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Md. Asadul Hasan

DECLARATION

I, Md. Asadul Hasan, declare that this present thesis work entitled "Comparison of plot based vs. plot less method for plant density estimation" is the result of my own work; has been carried out under the direct supervision of Dr. Md. Nabiul Islam Khan, Professor, Forestry and Wood Technology Discipline and it is not submitted or accepted for a degree in any other university or any other organization before.

I, hereby, give consent for my thesis, if accepted to be available for photocopying and for inter-library loans, and for the title and summary to be made available to outside organizations.

Signature... Md. Asadul Hasan

Name of the candidate: Md. Asadul Hasan

Dedicated to

My

Beloved parents.

Comparison of plot based vs. plot less method for plant density estimation

Course Title: Project Thesis

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Abstract

Plot less density estimators are those that are based on distance measures rather than counts per unit area (quadrats or plots) to estimate the density of some usually stationary event, e.g. number of plants burrow openings, damage to plant stems, etc. These estimators typically use distance measures between events and from random points to events to derive an estimate of density. Therefore in this study simulated and natural plant populations were used to create virtual forest and to perform simulation experiments. The error and bias of these estimators for the various spatial patterns found in nature have been examined using real and simulated populations. For tree density estimation in plot based for natural forest in lawachara national park we considered true density and it was 2000. Various spatial patterns show in various result that are to be used for chose appropriate plot less method to estimate tree density. To consider the best plot less method for random spatial structure PCQM is best. And others spatial structure gives different result for different plot less density estimators. Actually this study is show that to compare the efficiency of plot less methods to plot based method in tree density estimation in forest.

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Chapter 1

Introduction:

A basic problem common in many fields of biology is to estimate the density of stationary objects. The populations of interest most commonly are plant communities, but applications are as diverse as estimating the density of nests for colonial-nesting seabirds or estimating the density of rat damage in sugar cane. The two general sampling approaches available for producing density estimates include the well-known quadrat or plot method and the distance or plot less methods. At the other extreme, colonial seabird nests can tend towards a more rigid hexagonal or triangular pattern. A variety of estimators have been proposed to offer robust estimation over different spatial patterns (e.g., Morisita 1957, Batcheler 1975, Diggle 1975, Lewis 1975, Patil et al. 1979). Attempts also have been made to modify existing estimators to improve their robustness (e.g.,Clayton and Cox 1986) and to calculate the bias of some estimators when certain nonrandom spatial patterns are assumed (e.g., Persson 1971, Diggle 1975). However, little comparative information is available in the literature where a large group of estimators in a variety of circumstances are assessed simultaneously. Our study provides the field investigator with information concerning which estimators yield a reasonably accurate assessment of density, even if the population spatial pattern is unknown or nonrandom.

1.1 Estimation methods considered:

In lawachara national park tree density is very high and the regeneration is comparably high than plane land forest. Determining the tree density if the field plots is very large than every trees must be counted. On the other hand plot less sampling method or distance method is not reliable in all cases. Plot less sampling methods calculate the average area per tree by measuring distances between points and trees or between trees. These techniques have the advantage of not requiring plot boundaries and are generally fast, since inter tree distances tend to below in lawachara national park and therefore rapidly measured.

Before we describe the estimators that are included in the study, we mention some distance sampling methods that are excluded. A general categorization of these methods might be as "line-of-sight" methods, i.e., those methods needing a clear line of sight to the objects of interest to have a practical implementation in the field. Among these methods is line transect sampling (Burnham et al. 1980), variable circular plot sampling (Buckland 1987), and that described by De- lince (1986). The methods we study are applicable when an area must be thoroughly searched to find the objects of interest as well as when they are more readily visible to the investigator. The line-of-sight methods tend to become overly arduous or become equivalent to other methods when an area is completely searched. Also, for these methods, the simulation programming would become substantially more difficult and additional con- siderations, such as different sighting functions, would need to be included in the simulation design.

Various studies have been performed to crop (white 2008, engeman 1994, cottam 1996, pollard 1971 and others). However their performance in natural forest environment needs to be cheeked for a possibility of application in forestry. Therefore in this study simulated and natural plant populations were used to create virtual forest and to perform simulation experiments.

1.2. Set up of the study:

This study consists of several parts like; firstly an area must be selected in 100 m × 100 m. Then the plot divided into 10 m × 10 m sub plots. Secondly each sub plots trees are measured by using several instruments. Here the trees x and y position also be measured.

1.3. Objectives of the study:

- To compare the efficiency of plot less methods to plot based method in tree density estimation in forest.

Chapter 2

Methods:

2.1. Study site description:

Lawachara is one of the major national park/sanctuary/reserve in Bangladesh. In 1997 Bangladesh government declared it A National Park. This forest is built by the British, the time of their rule in Indian Subcontinent. Lawachara is the most beautiful tropical forest. The park is named after a small narrow tributary, named 'Lawachara'. Its previous name was 'West Bhanugan'. Lawachara is also called a Bird Safari.

Lawachara National Park is located in Kamalgonj Upazila of Maulavibazar District, about 160 km north east of Dhaka, well connected by the national highway. The Park has an area of 1250 ha and comprises forests of southern and eastern parts of West Bhanugach Reserve Forests within the Lawachara, Chautali and Kalachara Beats of Maulavibazar Range. The Park was notified in 1996 as per the wild life Act of 1974.Roughly 15% of forest cover is completely lost, and another 60% of its area thinned considerably due to illegal logging and fuel wood collection. Wild life has declined by roughly 80% and other forms of habitats have become extinct are facing near extinction.

Biological diversity in the Lawachara National Park consists of 460 species, of which 167 species are plants, 4 amphibian species, 6 reptile species, 246 bird species, 20 mammal species, and 17 insect species. One of this is the critically endangered western hoolock gibbons, of which only 62 individuals remain in the area.

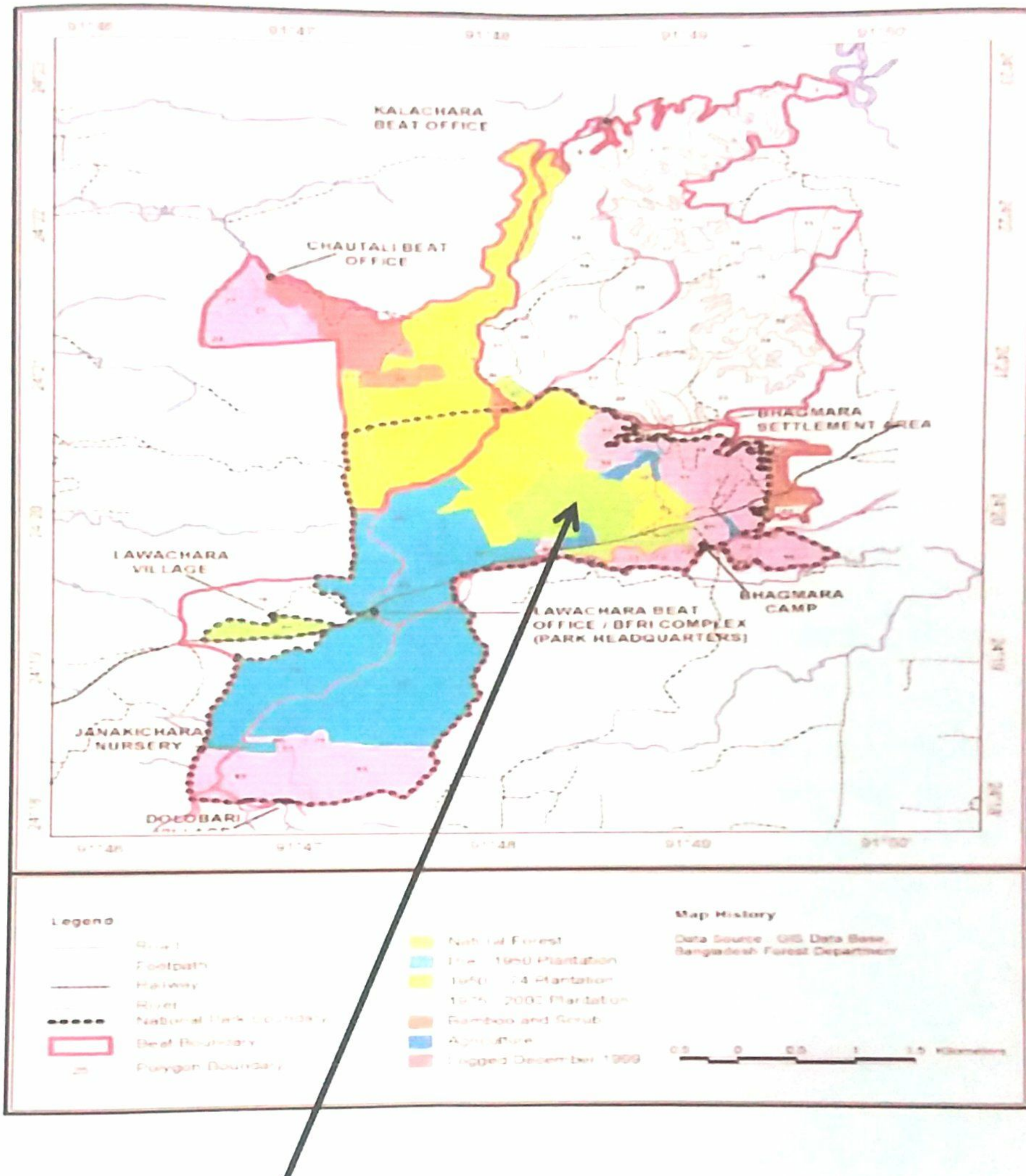

Figure: Map of the **study site** (Lawachara National Park) with forest covers and land use patterns (Source: Bangladesh Forest Department).

To find the accuracy of a sampling method at first knows the actual or true density. To established the true or actual density in lawachara national park counting and mapping all of the trees. In summarizing the sampling data, point –to-individual distances first should be totaled all species and all points, then averaged to give mean point-to-individual distance. This value squared gives the mean area per individual.The mean area individual is the average area of surface on which one individual occurs. The total density in the area sampled is obtained by dividing the mean area per individual into the unit area. This may be written as an equation:

$$\text{Total density of all species}=\frac{unit\ area}{(mean\ point\text{–}to\text{–}individual\ distance)^2}$$

This means that we could reproduce the forest stands on a computer to test the plot less sampling methods as if they were applied in the field. In plot less sampling distances are measured between trees and therefore the tree location is here variable. We digitized all trees locations and developed an algorithm for each Plot less sampling method. This allowed numerous repetitions of the density estimations and thus the calculation of the mean estimate and confidence intervals for each sampling method. Measuring the distances from the trees to the grid borders.

We know PCQM is the only plot less sampling method used in lawachara national park. To investigate possible alternative techniques, this evaluation is extended with four categories of plot less sampling found in the literature: plot based density methods, nearest neighbor methods; the order distance methods and the variable area transect methods. In each method distances are measured between trees or between points and trees to estimate tree density.

2.2. Simulation-based Study

From previous studies it is known that errors in plot less sampling can be (partly) ascribed to the degree of non-random ness of a vegetation pattern. In vegetation analysis, two basic types of spatial patterns are known besides randomness: regular and aggregated dispersion, where dispersion refers to the arrangement of points in a plane .In lawachara national park forests an additional spatial pattern. This at tern is probably duet or the different physiological adaptations and different tolerance levels (Saenger2002).We identify the six spatial patterns for the populations simulated in this study as random, clustered, repulsion, uniform, uniform-hexagonal, field-xy-position.


Figure2: Random spatial structure


Figure3: Clustered spatial structure

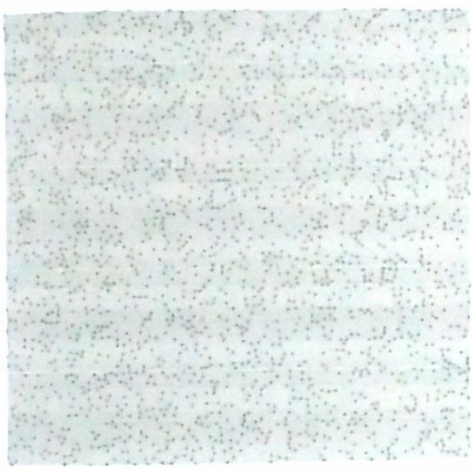
Figure4: Repulsion spatial structure

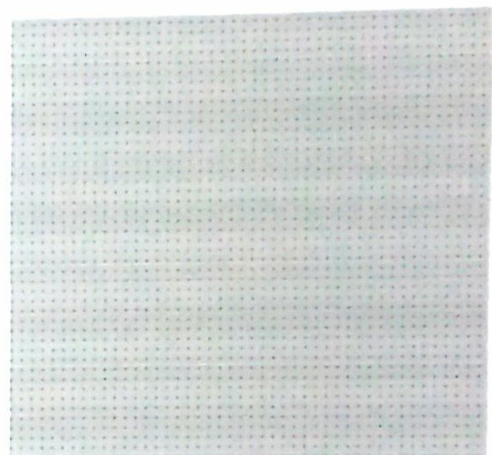
Figure5: Uniform spatial structure


Figure6: Uniform hexagonal spatial structure

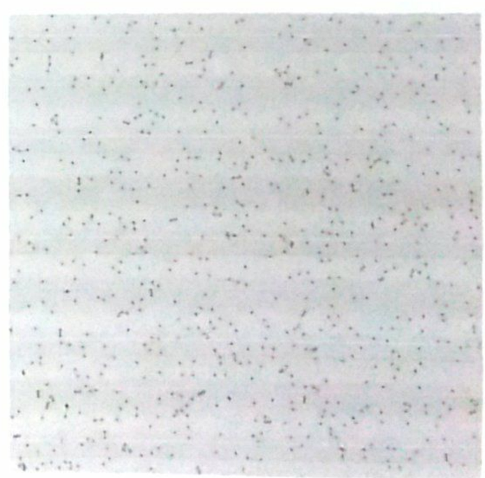
Figure7: Field-xy-position spatial structure

The random pattern (also called Poisson in recognition of the fact that the points are distributed as a two-dimensional Poisson process) was simulated by generating the appropriate number of random co-ordinates in the designated area. The random pattern (also called Poisson in recognition of the fact that the points are distributed as a two-dimensional Poisson process) was simulated by generating the appropriate number of random co- ordinates in the designated area. The regular spatial pattern was generated by dividing the area into a grid of rectangles, the same number as individuals in the population.

The population members were then situated by randomly locating one individual in each rectangle. The triangular patterns (sometimes referred to as a hexagonal pattern) were generated so that the population members were located at the vertices of a lattice of equilateral triangles. For the two aggregate patterns, the centers of a user-specified number of clumps were randomly located in the designated area. In addition to the clump center point, a user specified number of "offspring" for the clumps were located within a user- specified radius of the center (parent) point. These off- spring were located within the clump about the parent point using coordinates randomly generated from the standard bivariate normal distribution. This tends to concentrate the members of the clump near to the center point. The aggregate patterns approximate many of the naturally occurring biological population patterns.

Each plot less density estimator (PDE) assessed required randomly located sampling points to initiate the sampling procedures. The sample sizes considered in this study refer to the number of random sampling points placed in the population. Sample sizes that we examined were 25, 50, 75, and 100 sampling points. this study we concentrated on only the properties of the estimators as originally defined, without considering truncation formulae for restricted search areas.

There was one run of the simulation program for each spatial pattern x density x sample size combination. We used the RRMSE as the primary criterion for comparing the performance of the estimators (see, for example, Patilet al.1979, Engeman and Bro- maghin 1990), because it encompasses variance and bias, and it is unit less. RRMSE (The relative root mean square error) was calculated as:

$$\text{RRMSE}= \{[\Sigma((D_e - D)^2/D^2)]/I\}^{1/2}$$

We also estimate the RBIAS (relative bias).And this formula calculated as:

$$\text{RBAIS}=\frac{(\sum D_e/I)-D}{D}$$

Where De was the estimated density, D was the true density, and I was the number of replications in the simulation run.

2.3."Basic" distance (BD) estimators

The "basic" distance methods involve two types of measurements -from randomly placed sample points to the closest individual in the population (point-to- individual), or from individuals (usually the closest individual) to their nearest neighbor (individual-to-in-dividable).We use the following notation:

$$\hat{D}=\frac{1}{2.778*(\sum R_{(1)}/N)^2}$$

N =sample size (number of random sample points used to gather distance measurements), $R_{(1)i}$ = distance from the i^{th} sample point to the closest individual, $H_{(1)i}$ = distance from the i^{th} closest individual to its nearest neighbor.

2.4. Ordered distance (OD) estimators

Morisita (1957) described and developed the theory for several estimation methods. Included among these is the ordered distance method, the theory for which was further developed by Pollard (1971). The method involves measuring the distance from the random sampling point to the closest individual (hence the ordering). We define the distance to the closest individual at the sample point. The general formula for the ordered distance estimator is:

$$\hat{D}=\frac{n-1}{\pi\sum_i R^2}$$

Pollard (1971) demonstrated that, for the random spatial pattern, as g increases, the variance of the density estimate decreases. However, he also indicated that using g > 3 may be impractical in the field. We there- fore consider = 1, 2, and 3 (ODCI, OD2C, and OD3C, respectively) in our simulation study. The specific formulas for these estimators are given in Table 1.

2.5. Variable area transect (VAT) estimator

we include is the variable area transect estimator by Parker (1979). It can be considered as a combination of distance and quadrat methods, because a fixed-width (strip) transect is searched from a random point until the individual is encountered in the strip. For notation we define g as the number of individuals searched for (beginning at each random point), w as the width of the strip transect, and i as the length searched from the random point to the g^{th} individual. The general formula for the VAT estimator is:

$$\hat{D} = \frac{gn - 1}{w \sum_i L_{(g)i}}$$

2.6. Point-Centered Quarter Method (PCQM) estimator

The point-centered quarter method was developed by Cottam and Curtis in the 1950's as a plot-less technique to estimate density. It assumes that the key species follow a random spatial pattern, and is sensitive to bias when plants exhibit a more contagious arrangement. It also requires extra field effort and computational input than many of the other distance. Despite these disadvantages, the point-centered quarter method has been used in a wide variety of vegetation types, including some attempts to sample herbaceous vegetation. In the point-centered quarter method, a set of points (usually positioned along a transect to traverse the area) is initially selected.

The area around each point is divided into four 90° quadrants, and the plant closest to the point in each quadrant is identified. The distance between the central point and selected plant in each quadrant is measured, and then averaged across the four to represent the distance at each sample point. When entering the forest for research purposes that time must be aware in tide schedule. The research progress is so much difficult when trying to get into the forest because in high density population in the forest.

But Measuring distances between trees are comparatively more easy and fast. For these reasons plot less sampling method-the Point Centered Quarter Method (PCQM)-has been recommended for lawachara national park and since then been used for a variety of purposes Besides PCQM, a number of other plot less sampling methods exist. The general formula for the PCQM estimator is:

(Table No.1) An overview of the plot less sampling methods evaluated in this study:

Method	**Description of distance(s) measured**	**Equation**	**Source**
Nearest neighbor (NN)	The distance between a tree and the nearest tree is measured	$\widehat{D} = \frac{1}{2.778 * (\sum R_{(1)}/n)^2}$	[(Renske and Khan., 2013)]
PCQM 1	The distances between a point and the nearest tree in each quadrant around the point are measured.	$\widehat{D} = \frac{4(4n-1)}{\pi \sum_{i=1}^{n} \sum_{j=1}^{4} R_{ij}{}^2}$	[(Renske and Khan., 2013)]
PCQM 2	The distances between a point and the second nearest tree in each quadrant around the point are measured.	$\widehat{D} = \frac{4(8n-1)}{\pi \sum_{i=1}^{n} \sum_{j=1}^{4} R_{(ij)2^2}}$	[(Renske and Khan., 2013)]
PCQM 3	The distances between a point and the third nearest tree in each quadrant around the point are measured	$\widehat{D} = \frac{4(12n-1)}{\pi \sum_{i=1}^{n} \sum_{j=1}^{4} R_{(ij)3^2}}$	[(Renske and Khan., 2013)]
Variable Area Transect (VAT)	The distance from a point to the g[th] Individual in a given Direction with a certain width (a transect) is measured.	$\widehat{D} = \frac{gn-1}{w \sum_i L_{(g)i}}$	[(Renske and Khan., 2013)]
Order Distance 1	The distance between a point and the nearest tree is measured.	$\widehat{D} = \frac{n-1}{\pi \sum_i R^2}$	[(Renske and Khan., 2013)]

Order Distance 2	The distance between a point and the second nearest tree is measured.	$\hat{D} = \frac{n-1}{\pi \sum_i R^2}$	[(Renske and Khan., 2013)]
Order Distance 3	The distance between a point and the third nearest tree is Measured.	$\hat{D} = \frac{2n-1}{\pi \sum_i {R^2}_{(2)i}}$	[(Renske and Khan., 2013)]
Basic distance	The distance between a point and the nearest tree is measured.	$\hat{D} = \frac{3n-1}{\pi \sum_i {R^2}_{(3)i}}$	[(Renske and Khan., 2013)]

D= estimated density, R= distance measured in the field, i= number of sampling point, j= number of quadrant, g= the g^{th} individual, L= Lislen gth of transect and *W* is width of transect, n= number of sampling points.

2.7. Preventing edge effects

The data sets acquired are enclosed and thus contain borders. When a sampling point is located close to the border of a data set the nearest tree measured might be farther away then would be measured in the field. This effect is called edge effects. To prevent edge effects some actions were taken like:

- The sampling points were located at a minimal distance from the site boundaries.
- When a method mention that if a tree across the site boundary should be used for computation the relevant sampling point was omitted (this applied only for PCQM and the variable Area Transect method).
- Higher order methods were not analyzed for the field data, but only for the simulation based study, which had large areas of 100 m × 100 m.

2.8. Replication

Each method was used to estimate tree density using 25, 50, 75 and 100 random sampling points. These calculations were repeated one time for each spatial structural pattern to allow for the mean.

2.9. Analysis of data

All of the data produced during the field and analyzed by using Net Logo 5.0.3, Sigma Plot 12.0 and Microsoft Office Excel 2010 software.

Chapter 3

RESULT AND DISCUSSION

Different spatial structure show different result which is applicable for estimate tree density. We also interpretation of the performance of estimators based on relative root mean square error (RRMSE), (Table 8-13) and relative bias (RBIAS), (Table 14-19).

3.1. Random spatial structure

Comparatively plot based is always best than plot less for random spatial structure. But in this spatial structure the best suitable and more applicable plot less method is PCQM (Point-Centered Quarter Method) (Fig.8). Because it is more close to the plot based. The RRMSE (Table 8) and RBIAS (Table 14) Value is also low than others and the value is close to the plot based. So PCQM is more nearest than others to plot based density and when the true density is 2000 than PCQM show more accurate results.

3.2. Clustered spatial structure

OD (Order distance) is the best and more suitable plot less method for tree density estimation (Fig.9). And it is the nearest for true density and plot based density. And the RRMSE (Table 9) and RBIAS (Table 15) value is also nearest to the plot based method. So comparatively than others OD is the best.

3.3. Repulsion spatial structure

Form figure 10.we can see when the true density is 2000 than the plot based density is more accurate but if we compare the plot less density than we see most of the plot less method is not nearly to the plot based method. But compare than others the VAT (Variable area transect) density is more accurate than others plot less methods and it also close to the plot based method. The value of RRMSE (Table 10) and RBIAS (Table 16) is also less than others plot less method.

3.4. Uniform spatial structure

When the true density is 2000 and the best plot less method is VAT (Variable areas transect). It is very close than others to the plot based density (Fig.11). Comparatively the RRMSE (Table 11) and the RBIAS (Table 17) value is also close to the plot based. So for uniform spatial structure in plant density estimation the best plot less method is VAT.

3.5. Uniform hexagonal spatial structure

In this spatial structure the figure 12.show that the best plot less method is VAT (Variable area transect). And it is more nearest to the plot based. When the value is close someone than it is most perfect. Same thing the VAT is close to the plot based and the RRMSE (Table 12) RBIAS (Table 18) is also nearly to the plot based and it is low than others method. So VAT is the best plot less method for uniform spatial structure in tree density estimation.

3.6. Field xy position spatial structure in natural forest

In this spatial structure pattern the true density is 711.Here NN (Nearest neighbor) is the best plot less method for tree density estimation. Because it is closest to the plot based (Fig.13). And it is so accurate than others method for the value of RRMSE (Table 13) and RBIAS (Table 19). So we always consider NN for field xy position spatial structure in plot less method.

Table 2: Density for random spatial structure:

True density	Estimator	Sample points 25	50	75	100
2000	PCQM	1962.27	2038.87	1942.25	1996.71
	PCQM2	1962.18	2001.57	1924.74	1977.9
	PCQM3	1954.99	2002.07	1933.28	1983.69
	PB 5	1941.07	2010.46	1985.16	1959.76
	PB10	1946.26	1976.77	1944.03	2046.42
	VAT	1924.01	2015.7	1985.38	1983.08
	OD	1924.16	2065.79	1941.42	1991.48
	OD2	2603.31	2744.8	2598.22	2608.19
	OD3	2961.72	3136.26	2897.42	2963.51
	NN	2013.11	2056.97	1903.6	1936.13

Table 3: Density for clustered spatial structure:

True density	Estimator	Sample points 25	50	75	100
2000	PCQM	1372.51	1435.12	1475.64	1326.26
	PCQM2	1443.41	1490.99	1566.61	1404.65
	PCQM3	1500.81	1555.73	1631.5	1454.93
	PB 5	2038.34	2027.41	2203.35	1918.3
	PB10	2050.89	2082.2	1981.57	2077.9
	VAT	1666.26	1707.75	1869.39	1612.69
	OD	1405.11	1446.35	1467.26	1308.07
	OD2	1931.05	1978.95	2051.55	1828.05
	OD3	2263.68	2308.89	2385.16	2108.45
	NN	1711.94	1864.06	2014.32	1721.59

Table 4: Density for repulsion spatial structure:

True density	Estimator	Sample points			
		25	50	75	100
2000	PCQM	2568.42	2482.79	2445.45	2575.67
	PCQM2	2228.82	2182.29	2180.97	2287.66
	PCQM3	2137.51	2102.59	2099.02	2185.18
	PB 5	1980.2	1956.91	1956.59	1987.68
	PB10	1964.91	1948.08	1996.95	1942.44
	VAT	2042.95	2038.86	2052.09	2094.49
	OD	2617.03	2482.19	2464.19	2573.48
	OD2	3236.22	2996.62	3036.31	3195.55
	OD3	3485.3	3311.44	3300.36	3414.97
	NN	1518.25	1476.93	1508.16	1578.9

Table 5: Density for uniform spatial structure:

True density	Estimator	Sample points			
		25	50	75	100
2000	PCQM	3736.18	3733.5	3743.22	3741.51
	PCQM2	2134.66	2139.48	2140.73	2143.22
	PCQM3	2499.15	2497.66	2500.71	2498.61
	PB 5	1964.2	1564.59	1961.08	1962.42
	PB10	1969.35	1968.48	1960.59	1957.92
	VAT	1920.7	1916.61	1918.82	1917.16
	OD	3602.63	3739.54	3721.02	3767.22
	OD2	3705.57	3710.8	3730.56	3760.85
	OD3	3809.07	3756.85	3760.38	3759.89
	NN	707.5	707.5	707.5	707.5

Table 6: Density for uniform hexagonal spatial structure:

True density	Estimator	Sample points 25	50	75	100
2000	PCQM	3395.12	3418.93	3420.96	3426.11
	PCQM2	2672.74	2682.92	2684.76	2682.84
	PCQM3	2148.21	2150.12	2151.74	2152.77
	PB 5	2022.81	2014.18	2014.94	2020.83
	PB10	2005.27	2004.46	2002.96	2006.61
	VAT	2147.37	2178.21	2171.86	2171.48
	OD	3738.38	3811.57	3802.84	3853.77
	OD2	3804.24	3856.09	3861.14	3847.15
	OD3	3959	3881.43	3838.85	3888.85
	NN	727.64	727.64	727.64	727.64

Table 7: Density for field xy position spatial structure:

True density	Estimator	Sample points 25	50	75	100
2000	PCQM	797.02	804.82	799.87	804.99
	PCQM2	771.33	778.39	777	777.09
	PCQM3	757.86	761.25	759.95	763.28
	PB 5	704.95	729.11	726.07	734.53
	PB10	714.65	709.6	709.73	714.97
	VAT	848.23	851.06	849.71	851.45
	OD	795.87	809.17	807.5	798.27
	OD2	1086.19	1064.31	1056.13	1060.07
	OD3	1190.47	1168.49	1169.05	1185.57
	NN	721.35	707.02	719.56	720.65

Table 8. Relative Root Mean Square Error (RRMSE) and Relative Bias (RBIAS) of different spatial structure estimated based on 25, 50, 75and 100 random samples in the simulation using different plot-based and plot-less silvimetric methods.

	RRMSE				RBIAS			
	Sample point				Sample point			
Estimator	25	50	75	100	25	50	75	100
				Random				
PCQM	0.11	0.08	0.07	0.04	-0.01	-0.04	-0.03	0.01
PCQM2	0.11	0.06	0.05	0.03	-0.004	-0.02	-0.02	0.01
PCQM3	0.1	0.04	0.04	0.03	0.002	-0.006	-0.02	0.009
PB 5	0.11	0.06	0.05	0.1	-0.01	0.01	0.002	-0.01
PB 10	0.11	0.03	0.03	0.04	-0.01	-0.001	-0.01	0.03
VAT	0.12	0.06	0.05	0.66	0.007	0.02	0.44	0.03
OD	0.15	0.14	0.12	0.1	-0.03	-0.05	-0.33	0.008
OD2	0.38	0.33	0.33	0.37	0.31	0.28	0.30	0.34
OD3	0.55	0.5	0.47	0.54	0.50	0.47	0.44	0.52
NN	0.14	0.15	0.11	0.1	0.05	0.04	0.008	0.03
				Clustered				
PCQM	0.31	0.29	0.34	0.3	-0.3	-0.3	-0.33	-0.27
PCQM2	0.28	0.28	0.30	0.28	-0.27	-0.27	-0.30	-0.26
PCQM3	0.25	0.27	0.27	0.26	-0.25	-0.27	-0.2	-0.23
PB 5	0.17	0.12	0.14	0.13	0.02	0.02	0.11	-0.03
PB 10	0.10	0.09	0.05	0.12	0.03	0.05	0.00	0.04
VAT	0.18	0.20	0.18	0.18	-0.14	-0.19	-0.17	-0.13
OD	0.33	0.31	0.35	0.3	-0.23	-0.3	-0.34	-0.28
OD2	0.22	0.15	0.14	0.14	-0.02	-0.02	-0.09	-0.03
OD3	0.23	0.17	0.14	0.17	0.10	0.09	0.06	0.11
NN	0.25	0.20	0.17	0.21	-0.11	-0.16	-0.12	-0.16
				Repulsion				
PCQM	0.30	0.21	0.32	0.28	0.27	0.20	0.32	0.25
PCQM2	0.13	0.09	0.15	0.15	0.12	0.08	0.15	0.11
PCQM3	0.09	0.05	0.10	0.12	0.08	0.04	0.09	0.07
PB 5	0.06	0.05	0.3	0.1	0	-0.01	-0.01	0.003
PB 10	0.03	0.02	0.01	0.10	-0.007	-0.01	0.008	-0.01
VAT	0.08	0.06	0.08	0.11	0.04	0.01	0.07	0.03
OD	0.33	0.24	0.35	0.30	0.25	0.18	0.32	0.26
OD2	0.62	0.50	0.63	0.58	0.58	0.48	0.62	0.56
OD3	0.72	0.67	0.76	0.70	0.68	0.64	0.75	0.68
NN	0.24	0.23	0.23	0.28	-0.24	-0.23	-0.23	-0.26
				Uniform				
PCQM	0.86	0.9	0.1	0.89	0.87	0.89	0.89	0.89
PCQM2	0.07	0.08	0.08	0.08	0.07	0.08	0.08	0.08
PCQM3	0.26	0.26	0.26	0.26	0.25	0.26	0.26	0.26
PB 5	0.05	0.02	0.03	0.1	-0.008	-0.007	-0.009	-0.008
PB 10	0.03	0.02	0.02	0.02	-0.005	-0.005	-0.009	-0.001
VAT	0.06	0.04	0.04	0.04	-0.03	-0.02	-0.03	-0.03

OD	0.1	0.87	0.1	0.89	0.87	0.85	0.87	0.87
OD2	0.1	0.9	0.1	0.91	0.88	0.88	0.89	0.89
OD3	0.1	0.9	0.1	0.91	0.94	0.88	0.89	0.89
NN	0.64	0.64	0.64	0.64	-0.64	-0.64	-0.64	-0.64

Uniform hexagonal

PCQM	0.71	0.72	0.72	0.73	0.71	0.72	0.72	0.72
PCQM2	0.34	0.35	0.35	0.37	0.34	0.35	0.35	0.35
PCQM3	0.08	0.08	0.08	0.13	0.08	0.08	0.08	0.08
PB 5	0.04	0.03	0.02	0.1	0.02	0.01	0.01	0.02
PB 10	0.02	0.01	0.01	0.10	0.01	0.01	0.01	0.01
VAT	0.10	0.10	0.10	0.14	0.08	0.09	0.10	0.10
OD	0.94	0.96	0.92	0.92	0.90	0.94	0.91	0.91
OD2	0.93	0.96	0.95	0.96	0.90	0.94	0.93	0.94
OD3	0.97	0.1	0.95	0.94	0.94	0.98	0.93	0.92
NN	0.63	0.63	0.63	0.64	-0.63	-0.63	-0.63	-0.63

Field xy position

PCQM	0.17	0.15	0.14	0.18	0.13	0.13	0.13	0.13
PCQM2	0.11	0.11	0.10	0.15	0.09	0.09	0.09	0.10
PCQM3	0.10	0.08	0.08	0.13	0.08	0.07	0.07	0.08
PB 5	0.14	0.11	0.09	0.18	0.01	0.01	0.03	0.03
PB 10	0.06	0.08	0.03	0.11	0.01	0.003	0.01	0.02
VAT	0.24	0.21	0.21	0.24	0.22	0.20	0.20	0.21
OD	0.21	0.20	0.18	0.21	0.12	0.14	0.13	0.14
OD2	0.55	0.54	0.50	0.54	0.49	0.50	0.48	0.51
OD3	0.71	0.69	0.67	0.69	0.66	0.66	0.65	0.67
NN	0.18	0.12	0.09	0.12	0.004	0.03	0.01	0.01

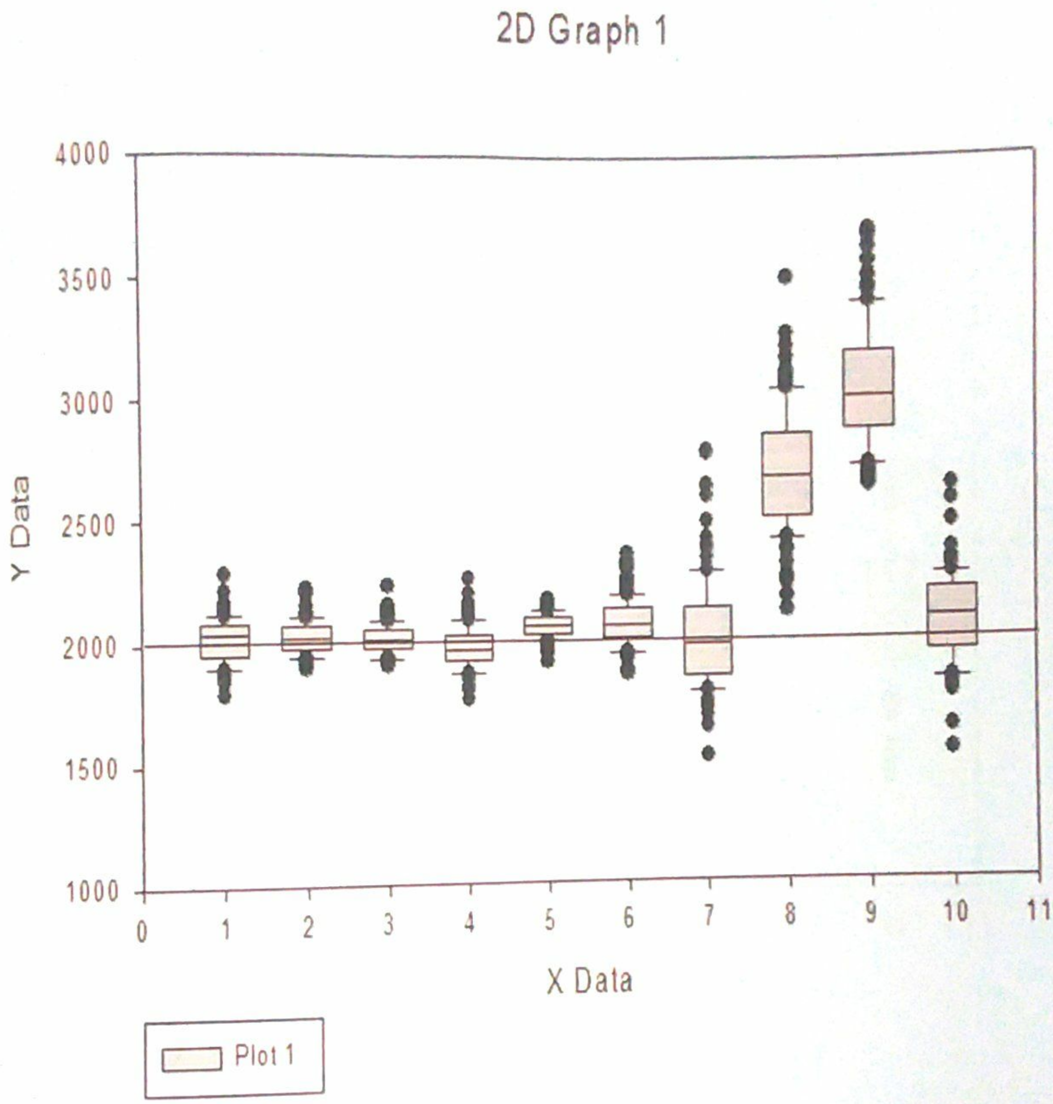

Fig 8: Box plot for random (here 1=PCQM density, 2= PCQM two density, 3= PCQM three density, 4=plot based density for plot size 5, 5= plot based density for plot size 10, 6=vat density, 7=OD density, 8=OD two density, 9= OD three density, 10=NN density).

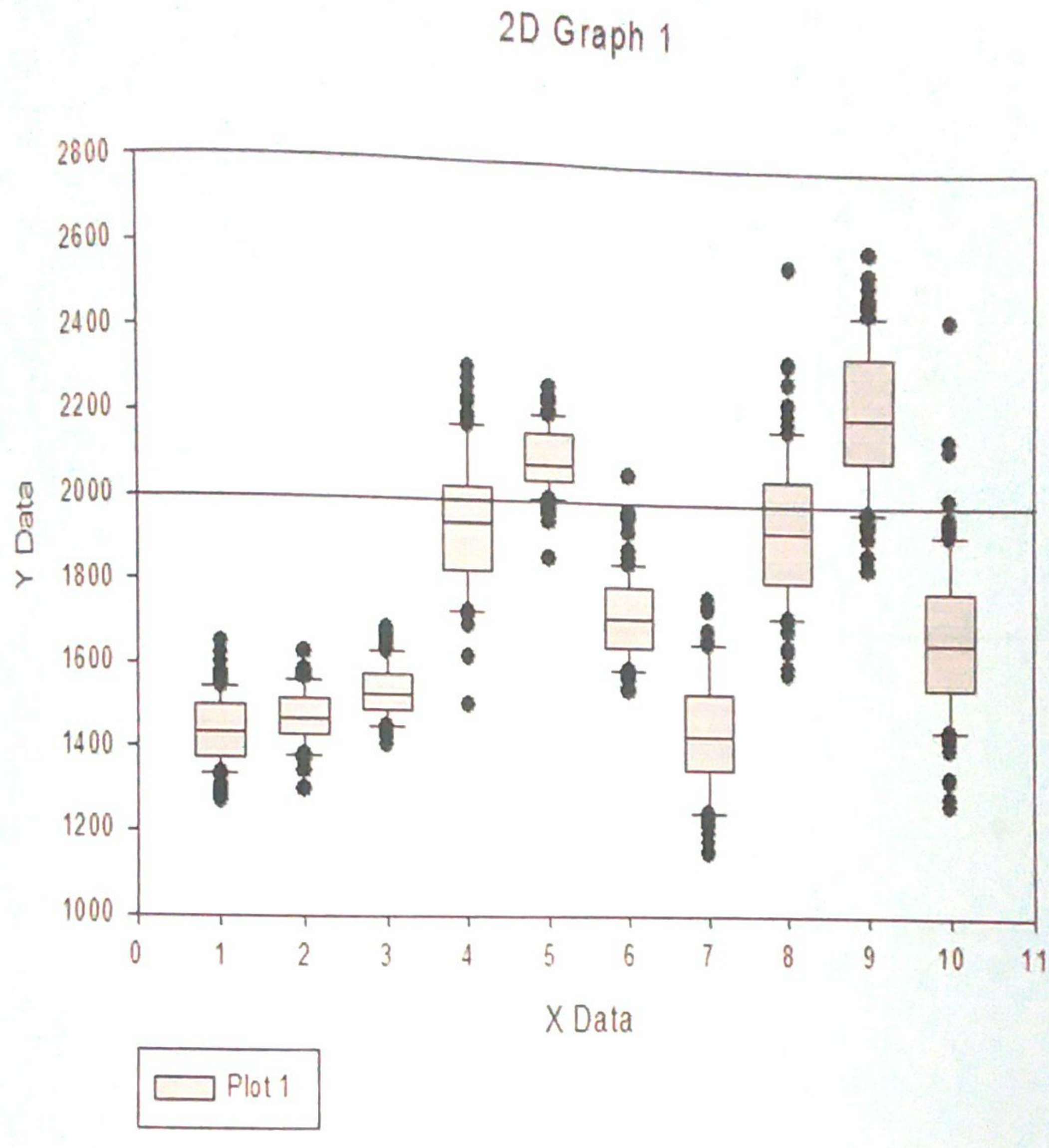

Fig 9 : Box plot for clustered (here 1=PCQM density,2= PCQM two density,3= PCQM three density,4=plot based density for plot size 5,5= plot based density for plot size 10,6=vat density,7=OD density,8=OD two density,9= OD three density,10=NN density).

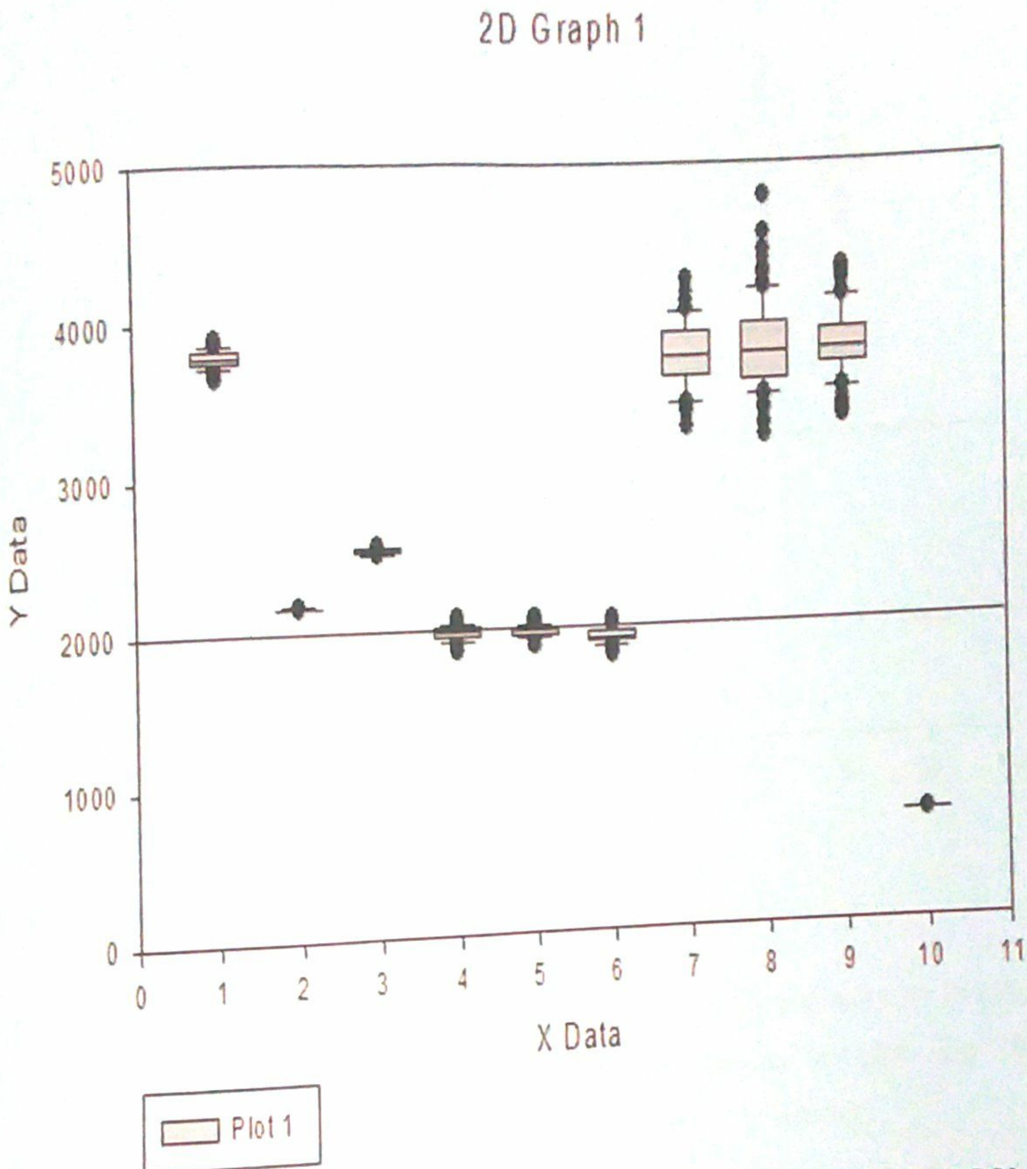

Fig 10 : Box plot for repulsion (here 1=PCQM density,2= PCQM two density,3= PCQM three density,4=plot based density for plot size 5,5= plot based density for plot size 10,6=vat density,7=OD density,8=OD two density,9= OD three density,10=NN density).

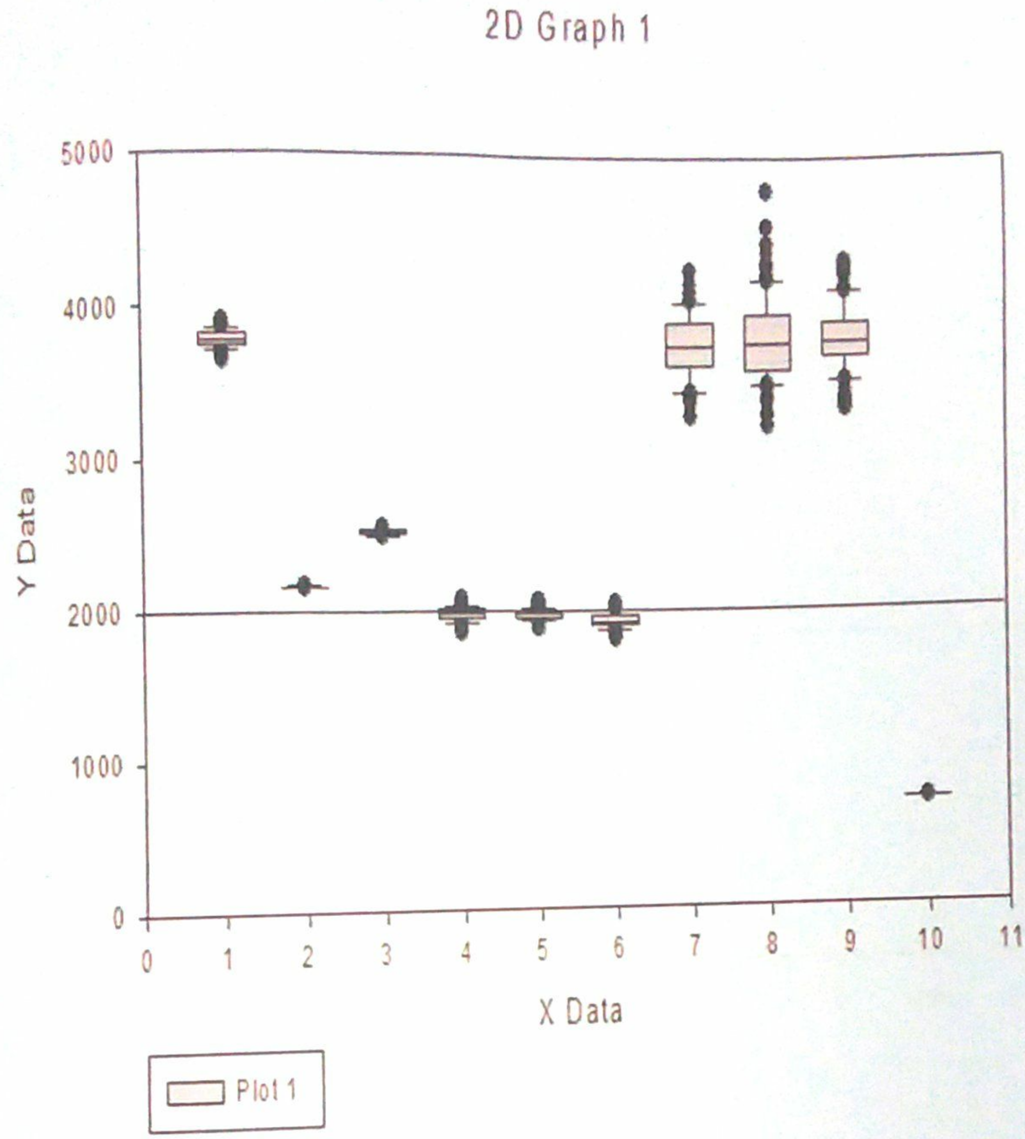

Fig 11 : Box plot for uniform (here 1=PCQM density,2= PCQM two density,3= PCQM three density,4=plot based density for plot size 5,5= plot based density for plot size 10,6=vat density,7=OD density,8=OD two density,9= OD three density,10=NN density).

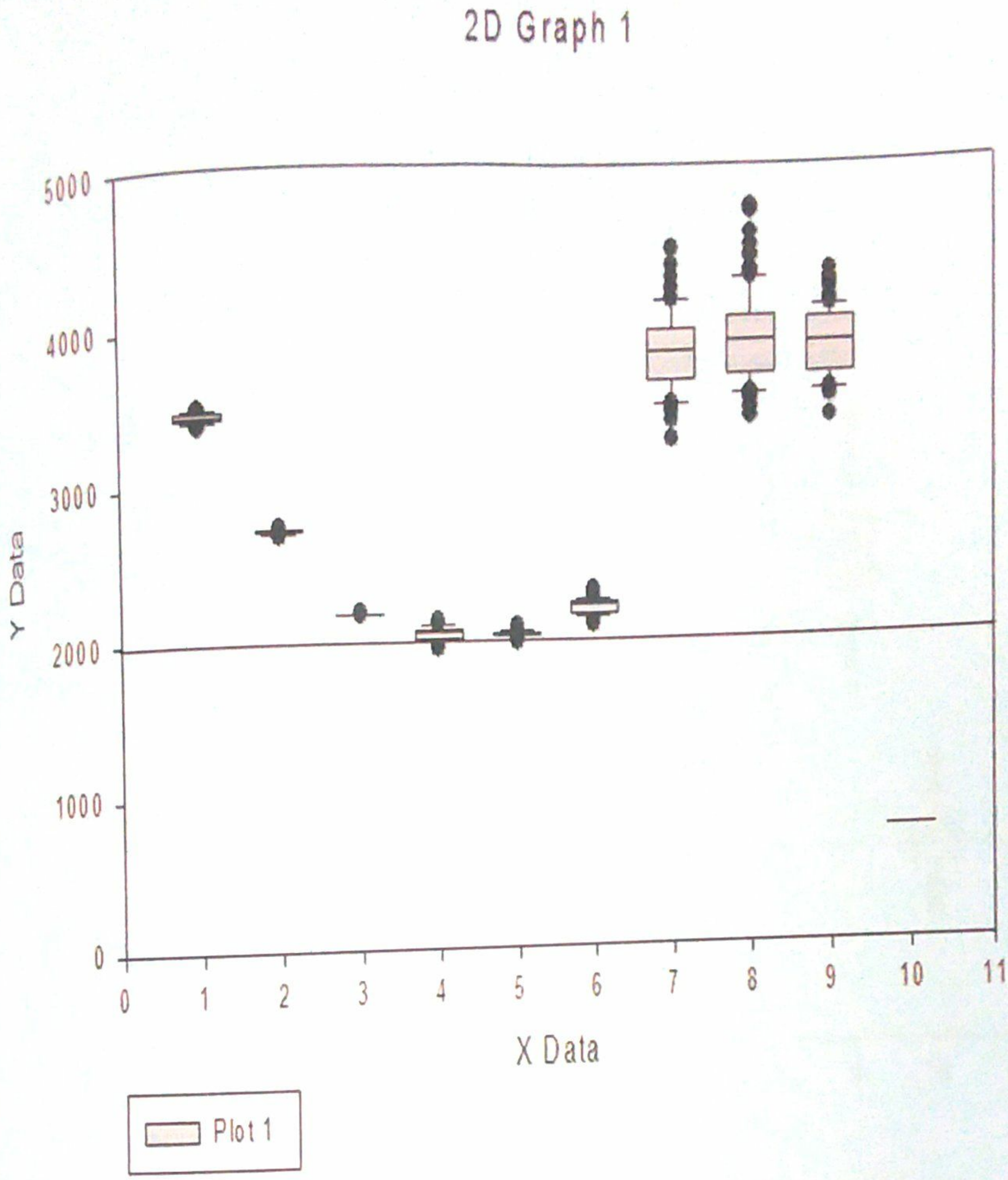

Fig 12: Box plot for uniform hexagonal (here 1=PCQM density, 2= PCQM two density, 3= PCQM three density, 4=plot based density for plot size 5, 5= plot based density for plot size 10, 6=vat density, 7=OD density, 8=OD two density, 9= OD three density, 10=NN density).

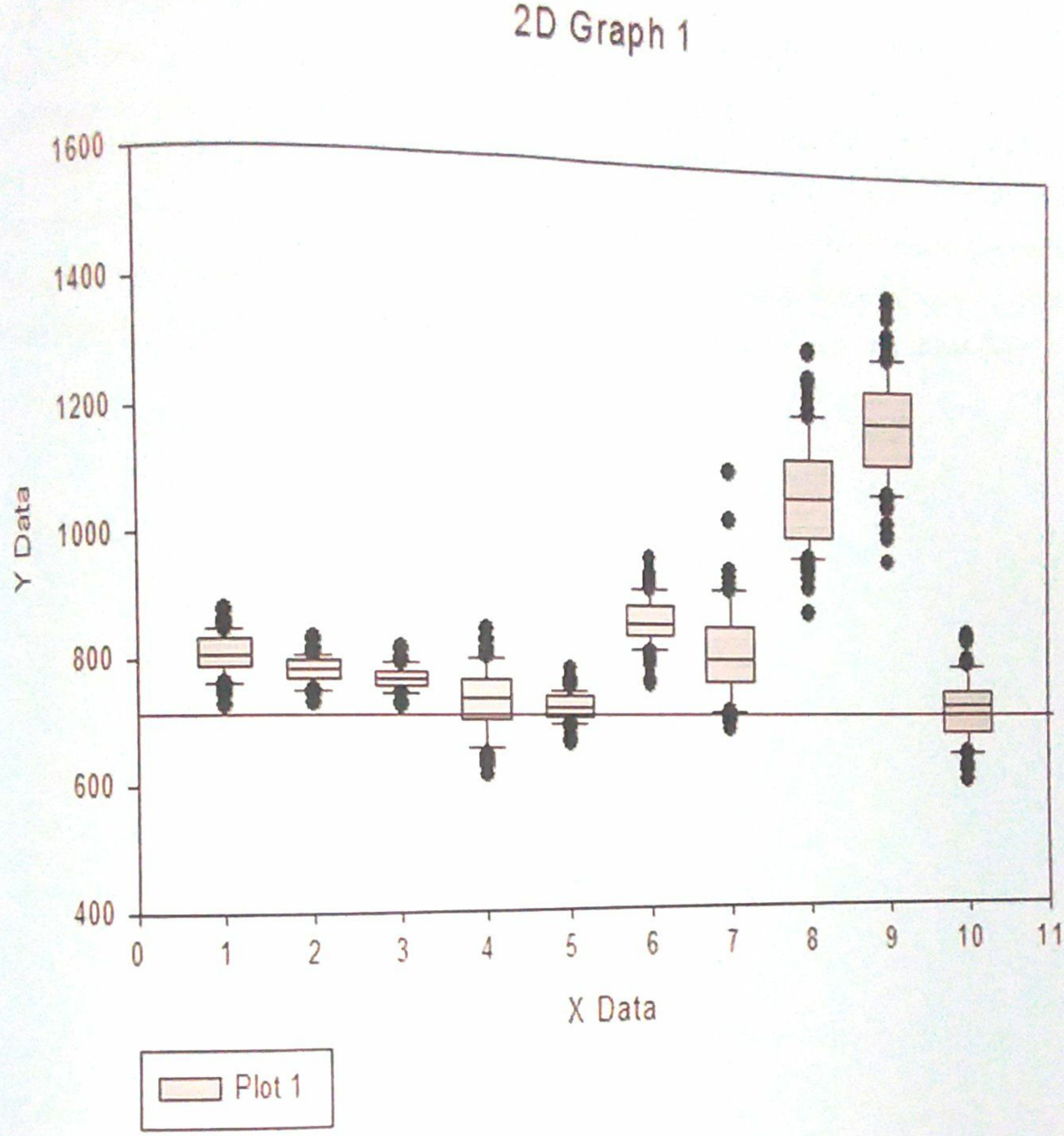

Fig 13: Box plot for field xy position in natural forest (here 1=PCQM density, 2= PCQM two density, 3= PCQM three density, 4=plot based density for plot size 5, 5= plot based density for plot size 10, 6=vat density, 7=OD density, 8=OD two density, 9= OD three density, 10=NN density).

Chapter 4

Conclusion:

The most important reason why plot less sampling techniques are being used is the relative ease compared with plot-based methods. This reflects the tradeoff between maximum accuracy and minimum time required. Because plot less methods give the largest bias when vegetation has a high degree of non-randomness, we would like to recommend not using these methods when this is a known vegetation feature beforehand. For plantation plot-less not is suitable. For natural forest we don't know existing spatial pattern of forest before survey normally mixture of pattern. Plot less density estimators can provide an estimate of density in situations where it would not be practical to lay out a plot or quadrat and can in many cases reduce the workload in the field.

Reference:

Batcheler, C. L. 1971. Estimation of density from a sample of joint point and nearest neighbor distances. Ecology 53: 703-709. 1975. Development of a deer census from pellet groups. Journal of Wildlife Management 39:641-652.

Batcheler, C. L., and D. J. Bell. 1970. Experiments in estimating density from joint point and nearest neighbor distances. Proceedings of the New Zealand Ecological Society 17:111-117.

Besag, J. E., and J. T. Gleaves. 1973. On the detection of spatial pattern in plant communities. Bulletin of the Inter-national Statistical Institute 45:153-158.

Bratley, P., B. L. Fox, and L. E. Schrage. 1983. A guide to simulation. Springer-Verlag, New York, New York, USA.

Brody, M., and D. Morais. 1987. UNIF is fast, reliable random number generator for IBM-AT microcomputer. Research Information Bulletin number 87-84. USDI Fish and Wildlife Service, Washington, D.C., USA.

Buckland, S. T. 1987. on the variable circular plot method of estimating animal density. Biometrics 43:363-384.

Burnham, K. P., D. R. Anderson, J. L. Laake. 1980. Estimation of density from line transects sampling of biological populations. Wildlife Monographs 72:1-202.

Byth, K. 1982. on robust distance-based intensity estimators. Biometrics 38:127-135.

Clayton, G. and T. F. Cox. 1986. Some robust density estimators for spatial point processes. Biometrics 42:753- 767.

Cottam, G. 1947. A point method for making rapid surveys of woodlands. Bulletin of the Ecological Society of America28:60.

Cottam,G., and J. T. Curtis. 1956. The use of distance measures in photo-sociological sampling. Ecology 37:451- 460.

Cottam, G., J. T. Curtis, and A. J. Catana. 1957. Some sampling characteristics of a series of aggregated populations. Ecology 38:610-621.

Cottam, G., J. T. Curtis, and B. W. Hale. 1953. Some sampling characteristics of a population of randomly dispersed individuals. Ecology 34:741-757.

Delince, J. 1986. Robust density estimation through distance measurements. Ecology 67:1576-1581.

Diggle, P. J. 1975. Robust density estimation using distance methods. Biometrika 62:39-48.

Engeman, R. M., and J. F. Bromagh in.1990. An approach to estimating density from line transect data where animals move in response to the observer. Journal of Statistical Computation and Simulation 34:145-154.

James, I. L. 1971. A computer study of corrected density estimators for distance sampling of nonrandom populations. Diploma of Agricultural Science, Dissertation. Massey University, Palmerston North, New Zealand.

Kendall, M. G., and P. A. P. Moran. 1963. Geometrical probability. Griffin, London, England.

Lewis, S. M. 1975. Robust estimation of density for a two- dimensional point process. Biometrika 62:519-521.

Morisita, M. 1954. Estimation of population density by spacing method. Memoirs of the Faculty of Science Kyushu University, Series E, Biology 1:187-197.

1957. A new method for the estimation of density by spacing method applicable to non-randomly distributed populations. Physiology and Ecology 7:134-144 (in Japa- nese). [Available as Forest Service translation number 11116, USDA Forest Service, Washington, D.C., USA.]

Parker, K. R. 1979. Density estimation by variable area transects. Journal of Wildlife Management 43:484-492.

Patil, S. A., K. P. Burnham, and J. L. Kovner. 1979. Non- parametric estimation of plant density by the distance method. Biometrics 35:597-604.

Patil, S. A., J. L. Kovner, and K. P. Burnham. 1982. Optimum nonparametric estimation of population density based on ordered distances. Biometrics 38:243-248.

Persson, 0. 1971. The robustness of estimating density by distance measurements. Pages 175-187 in G. P. Patil, E. C. Pielou, and W. E. Waters, editors. Statistical ecology. Volume 2. Pennsylvania State University Press, University Park, Pennsylvania, USA.

Pollard, J. H. 1971. on distance estimators of density in randomly distributed forests. Biometrics 27:991-1002.

Steams, F. W. 1949. Ninety years change in a northern hardwood forest in Wisconsin. Ecology 30:350-358.

Saenger. P (2002) Mangrove ecology, silviculture and conservation. The Netherlands: Kluwer Academic Publishers.

Aleman SM, Bourgeois, Appellants, VanhoorneB, De Hauwere N, etal. (2010) The 'Mangrove Reference Database and Herbarium'.

Duke NC, Meynecke JO, Dittmann S, Ellison AM, Anger K,etal.(2007) A World without Mangroves? Science 317:41–42.

FAO (2003) Status and trends in mangrove area extent worldwide. Paris: Forest Resources division, FAO.

Houghton RA (2005) above ground Forest Biomass and the Global Carbon Balance. Glob Chang Bio 111:945–958.

Gibbs HK, Brown S, Niles JO, Foley JA (2007) Monitoring and estimating tropical forest carbon stocks: making REDD a reality. Environ Res Lett 2:045023.

Minang PA, Murphy D (2010) REDD After Copenhagen: The Way Forward. REDD After Copenhagen: The Way Forward .Nairobi, Kenyaand Hue City,Vietnam: International Institute for Sustainable Development.

Cottam G, Curtis JT (1956) The Use of Distance Measures in Phytosociological Sampling. Ecology 37:451–460.

Pollard JH (1971) On Distance Estimators of Density in Randomly Distributed Forests. Biometrics 27:991–1002.

Parker KR (1979) Density Estimation by Variable Area Transect.J Wild Manage 43:484–492.

Mitchell K (2007) Quantitative Analysis by the Point Centered Quarter Method. Geneva: Department of Mathematics and Computer Science, Hobartand William Smith Colleges.

Engeman RM, Sugihara RT, Pank LF, Dusenberry WE (1994) AC comparison of Plotless Density Estimator Usin gMonte Carlo Simulation. Ecology 75:1769–1779.

White N, Engeman R,Sugihara R, Krupa H (2008) a comparison of plotless density estimators using Monte Carlo simulation on totally enumerated field data sets. BMCE col8:6

Cintron G, Schaeffer Novelli Y (1984) Methods for studying mangrove structure. In: Snedaker SC, Snedaker JG, editors the mangrove ecosystem: research Methods: United Nations Educational, Scientific and Cultural Organization.

Satyanarayana B,Thierry B,LoSeen D, Raman AV, Muthusankar G(2001) Remote sensing in mangrove research-relationship between vegetation indices and dendromatric parameters: A case for Coringa, East coast of India. 22nd Asian Conference on Remote Sensing. Singapore: Centre for Remote Imaging, Sensing and Processing (CRISP), National University of Singapore.

Piou C, Feller IC, Berger U,ChiF(2006) Zonation Patterns of Belizean Offshore Mangrove Forests 41 Years After a Catastrophic Hurricane 1.Biotropica 38:365–374.

Cho-Ricketts L,Cherrington E (2011) Technical report: Validation of the 2010 Belize Mangrove cover map. Environmental Research Institute, University of Belize,Water Center for the Humid Tropics of Latin America and the Caribbean.

Tomlinson PB (1986) The botany of mangroves. Cambridge: Cambridge Press.

Matthijs S,Tack J,van Speybroeck D, Koedam N(1999) Mangrove species Zonation and soilredox state, sulphide concentration and salinity in Gazi Bay (Kenya),a preliminary study.Mangroves and Salt Marshes 3:243–249.

Byth K (1982) On Robust Distance-Based Intensity Estimators Biometrics 38:127–135.