International Journal of Science and Research (IJSR)
ISSN: 2319-7064
Impact Factor (2018): 7.426

Spatial Distribution of Plant Species Richness: Context Satchari National Park, Sylhet, Bangladesh

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Abstract: ***The number of different species varies by place to place. Spatial pattern of species richness varied with the different spatial and that's why location mapping is necessary. The aim of the study is to map out the spatial pattern of the species richness of a national park as to understand about the conservation of biodiversity or species richness along with different spatial pattern which helps to know how trees, herbs and shrubs are associated using ordinary kriging and regression kriging method and comparing methods explain better variation. In regression kriging elevation (m) is used as a week predictor and interpolation finds that species richness is higher in north zone of the study area. The amount of variation in ordinary kriging is 29.45 per cent and in regression kriging 25.78 per cent and the change in comparison of both ordinary kriging and regression kriging method is very low. The findings of the study support and contrast that species richness higher in the north zone of the study area and the variation of ordinary kriging and regression kriging interpolation is not strong.***

Keywords: Spatial distribution, plant species richness, Multidimensional gradients, Regression kriging prediction and Ordinary kriging prediction

1. Introduction

Spatial distribution is the variations in distribution related to position in space and alsothe property possessed by an array of things that have space between them. One approach to describing the spatial patterns of plant diversity in landscape mosaics consists of accounting for the diversity within and between particular habitats that could be considered homogeneous communities, as α and β diversity (i.e., within and between communities). The number of different species in species richness varies enormously from one place to another. Gradients of species richness are obvious and well documented on several spatial scales.Species richness is the number of different species represented in a set or collection of individuals.Estimating species richness (i.e., the actual number of species present in a given area) is a basic objective of many field studies carried out in community ecology and is also of crucial concern when dealing with the conservation and management of biodiversity. Species richness or the number of species is currently the most widely used diversity measure. Relative species abundance in a community is another factor that affects diversity (Stirling and Wilsey, 2001).

Diversity is a commitment to recognizing and appreciating the variety of characteristics that make individuals unique in an atmosphere that promotes and celebrates individual and collective achievement. Diversity relates to the variety and variability of individuals on the earth and is measured for three reasons- to measure stability to determine if an environment is degrading, to compare two or more environments, and to eliminate the need for extensive lists.Spatial heterogeneity can drive species richness at different spatial scales. Spatial pattern (distribution of individuals in space) is an important characteristic of populations. The importance of spatial processes for dynamics of populations and communities of sedentary organisms was emphasized many times. The growth of individuals under strong competition stress is suppressed first and then these individuals die in the under canopy position. Comparing the patterns of canopy (dominant) and under canopy (suppressed) individuals, the canopy ones are usually spaced more evenly. Species richness as a measure of diversity means number of species or indices weighted by abundance distribution of species implying of it no standardization of sampling.The distribution of plant species richness is of importance parameter to know about the diversity of any natural area. In most of the tropical forest country trees are remaining as both natural and planted in national park. A key issue in ecology is how patterns of species diversity differ by various areas. As the main objective of national park is to conserve the biodiversity or species richness, spatial pattern helps us to know how trees, herbs and shrubs are associated along with different topographic variation.

Objectives

The objectives of the study are-

1) Mapping the spatial patternof species richness using ordinary and regression krigging;
2) Compare which method explains better variation in spatial pattern of species richness.

2. Literature Review

As the American Heritage Dictionary of the English Language (2000), Distribution means the act of dispersing or the condition of being dispersed. The specific location or arrangement of continuing or successive objects or events in space or time is called distribution. Distribution can be measured in various ways as frequency distribution, which describes the distribution of measurements on a scale for a specific population; normal distribution, which describes a symmetrical distribution of scores with the majority concentrated around the mean; probability distribution, which describes the function that assigns to each measurable event in a sample group the probability that the event will occur. It may also define as the spatial or temporal array of objects or events. The property possessed by an array of things that have space between them is said as spatial distribution.

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One approach to describing the spatial patterns of plant diversity in landscape mosaics consists of accounting for the diversity within and between particular habitats that could be considered homogeneous communities, as α and β diversity (i.e., within and between communities).

A spatial distribution is the arrangement of a phenomenon across the Earth's surface and a graphical display of such an arrangement is an important tool in geographical and environmental statistics. A graphical display of a spatial distribution may summarize raw data directly or may reflect the outcome of more sophisticated data analysis. Many different aspects of a phenomenon can be shown in a single graphical display by using a suitable choice of different colors to represent differences. Three types of spatial distribution are usually considered. They are-

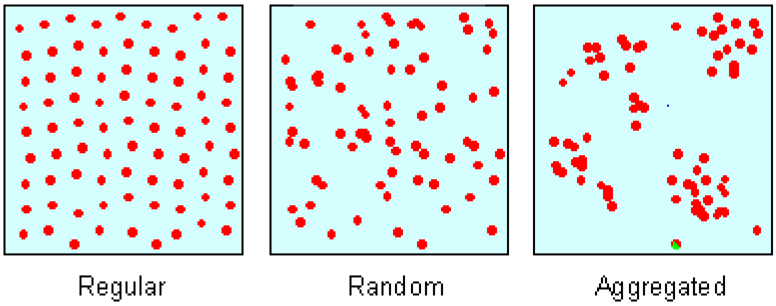

Figure 1: Different patterns of species richness Source: Wikipedia, 2012

The importance of spatial patternlies in two reasons. One is that it is an outcome of theinteractions of biological and ecological processes where spatialpattern combined with other aspects of data are veryuseful to infer mechanisms generating the pattern (Heand Duncan 2000). Tree distribution pattern is a useful testimony of this mechanism (Hubbell 1980).Spatial distribution of species is essential for understanding and modelling biodiversity patterns over space (L. Li *et al* 2009).

According to Gould W et al. 2000 diversity estimation and mapping techniques generally take advantage of the relationship between species richness and habitat diversity, wherein species richness increases as environmental heterogeneity increases at a variety of scales.Diversity is a commitment to recognizing and appreciating the variety of characteristics that make individuals unique in an atmosphere that promotes and celebrates individual and collective achievement along with different kinds or types- ***Species diversity*** is the effective number of different species that are represented in a collection of individuals (a dataset). The effective number of species refers to the number of equally-abundant species needed to obtain the same mean proportional species abundance as that observed in the dataset of interest (where all species may not be equally abundant). Species diversity consists of two components, species and species evenness. Species richness is a simple count of species, whereas species evenness quantifies how equal the abundances of the species are.

Species richness is the number of different species represented in a set or collection of individuals and it doesn't take into account the abundances of the species or their relative abundance distributions. Species richness (usually notated S) of a dataset is the number of different species in the corresponding species list which is renowned as a simple measure that has been a popular diversity index in ecology in where abundance data are often not available for the datasets of interest due to not take the abundances of the types into account, not the same thing as diversity.Diversity indices provide important information about the composition of a community. These indices not only measure species richness, but also take into account the relative abundance of species, or evenness. In addition, indices provide important information about species rarity and commonness in a population. These are important and common tools used by biologists in order to understand community structure (Wikipedia 2012).

The impact of forest edges on plant species richness is poorly understood. In a sugar maple (*Acer saccharum*) stand in Southern Québec, variations in species richness and spatial pattern were observed as a function of distance to the edge and were associated with different environmental variables (Marchand P and Houle G*et al* 2006).The decline of an oak forest stand is analyzed in terms of species richness in KwiatkowskaAJ *et al* 1994. In this work different phenomenon occurs as species diversity decreased; spatial homogeneity of the patch increased; the number of species per unit area markedly decreased etc.J. Julio Camarero, Emilia Gutiérrez and Marie-Josée Fortin have been found in their paper that, plant richness increased above the forest limit and was negatively related to tree cover in the undisturbed sites. The mean size of richness patches in one of these sites was 10–15 m in Global Ecology and Biogeography 2006.

Estimating species richness (i.e., the actual number of species present in a given area) is a basic objective of many field studies carried out in community ecology and is also of crucial concern when dealing with the conservation and management of biodiversity. Spatial heterogeneity can drive species richness at different spatial scales.

Biodiversity has recently emerged as an issue of both scientific and political concern primarily becauseof an increase in extinction rates caused by human activities. Several very large experiments (Tilman and Downing 1994; Tilman 1996; Naeem 1994, 1995; Kareiva 1994, 1996) have addressed the relationship between biodiversity, measured as species richness and ecosystem function. However, they have failed to reveal a clear causal effect (Huston 1997). After a revision of some of the problems and hidden treatments in these experiments,Huston (1997) concluded that they do not provide evidence that increasing biodiversity improves ecosystemfunction and that "both

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local species diversity and the rate of ecosystem processes such as productivity yare determined by the amount and variability of the fundamental environmental resources that regulate plantgrowth and ecosystem processes". Species richness patterns in relation to the environment need to be understoodbefore drawing conclusions on the effect of biodiversity in ecosystem processes.

In general, plant community ecologists are concernedwith patterns of species response to environmental gradients (e.gWisheuandKeddy 1989; Moore and Keddy 1989) and tend to adopt (if only implicitly) a continuum approach to vegetation with its assumption of continuous change in composition with position in the multi-dimensional environmentalspace (Austin, 1999). Huston (1994) reviewed species richness extensively, and regardedpatterns of species richness as being determined by the interaction of disturbance with environmental gradients andcompetitive exclusion.

3. Patterns of Plant Species Richness

1) Nutrients

Studies have found relationships between changes in species richness and a gradient of nutrient availability. The typical response observed has been a 'humped-back curve' (Grime 1979; Tilman 1982): species richness is low at low nutrient levels, increases to a peak at intermediate levels and declines more gradually at high nutrient levels. This pattern has been observed in a number of studies. The humped pattern has been interpreted in different ways by different researchers. According Grime *et al* 1979, few species are able to tolerate extreme conditions of nutrient deficiency. As resources increase, more species can survive and hence species richness rises. At higher nutrient levels, a few highly competitive species become dominant, suppressing other species. This competitive exclusion causes a decline in species richness (Pausas, J G and Austin, M P 2001).

2) Water

Different variables have been used as a surrogate for water availability (e.g., rainfall, topography, evapotranspiration, soil drainage index). As a resource, water, if appropriately measured, could generate a similar hump shaped curve to that proposed for nutrients. Richardson and Lum*et al* 1980 found a positive logarithmic relationship between Californian plant-species richness and rainfall, the environmental variable that accounted for the greatest variance in species richness in their study. Knight *et al* 1982 and O'Brien *et al* 1993, found a positive correlation between mean annual rainfall and woody species richness in southern Africa. Gentry *et al* 1988 found an increase in Neotropical plant species richness with precipitation up to about 4000 mm where species richness reaches an asymptote; however, he also noted that there were differences that could be explained by seasonality of rainfall and soil nutrients.

The main purpose of studying the spatial distribution of plant species richness is to identify the important theme particularly in tropical forest, because high diversity in the tropics begets low densities (Condit *etal*2000). The distribution of plant species richness is of importance parameter to know about the diversity of any natural area. Trees are remaining as both natural and planted in national park in most of the tropical forest country. A key issue in ecology is how patterns of species diversity in one area differ as from other area. According toMittelbach, Gray G*et al* (2001) understanding the relationship between species richness and productivity is fundamental to the management and preservation of biodiversity.

The main objective of national park is to conserve the biodiversity or species richness.Spatial pattern helps us to know how trees, herbs and shrubs are associated along with different topographic variation (Pausas, J G and Austin, M P 2001).

3) Light

Currie, DJ*et al* 1991havesuggested that the capacity of the environment tosupport species is determined by the availability ofenergy. Knight *et al*. 1982 and Austin *et al (*1996) found a negative relationship between tree speciesrichness and annual incoming solar radiation in southern Africa and south-eastern Australia, respectively. However, in the Knight *et al*(1982)study, the radiation is also negatively correlated with rainfall, and the decrease in richness could be explained by the decrease in rainfall.

4) Temperature

RichersonandLum (1980) found that plant speciesrichness in California shows a negative response alonga temperature gradient. Knight *et al* (1982) found apositive linear relationship between South Africa tree species diversity and temperature. Austin *et al* (1996) showed an increased disposition in the richness of treespecies, *Eucalyptus* species, and rainforest species withincreasing temperature. However, they also showed, the pattern of increase depends on other environmentalvariables such as rainfall. Both Austin *et al* (1996) and Leathwick*et al* (1998) found that temperaturewas the environmental predictor that explainedthe most variance in total tree species,rainforest species (Austin *et al* 1996), conifer species(Leathwick*et al*, 1998), and eucalypt species (Austin*et al*, 1996). The relative importance of the differentenvironmental gradients and their interaction in determiningthe species richness of different growthforms needs to be examined further.

5) Disturbance

Disturbance, resource and direct environmental gradients constitute three types of gradients that determineplant growth and survival. The intermediatedisturbance hypothesis suggests that species richness reaches a maximum atsome 'intermediate' level of disturbance.

According to Pausas, J G and Austin, M P*et al* 2001, a major goal of biology is to understand the diversity of life, and how and why the number of species varies among regions, habitats, and taxonomic groups. Understanding patterns of species richnesshas taken on new urgency, as human activities may soon lead to the extinction of the majority of extant species (Dirzo and Raven 2003) even as the majority of extant species have seemingly yet to be described (Wilson 1992).Dozens of hypotheses have been proposed to explain patterns of species richness, especially variation between

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habitats and large-scaleregions (e.g., the latitudinal diversity gradient; Willing et al, 2003; Mittelbach et al, 2007). However, ultimately only a limited number of processes can directly change the number of species in a given group or region. In fact, there are only three. Species richness patterns are ultimately caused by speciation, extinction, and dispersal. Speciation creates new species and increases species richness. Extinction eliminates species (either locally or globally) and decreases species richness. Dispersal influences spatial patterns, and can add species to a given location, habitat, or region without speciation (but all species must arise through speciation ultimately).

6) Multidimensional Gradients

In many of the studies only single environmental gradients have been considered where multiple regressiontechniques have been used- only linear additive models with no interaction terms have been fitted. To draw a strong ecological conclusion it is essential to consider testing linear regressions and non-linear relationships in ecology. Few studies (Austin et *a*l. 1996) have considered how species richness varies in an environmental space defined by morethan one axis of environmental variation and tested for different possible response shapes.Understanding patterns of species richness has taken on new urgency, as human activitiesmay soon lead to the extinction of the majority of extant species even as the majority of extant species have seemingly yet to be described (John, JW *et al* 2011).

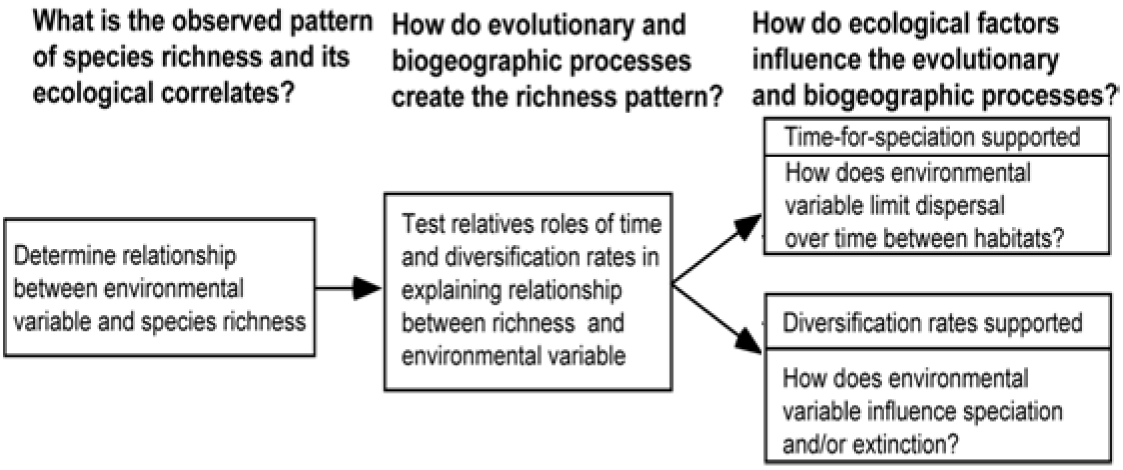

Figure 2: A General Framework for Understanding Spatial Patterns in Species Richness Source: John, JW*etal.* 2011

A critical point is that showing that species richness correlates with ecological variables does not mean that any evolutionary factors are not involved. Even if there is a perfect relationship between ecological variables and richness, this climate-diversity relationship must still be explained by the influence of the ecological variable on speciation, extinction, and/or dispersal (e.g., Wiens and Donoghue 2004).A relationship between time and richness can be tested by calibratedphylogeny for any group and data on the distribution of each species in the group along the gradient which make possible to reconstruct approximately howlong the group has been present at different parts of the gradient, by mapping the distribution of the environmental variable on the phylogeny. The time-for-speciation hypothesis predicts a strong correlation betweenthe approximate amount of time that the group has been presented in each major segment of the gradient (e.g., dividing the gradient into bins of equal size) and the number of species in each major segment of the environmental gradient (typically after log transforming the number of species) (John, JW 2011**).**

A relationship between the environmental variable and diversification rates can betested in two general ways according to John, JW (2011). *First,* if all or most of the relevant species are included in a time-calibrated phylogeny, the relationship between the environmental variables and diversification rate can be tested directly using various methods, including new methods that can incorporate continuous variables (e.g., Freckleton et al. 2008; Fitz John 2010).*Second*, if only some species are included in the phylogeny, but the species richness of subscaleswithin the groups are known (e.g., if a genus is known to have 10 species but only three are included in the tree), it is possible to estimate the diversification rate for these sub groups (clades) (Magallo´n and Sanderson 2001; Ricklefs 2007).

4. Methodology

Location

The study was conducted at Satchari National park (SNP), situated in Habiganj District, Bangladesh, was established in 2005 to preserve the remaining natural hill forest patch of Raghunandan Hill Reserve Forest (an area of 243 hectares). However, the total area of Satchari wildlife range is about 1,760 hectares (IPAC2009). The park is divided into two administrative sectors known as forest beats, namely Satchari Forest Beat and Telmachara Forest Beat. Satchari National Park stands on the old Dhaka-Sylhet Highway and is about 130-140 kilometers north-east of Dhaka, between Teliapara and Srimongal.Literally 'Satchari' in Bengali means 'Seven Streams' and there are seven streams flowing in this jungleand it is known to the mass people as the name of 'Satchari'.The park is situated in Raghunandan hill, under Paikpara Union, ChunarughatUpazilla, Habiganj District, under Sylhetdivision region. It is 130 kilometers (81 miles) far from the capital city of Bangladesh, Dhaka.

Topography and soil

The topography of the park shows undulating with slopes and hillocks, locally called *tila*, ranging from10-50 m height and running from south to north and these are composed of

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upper tertiary rocks inwhich sand stones are largely predominant (Rizvi, 1970). The soils of the park area arecharacteristically sandy loams and accumulation of humus on the top soil is very low due to rapiddecomposition of debris under moist warm tropical condition (Rizvi, 1970). Soils are more acidicthan in adjoining ecological zones (Mukul*et al.*, 2006).

Climate

The area enjoys a moist tropical climate characterized by a period of high precipitation from May to October and six months between November and April are relatively dry. The water condensation is distributed throughout the year in different forms and greatly influences plants and wildlife. The area covered under the park is one of the wettest in the country and so the rainfall is quite high with an annual average of 4,000 mm approximately, with maximum rainfall falling during June to September from South-West monsoon (NSP, 2006).

Vegetation

The vegetation of the park area comprises a patch of 120 hector of natural forest and remaining area covered by a short rotation plantation of *Eucalyptus* sp. and *Acacia* sp. and as well as long term plantation of oil palms. There are approximately above 200 trees are in Satchari National Park as such the most common species of trees are-Shal (*Shorearobusta*), Segun (*Tectonagrandis*), Agar, *Garjan*, *Chapalish*, Palm, Mehgani, Krishnachur, Dumur (*Ficus*), Jamrul, ShidhaJarul, Awal, Malekas, Eucalyptus, Akashmoni, Bamboo trees, Bet trees (regional name *Mutra*).

Wildlife

Wildlife as such-Red Jungle fowl, Red-headed Trogon, Oriental Pied Hornbill, and Pygmy Woodpecker in the park is rich. Critically endangered Hoolock Gibbon, Phayre's Leaf Monkey,Langur also resides here.

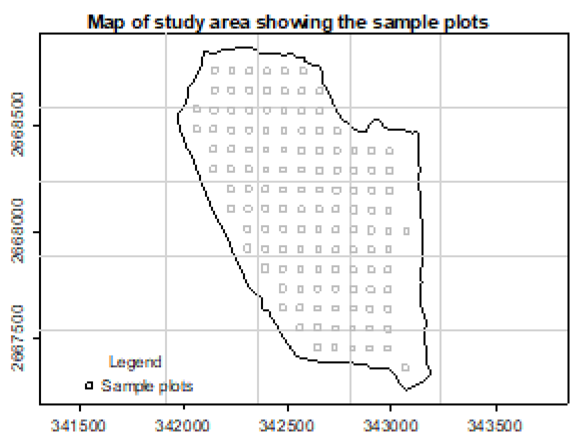

Figure 3: Map of Satchari National Park

Method

As there tends to be a correlation between the number ofspecies and many other biodiversity measures (Gaston, 1996), an accurate description of the geographical distribution ofspecies richness is critical for biologists (Miller, 1994) andcan aid in the elaboration of precise conservation strategies (Margulesand Usher, 1981; Haila and Kouki, 1994). Unfortunately, even in countries with a tradition of naturalist studies, taxonomic knowledge is not uniform across regions, and the pattern of species richness is influenced frequently bysampling effort (Prendergast *et al.*, 1993; Gaston, 1996).The study process divided into two parts- data collection and analysis.The overall study method is briefly discussed below-

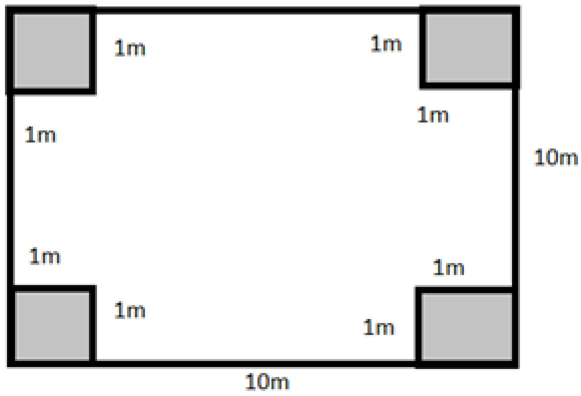

Figure 4: Sampling Design

Total 100 plots were inventoried (the size of 10m×10m for sampling tree and shrub and 1m×1m for herb within the 100m^{2}plot areas whereas each 100m^2 plots counts the number of different species along with trees, herbs and shrubs etc) for random sampling.A practical problem that arises during measuring species richness and species diversity is determining that when should have done sufficient collecting to stop sampling, or in other words, to know when should have gotten just about all the species that matter. A good technique is to generate a cumulative species/sample (or cumulative species/area)curve, which plots the cumulative number of species collected (y-axis) vs. the number of samples collected (x-axis). This technique assumes the initially collecting new species with each subsequent sample.

Data Analysis

In this study statistical data analysis tool R, version 2.15.2 (2012-10-26) (R Core Team, 2012) have been used that is an integrated suite of software facilitates data manipulation, calculation and graphical display.

5. Results and Discussion

5.1 Plant species accumulation curve

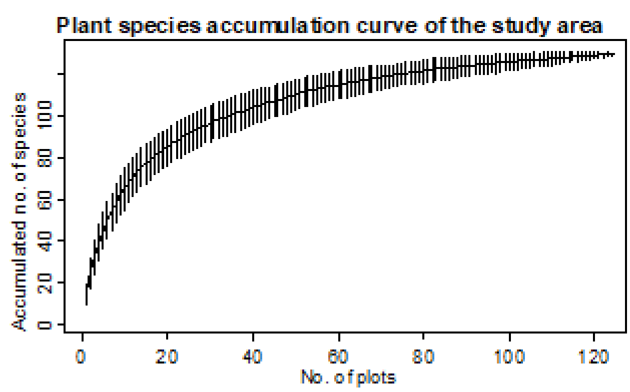

Figure 5: Species accumulation curve

Species accumulation curve assesses the adequecy of sampling in diversity study. In the figure 5 it is noticed that

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the number of new species increases upto 100 plots. If it is accept more plots it not found as new form with more new species. To be more confirmation about the adequecy of sampling it will have taken 125 plots on the basis of which have interpolated the species richness of the study area.

4.2 Interpolation grid and sample plots

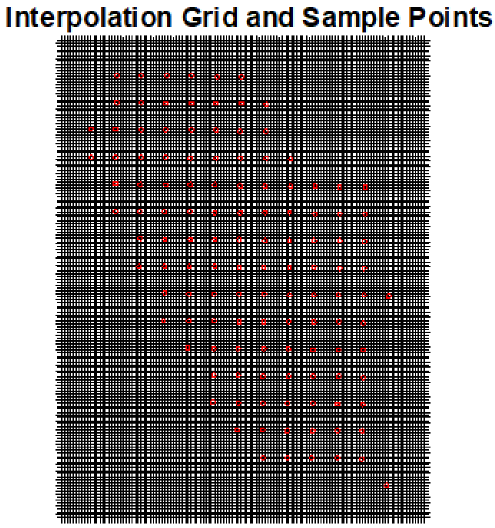

Figure 6: Interpolation gri**d and sample plots**of the study area

Data from total 125 plots of 10m×10m shows in each cells of a grid map. The basis of the individual sampling areas covers 100 m^2areas. This interpolation shows the predicted value ofeach sampling points.Kriging is a family of estimators used to interpolate spatial data.

Ordinary kriging

Ordinary Kriging is a spatial estimation method where the error variance is minimized and this error variance is called the kriging variance, is based on the configuration of the data and on the variogram, hence is homoescedastic (Yamamoto, 2005). It is not dependent on the data used to make the estimate. Recently, Yamamoto derived an error variance for ordinary kriging that is conditional to the data values. He referred to this variance as the ordinary interpolation variance. Yamamoto*et al.* 2005 has shown that the ordinary interpolation variance is a better measure of accuracy of the kriging estimate.

4.3 Variogram of species richness

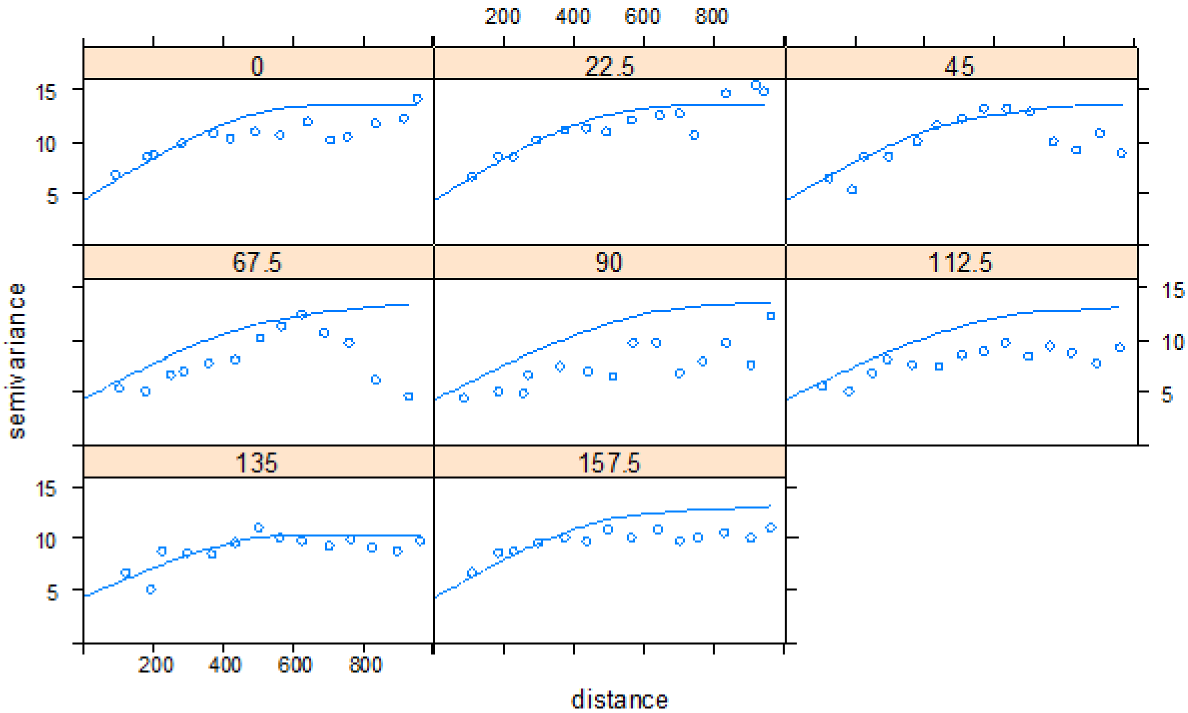

Figure 7: Variogram model of species richness

Variogram (Fig 7)shows that major axis is 67.5^{0}and minor is 157.5^0 with a range of about 650m and 387m respectively.For modeling geometric anisotrophy we have fitted the variogram in the major axis. To fit the variogram model we have tried three kinds of variogram, namely spherical, exponential and gaussian. The crossvariogram shows that the spherical model is the best fit one with mean z-score near zero (0.000416) and variance of z-score is near one (1.077). The sill of the variogram in different direction varies. So, we will have to fit a zonal anisotropic variogram with spherical model. Variogram shows that 45^{0}have the highest sill and 135^0 should have the lowest sill. We will fit the zonal variogram to the 135^0 direction with an anisotropic ratio of 500/(1200*10000).

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4.4 Ordinary kriging interpolated plant species richness

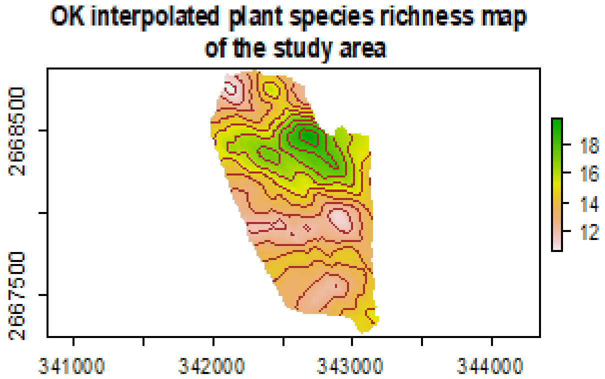

Figure 8: Ordinary Kriging interpolated plant species richness map

Ordinary kriging interpolation shows the spatial locations along with latitude and longitude. The results shows that at north zone colored bydark greenand in that area total 18 species are foundwhich indicates higher species richness. The other portion as the light brown colors shows the number of species richness is 12 which are low. The result gives a view that species richness is higher at the north zone than other parts of the study area.

4.5 Variance of ordinary kriging interpolated plant speciec richness of the study area

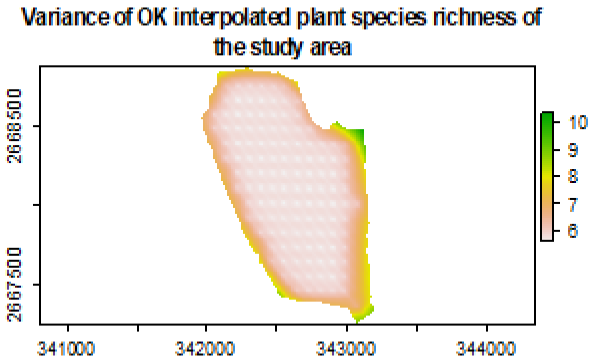

Figure 9: Variance of ordinary kriging interpolated plant species richness

The result shows in fig (9) the variance of samplepoints from meanvalue. The lowest value of variance as 6 indicates that it varies as low from its mean value which indicates by the white dot points , where the sample plots were taken.At the corner north zone where sample plots were not taken variance is 10 as showing highvariability from the mean value.

Kriging

In this study regression kriging is conducted considering species richness as dependent and elevation as independent variable. To do so we have first interpolated the elevation of the whole study area using ordinary kriging method.

Ordinary kriging of independent variable: Elevation

4.6 The distribution of normal Q-Q plot of elevation

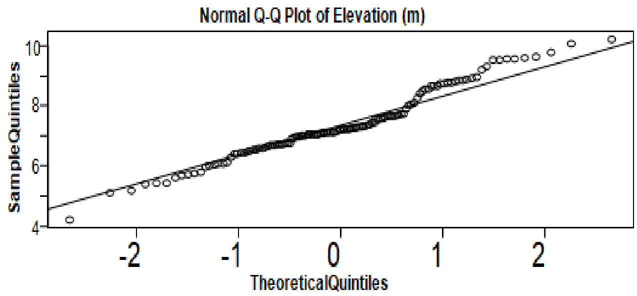

Figure 10: The normal Q-Q plot of elevation (Predicted)

The normal Q-Q plot is a probability plot which is a graphical method for comparing two probability distributions by plotting their quintilesagainst each other.The result shows in figure (10)that the normal Q-Q plot follows stronglylinear pattern. All data distributed around the linear line. As they are not much scattered around the line and shows the linearity. So result indicates that data of elevation isnormally distributed.

4.7 Variogram of elevation

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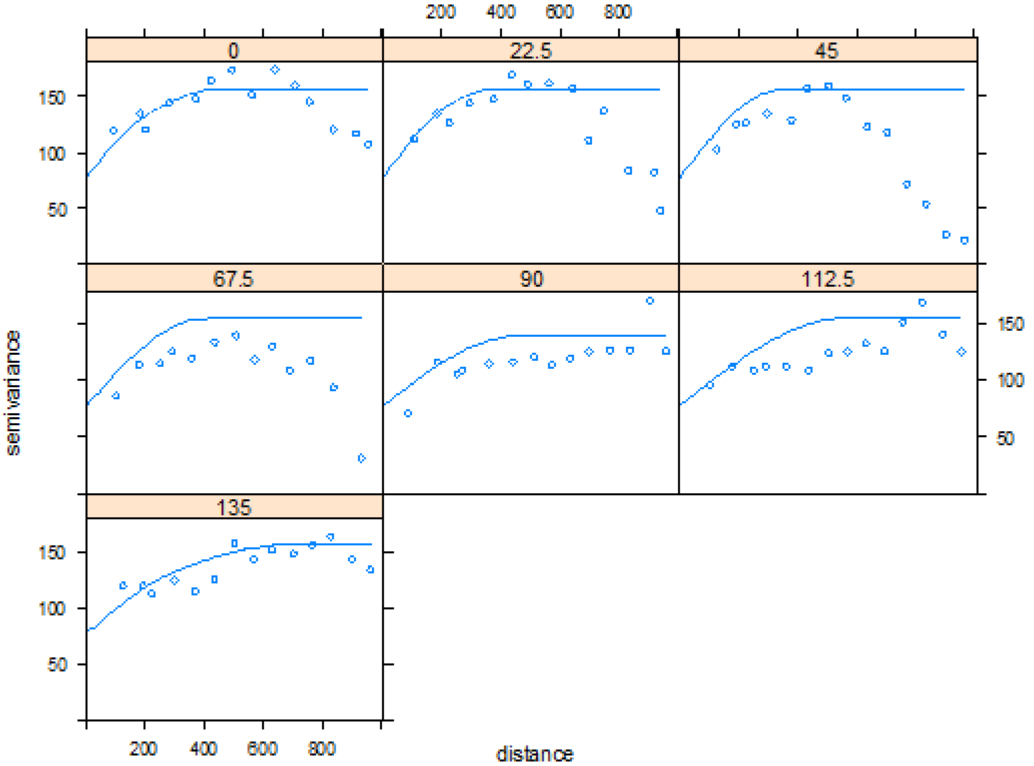

Figure 11: Variogram model of elevation

Variogram (Fig 11)shows that major axis is 45^{0}and minor is 112.5^0 with a range of about 500m and 400m respectively.For modeling geometric anisotrophy we have fitted the variogram in the major axis. To fit the variogram model have tried three kinds of variogram, namely spherical, exponential and gaussian. The crossvariogram shows that the spherical model is the best fit one with mean z-score near zero (9.512325e-05or 0.0000951) and variance of z-score is near one (1.094643). The sill of the variogram in different direction varies. So, we will have to fit a zonal anisotropic variogram with spherical model. Variogram shows that 22.5^{0}have the highest sill and 112.5^{0}should have the lowest sill. We will fit the zonal variogram to the 112.5^0 direction with an anisotropic ratio of 293/ (1600*10000).

4.8 Interpolated three dimensional elevation map

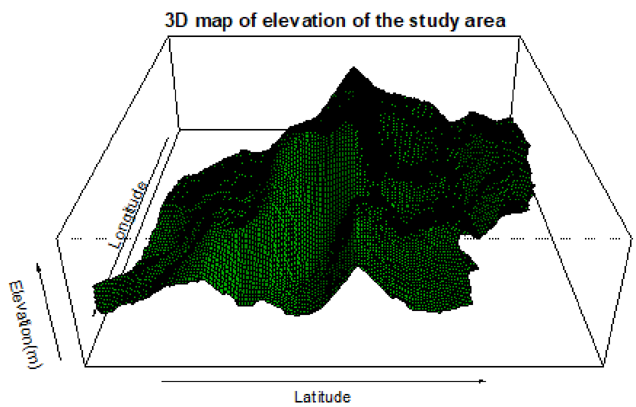

Fig 12: Interpolated three dimensional elevation map

The interpolation three dimensional elevation map in figure12 shows elevation increases from south to north direction. The dark black portion of the map in different places shows that magnitude is not same at those places.Elevation (m) is higher at the north part of the map.

4.9 Interpolated two dimensional elevation map

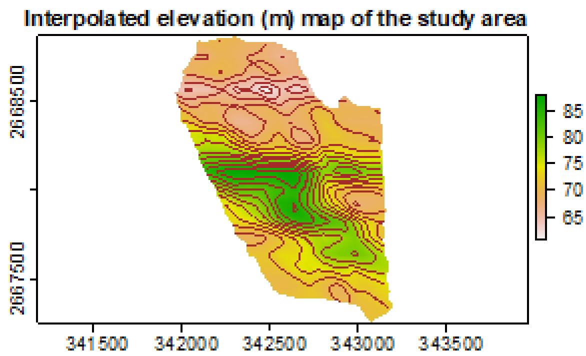

Figure 13: Interpolated two dimensional elevation map

The two dimensional elevation maps of figure (13) shows that at center at the map have higher elevation which is indicated by dark green portion of 85m. The light pink part of the map shows that elevation is lower with65m. The light yellow portion has the elevation of 75m.

4.10 Regression kriging interpolated plant species richness map of the study area

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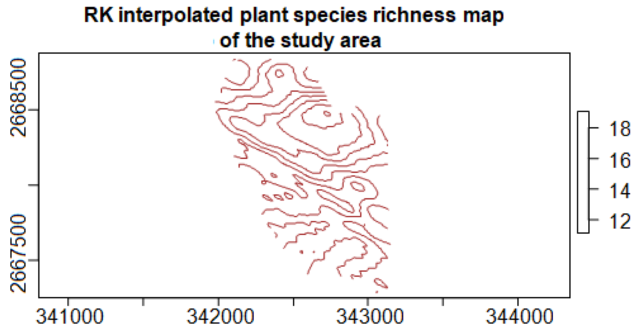
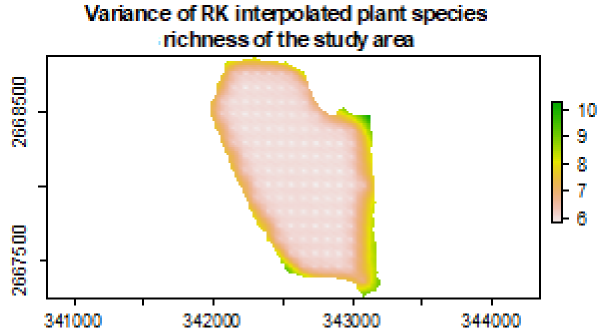


Figure 14: Regression kriging interpolated plant species richness map



Figuree 15: Variance of regression kriging plant species richness

The map shows in figure (14), that in northern parts species richness is higher indicates by dark green portion. In that portion the number of species are 18. The other parts of the map which are lighter color shows that the species richness is not much high. The number of species are 12 in that area.

4.11 Variance of regression kriging interpolated plant species richness

The variance of regression kriging plant species richness shows in figure 15 that,the sample points are showing low variability as 6 from their mean value. The low variance colored by light white dots points. At the corner zone of north variance is higher as indicate by 10. The dark green portion at the north corner and other site shows greater variance as they are more dispersed from their average.

4.12 Comparison of regression kriging prediction and ordinary kriging prediction maps

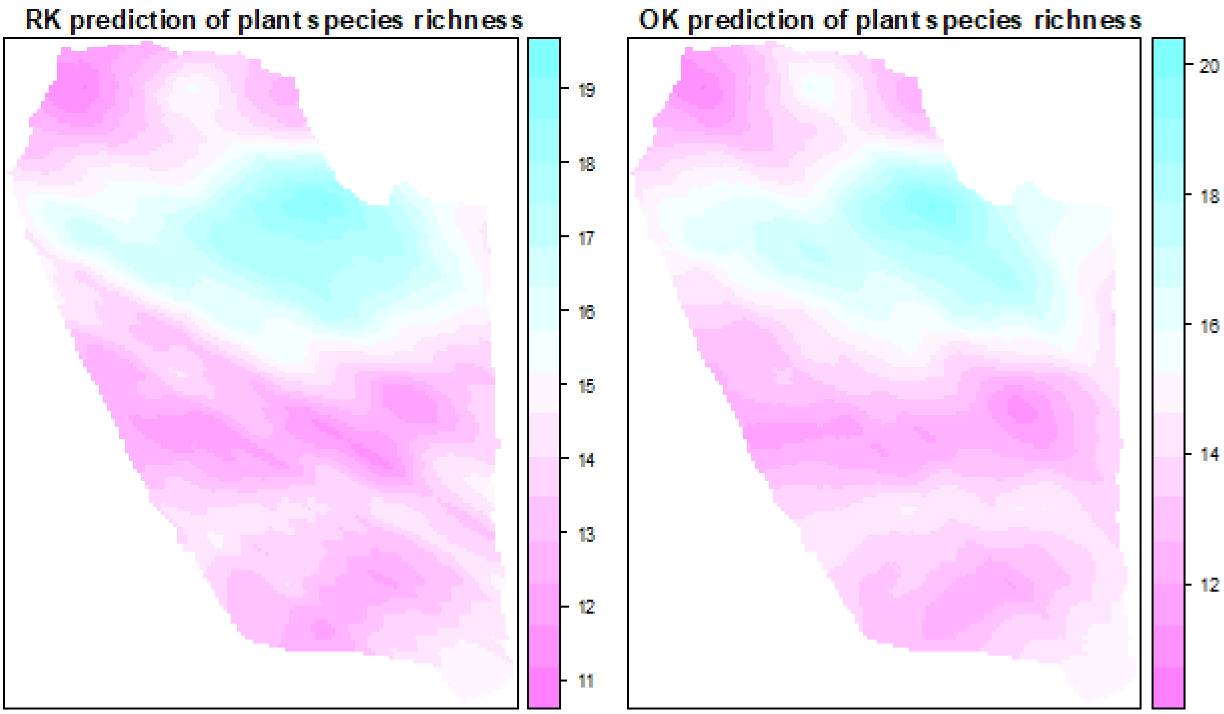


Figure 16: Comparison of regression kriging prediction and ordinary kriging prediction

Amount of variation explained by the models: The regression kriging and ordinary kriging prediction of plant species richness map are very slightly differ. The apparent visually difference is very lower.

4.13 Difference between regression kriging and ordinary kriging

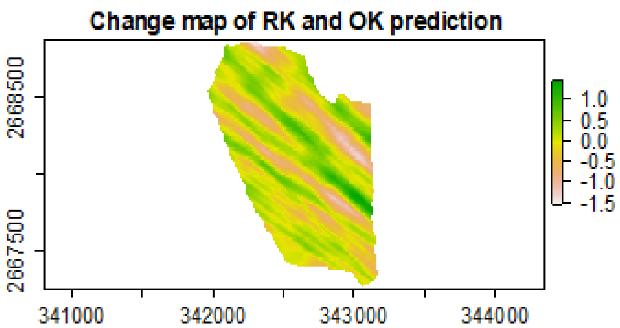


Figure 17: Change map of regression kriging and ordinary kriging prediction

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The result shows in figure 17 that the dark green portion directed towards north-east portion along as a line. This lines indicates species richness is higher.Here the variance between the ordinary kriging and regression kriging is 1 i.e. as the elevation is used as a very weak predictor and for that prediction is low there. The most of the area of the map shows the dark green directed line along with the direction of north to west as bending.

The light brown colour lined portion of the map shows that along side of the green line portion the variance is high at that portion between the ordinary kriging and regression kriging i.e. -1.5. The dark green lined apparent portion shows the positive values whereas ordinary kriging value is less than that of regression value.The light brown color portion shows negative values, as ordinary kriging value is greater than regression value. In 0.0 there is no difference between the ordinary kriging and regression kriging. The change map shows that the prediction value of ordinary kriging is 29.45 per cent and regression kriging is 25.78 per cent. So from the overall discussion it isnoated that in dark green site regression kriging is greater than that of ordinary kriging in lighter site.

6. Discussion

Spatial pattern of species richness varies with the spatial location.Huston *et al*1994reviewed species richness extensively, and regardedpatterns of species richness as being determined by the interaction of disturbance with environmental gradients and competitive exclusion.Mapping out spatial pattern of species richness in ordinary kriging minimizes the error variance. Variogram quantifies the spatial continuity of richness which shows model fitted with spherical major axis of 67.5^0. Predicted ordinary kriging interpolation of species richness shows in northern part of the study area species richness are comparatively higher and variance of sample points are not show high as it is respectively lower.In general, plant community ecologists are concerned with patterns of species response to environmental gradients (e.gWisheuandKeddy 1989; Moore and Keddy 1989) and tend to adopt (if only implicitly) a continuum approach to vegetation with its assumption of continuous change in composition with position in the multi-dimensional environmentalspace (Austin, 1999). In this study independent variable elevation (m) is used to find out position of elevation in study area. The three dimensional map as predicted and two dimensional map of elevation result that it is high at the centre of the area where spices richness high. Variogramquantifies the spatial continuity of richness which shows model fitted with spherical major axis of 45^0. Predicted regression kriging interpolation of species richness shows in northern part of the study area species richness is comparatively higher and variance of each sampling point is lower.

7. Conclusion

Spatial pattern of species richness vary with location or space.The spatial correlation structure of the data that shows in the north zones in SNP where the species richness is higher. In regression krigingelevation (m) is used as a weak predictor and the interpolation finds that species richness is higher in northern partand they vary a little amount from their mean. The change map explains towards north-east directional portion species richness is higher as by dark green line. They changes very slightly amount with other parts. The amount of variation by percentages in ordinary kriging is 29.45 per centand in regression kriging is 25.78 per cent.If new other properties were added as independent variables in regression kriging interpolation, the prediction variance would be higher and the amount of variation from mean wouldalso behigher than from present study.

8. Acknowledgement

I would like to acknowledge my undergraduate supervisor Md Abdul Halim, Assistant Professor, Dept. of Forestry and Environmental Science, Shahjalal University of Science and Technology, Sylhet-3114, Bangladesh for his consistent support during this work, without which this work would have been difficult to accomplish.

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