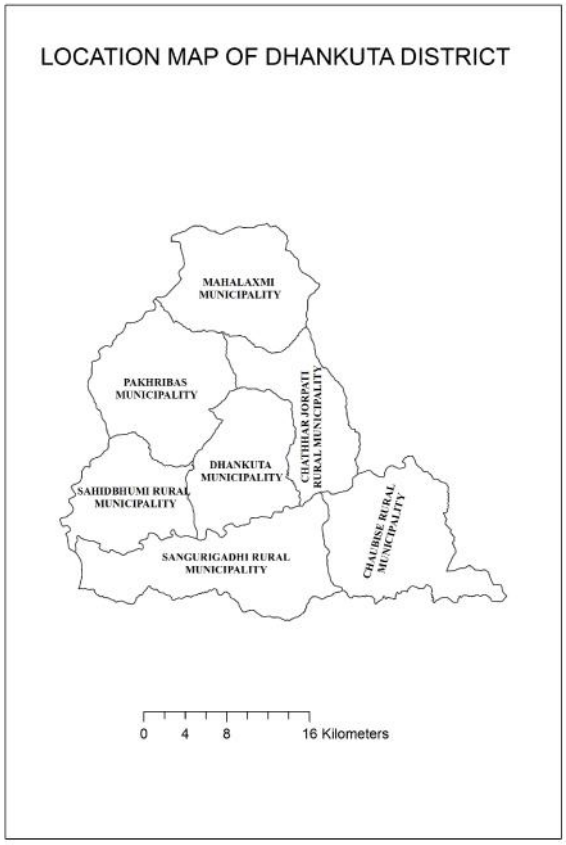

Figure 1. Study Area

Figure 2: Distribution of Settlements in Dhankuta

Data sources and methods: The present study is based on secondary data sources. Both spatial and non-spatial data are collected by secondary sources. ArcGIS and excel are applied for data mapping, analysis, and calculation. The spatial layer of local administrative units` boundary is obtained from the Survey Department of Nepal, 1997 in the scale of 1:25000 and settlements data are derived from the same source. The spatial

data layer for newly restructured local level administrative unit boundaries was created by merging the old VDC boundaries in ArcGIS software. The quantitative statistical technique has used for determining the patterns of settlements in terms of random or cluster or uniform. Among the numerous methods of point pattern analysis, the nearest neighbor analysis technique is applied to calculate the index of the nearest neighbor and index of dispersion. Nearest neighbor analysis is calculated by two types; distance-based and area-based methods. The distance-based analysis is calculated by an automated method in ArcGIS software and Microsoft excels for a manual calculation. These statistics were calculated by the following formulas:

I) Formula one:Near Neighbor Index (NNI) = 2D√(N/A)
II) Formula two: $R = \frac{D(O\ \ )}{0.5\sqrt{\frac{n}{n}}}$

Where,

D = ∑d/N (Mean distance of total settlement)
N = Total number of Settlements
A = Total area of specific polygon (Rural Municipalizes/Municipalities)

After calculation in excel environment, Clark & Evans (1954) applied by following formula to calculate nearest neighbour index:

$R = \frac{\bar{r}_A}{\bar{r}_E}$Where,R = Nearest Neighbor Index

$\bar{r}_A$=average distance from randomly selected points to their nearest neighbors
$\bar{r}_E$= expected mean distance between nearest neighbors. Under the Poisson distribution with intensity ^{a}, we have $\bar{r}_E = \frac{1}{2\sqrt{a}}$

This paper has also used an area-based technique to analyze the spatial patterns of settlement. Area-based technique relying on various characteristics of the frequency distribution of the observed numbers of points in regularly defined sub-regions of the study area, which is called quadrat analysis. This paper is prepared a quadrats ratio at 1000×1000 meters cell height and cell width to calculate corresponding values of the selected variables for each point in ArcGIS. Then, prepare a series of quadrat maps in ArcGIS using the following formula in Microsoft excel:

- Mean ($\bar{X}$) = ∑fx/N
- Variance (S^2) = $\frac{\sum f(\sum fx^2)-(\sum fx)^2}{\sum f\ (\sum f-1)}$
- Coefficient of Dispersion (C) = Variance/Mean
- Index of dispersion (I) = ∑f ($\sum fx^2$-∑fx) / ∑fx (∑f x-1)

Where,

'x' and 'f ' denotes the grid number and number of settlements occurred in specific grid respectively and 'N' indicates total number of settlements.

Calculation of index of randomness: This paper has also used a parametric statistic to calculate the distances between two (Taylor, 1977 cited from Chidi, 2015). In this method, the distance from each point to its nearest neighbor is measured. The ratio of observed to expected nearest neighbor distances is calculated from, and it is known as the nearest neighbor index. The mean distance between the nearest neighbor of the study area can be compared with the means of three theoretical patterns: clustered, dispersed and random. Burt *et al*. (2009) provided the index of randomness as follows presented in Table 1:

RESULTS AND DISCUSSIONS

Point pattern analysis by automatedmethod: In this method, the nearest neighbor index is computed automatically through ArcGIS after input the necessary commands. For this, we just put the data of any point features in the GIS environment then user inputs the required command, after it, automatically computed the value of nearest neighbor index value as well as a figure as shown in below (Figure 3). It is a very quick and easy method to calculate the pattern of any point features although the user himself could not understand how this result has come? So, the user could not understand its internal mechanisms and its meaning exactly therefore, it is difficult to interpret its results appropriately. It gives only broad categorization of results such as cluster, random and dispersed. For example, in the following figure, the computed value is 1.2, and it indicated as dispersed. But exactly, it is not really dispersed pattern however, it is more random than dispersed or towards dispersed. This kind of calculation does not consider the areas; it only considered the distance between points.

Manual computation (through excel) of nearest neighbor index: Besides the automated method, there is also another method for computing the nearest neighbor index by manual with the help of excel in the computer. For this, first, we generate near table of each point through spatial analysis tools in ArcGIS and joins this near table with the settlements layer for the labeling of each settlement. Then, export this joined table into excel from the ArcGIS environment. While the table opens in an excel environment, we can calculate the necessary computation manually. We can calculate without excel too but it is lengthy as well as difficult to perform. For instance, the following two formulas are used to calculate the NNI of Mahalaxmi municipality;

Formula one: Here, D = 0.64, N=117 and A=129.26

We know the formula, NNI = 2D√(N/A)

= 1.22
So, the value of NNI is 1.22

It indicates that the settlement pattern of the Mahalaxmi Municipality is more random than dispersed or towards dispersed because the calculated NNI value is 1.22. If the mean value is 1, the distribution is perfectly random. But, the NNI value seemed slightly more than 1. Hence, we conclude that the settlements are little concentrated in some specific areas in this municipality.

Formula Two: Here, there are D = 0.64, N=117 and A=129.26
We know the second formula, NNI= D/0.5√(A/N)

= 1.22
So, the value of NNI is 1.22 (Same results only method is different).

Table 1. Index of randomness

S.N	Value of 'R'	Pattern	Basic Characteristics
1	0	Cluster	Clustered arrangement of points, where the objects of interest are found close to one another and it tend to result from a contagion pattern process where a particular location attracts a number of points.
2	2.14	Disperse	The dispersed point is commonly thought to result from some form of competition in space where points repel one another.
3	1	Random	Random point patterns, result from the operation of an independent random process (or a process consistent with complete spatial randomness). An independent random process is one in which every location of a study region has an equal probability of receiving an event or a point, and one from which the location of an event is independent of the location of all other events.

Table 2: Average NNI (Clark and Evans, 1954)

S.N	Name of Local Levels	Area (Km^2)	Total Settlements	Mean distance (M.)	Sett. Density	Mean dis. (KM)	√of sett. density	√of sett. Density × 2	Expected mean distance (KM)	NNI	Pattern
					λ	$\bar{r}_A$	$\sqrt{\lambda}$	$2\sqrt{\lambda}$	$\bar{r}_E$	R	
1	Mahalaxmi M	129.26	117	640.87	0.91	0.64	0.95	1.91	0.52	1.22	MRD♣
2	Chhathar-Jorpati RM	102.15	95	576.21	0.93	0.58	0.96	1.93	0.52	1.11	MRD
3	Pakhribas M	143.83	104	761.59	0.72	0.76	0.85	1.70	0.59	1.30	MRD
4	Dhankuta M	110.41	112	548.72	1.01	0.55	1.01	2.01	0.50	1.11	MRD
5	Sahidbhumi RM	99.29	90	675.99	0.91	0.68	0.95	1.90	0.53	1.29	MRD
6	Sangurigadi RM	166.36	135	744.32	0.81	0.74	0.90	1.80	0.56	1.34	MRD
7	Chaubise RM	147.32	110	752.27	0.75	0.75	0.86	1.73	0.58	1.30	MRD

Source: Settlements and area from Survey Department, 1997 and calculated by author♣ MRD represents more random than dispersed. M & RM indicates Municipality and Rural Municipality.

Table 3. Dispersion details of local levels of Dhankuta

S.N	Local Levels	Mean ($\bar{X}$)	Variance (S^2)	Coefficient of Dispersion (C)	Index of Dispersion (I)
1	Mahalaxmi M	113.47	2203.54	19.42	1.16
2	ChhatharJorpati RM	161.92	1788.82	11.05	1.06
3	Pakhribas M	86.13	1829.18	21.24	1.23
4	Dhankuta M	85.20	1323.44	15.53	1.17
5	Sahidbhumi RM	81.91	1076.62	13.14	1.15
6	Sangurigadi RM	159.84	3747.76	23.45	1.14
7	Chaubise RM	69.30	2282.71	32.94	1.46

Source: Calculation by author

Nearest neighbor calculation by Clark and Evans method: This index is the simplest one, based on the distance from point location to its nearest neighbor. It was developed by Clark and Evans in 1954. According to the NNI index developed by Clark and Evans, all the settlement patterns of the local levels of Dhankuta seemed more random than dispersed (Table 2). This indicates that the settlements of different local levels of Dhankuta are concentrated only in limited places. In other words, more or less the distribution of settlements is distributed independently. To compare among the local levels, the settlement pattern seemed more random in Dhankuta municipality and ChhatharJorpati rural municipality because the NNI value is 1.11 in both. It indicates that, in comparison to other local levels, the settlement pattern of these two local levels have less dispersed. Similarly, there seemed high NNI value in Sangurgadi rural municipality (1.34), Pakhribas rural municipality (1.30) and Chaubise rural municipality (1.30). It says that the settlement pattern is highly dispersed in Sangurigadi rural municipality then Pakhribas municipality and Chaubise rural municipality. There are different factors to determine the pattern of settlements on the earth. Gaisen*et al*. (2015) claimed that the settlement pattern is determined in Tatarstan by geographical, natural, demographic, transport, economic, social and domestic circumstances. Same way, the settlement pattern of Dhankuta district of Nepal also might be determined by geographical

(flat land, arable land), natural (source of drinking water, available of fodder and firewood, far from hazard-prone areas), cultural (community, religion) and economic (accessible) factors although it demands more systematic research. The settlement pattern of local levels of Dhankuta district is shown in Table 2.

Quadrat measure: Quadrat measure was initially developed by ecologists studying the spatial distribution of plants (Burt *et al*. 2009). In quadrat analysis, a grid of square cells of equal size is used as an overlay on top of a map of incidents. One then counts the number of incidents in each cell. In other words, quadrat analysis is also another method of point pattern analysis that is operationalized by overlaying a regular grid on the region of interest and then counting the number of points found in each quadrat (cell) of the grid. It has become common to use square quadrats (grid squares), though circular quadrat also employed. But square quadrat is appropriate for cover complete areas whereas circular quadrats leave some spaces uncovered.

Point density using quadrat analysis based on area method. NNI only examines the association of points but quadrat is related to the area, density and there is always link with point and area. Quadrat examines the frequency of points occurring in various parts of an area. It is also a method for studying the spatial arrangement of point locations. In the nearest neighbor, we look at an average spacing of closest whereas quadrat analysis looks at variability in the number of points per cell.
Applied by the above-mentioned formula in quadrat measure method, the settlement pattern of thelocal levels of Dhankuta district is presented in table 3.

Dispersion gives us an idea about the spread of the observation about an average value. If the dispersion is small, it means that the given data values are closer to the central value (average) and hence the average may be regarded as reliable in the sense that it provides a fairly good estimate of the corresponding population average. If the dispersion is large, then the data values have more deviated from the central values, thereby implying that the average is not representative of the data and hence not quite reliable (Gupta, 2011). Variance measures how far a set of numbers are spread out from their mean value. It is the square of the standard deviation. The variances of the local levels of Dhankuta seemed so great, therefore, the distribution of settlements is greatly spread out from their mean value. In Sangurigadi, the variance seemed so large as compared to others and low in Sahidbhumi. It indicates that the settlements are largely spread out from their mean value in Sangurigadi and lower spread out in Sahidbhumi rural municipality.

The values of the index of dispersion (I) also reflect the settlement patterns as random, uniformity or cluster. If the index of dispersion (I) is equal to 1, the pattern is random, index of dispersion (I) is less than one, the pattern tends toward uniformity and the index of dispersion (I) is greater than 1, the pattern tends toward cluster (Chidi, 2015). According to the index of dispersion from the local levels of Dhankuta, the settlement patterns seemed to tend toward cluster in entire local levels. Among these, the index of dispersion is high in Chaubise and lower in ChhatharJorpati. It indicates that the settlement pattern seemed highly clustered in Chaubiseruralmunicipality than others and settlement patterns seemed less clustered in ChhatharJorpati rural municipality.

Conclusion

This paper primarily aims to identify the settlement patterns of Dhankuta district applying different two methods; distance-based and area-based techniques for nearest neighbor analysis. ArcGIS and Ms-excel are used to calculate the value of the nearest neighbor and the index of dispersion. After the restructured the newly municipality and rural municipality, the settlement pattern might be changed than old pattern. In this context, this paper presented the recent pattern of settlements. The settlement patterns are directly linked with development works.

Moreover, settlements are considering the important factors for development because the entire development needed by people and people are living in settlements. Like other places, the settlement pattern of Dhankuta district might be determined by different factors such as geographical, natural, cultural and economic although this paper did not explore and analyze in that dimension. It is concluded that the settlement pattern of Dhankuta seemed more random than clustered according to the criteria developed by Clark and Evans (1954). It means the distribution of settlements in different local levels is nearly random in one hand. On the other hand, some limited places have clustered settlements too.

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Annex I.NNI Computations

Formula I	Formula II
D = 0.64, N=117 and A=129.26	D = 0.64, N=117 and A=129.26
We know the formula, NNI = 2D√(N/A)	We know the second formula, NNI= D/0.5√(A/N)
2×0.64√ (117/129.26)	0.64/0.5√ (129.26/117)
2×0.64√0.91	0.64/0.5√1.1
2×0.64×0.95	0.64/0.525
1.22	1.22

Annex II.NNI calculation by Quadrat calculation method (Example)

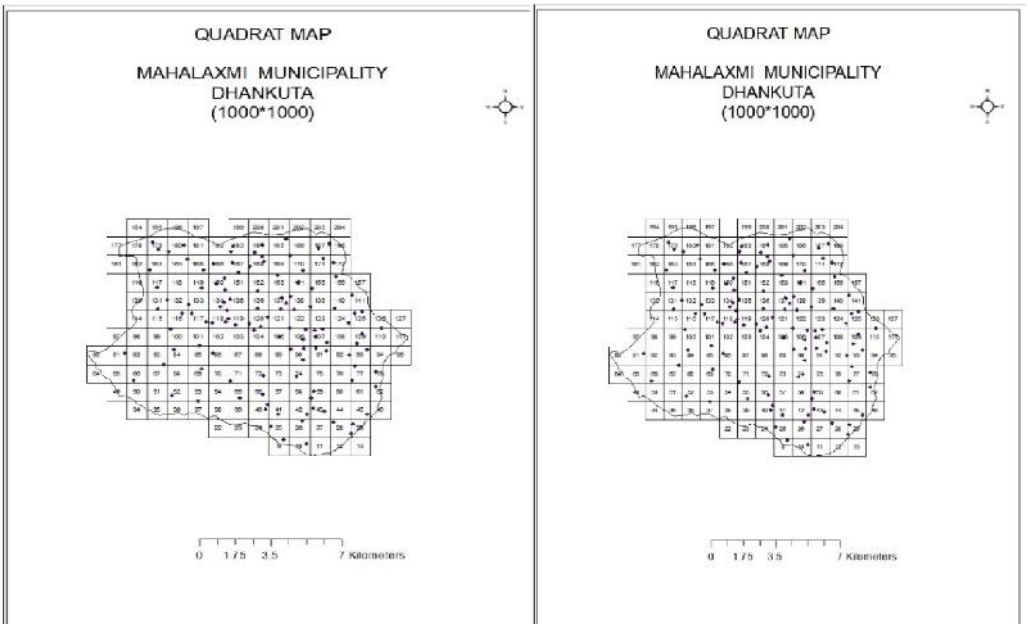
X (Grid No.)	F (Settlement)	FX	x^2	FX^2
3	2	6	9	18
8	1	8	64	64
9	1	9	81	81
10	1	10	100	100
11	2	22	121	242
12	5	60	144	720
15	1	15	225	225
16	2	32	256	512
	□f= 15	**□fx = 162**	**□x^2=1000**	**□fx^2=1962**

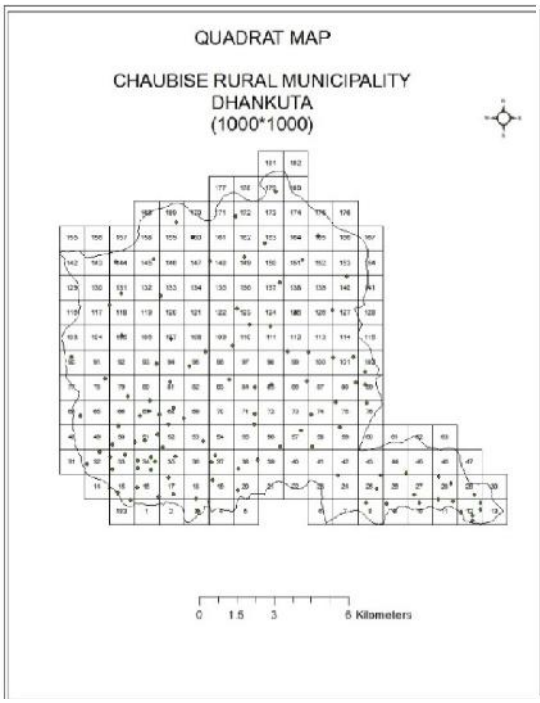
Here, we know the formula,

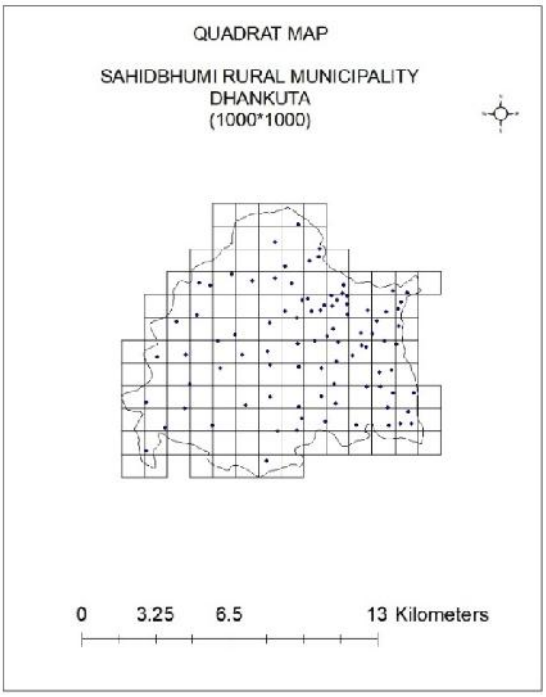
- Mean ($\bar{X}$) = ∑fx / N
  = 162/15
  = 32.4

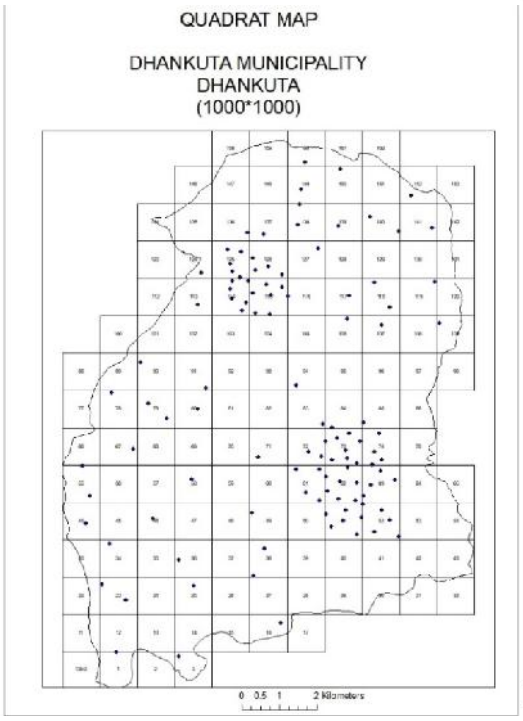
- Variance (S^2) = $\frac{\sum f(\sum fx^2)-(\sum fx)^2}{\sum f\,(\sum f-1)}$
  = $\frac{1\ (1\quad)-(1\quad)^2}{1\ (1\ -1)}$
  = 15.17
- Coefficient of Dispersion (C) = Variance/Mean
  = 15.17/32.4
  = 0.46
- Index of dispersion (I) = ∑f (∑fx^2-∑fx) / ∑fx (∑f x-1)
  = 15(1962-162)/162(162-1)
  = 1.03

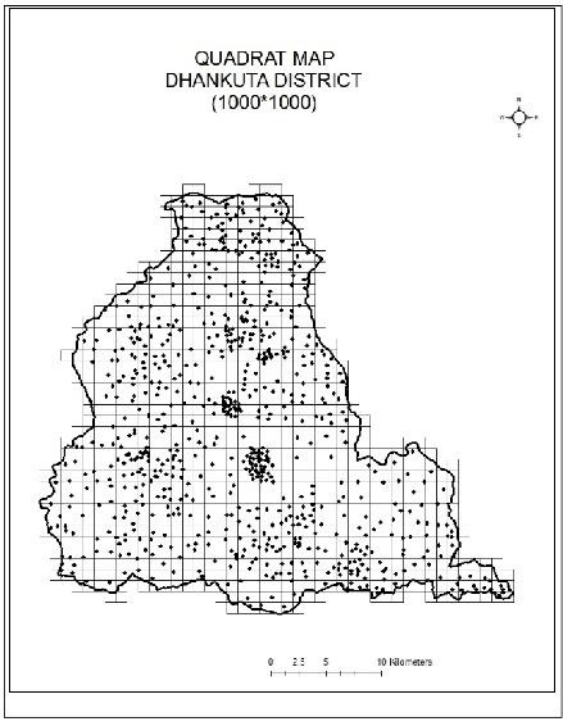
Annex III. Settlement Pattern of Local Levels in Dhankuta district




QUADRAT MAP
CHAUBISE RURAL MUNICIPALITY
DHANKUTA
(1000*1000)
0 1.5 3 6 Kilometers


QUADRAT MAP
SAHIDBHUMI RURAL MUNICIPALITY
DHANKUTA
(1000*1000)
0 3.25 6.5 13 Kilometers


QUADRAT MAP
DHANKUTA MUNICIPALITY
DHANKUTA
(1000*1000)
0 0.5 1 2 Kilometers


QUADRAT MAP
DHANKUTA DISTRICT
(1000*1000)
0 2.5 5 10 Kilometers

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