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Patterns of variations in earthworm density in multivariate landscape of Camiguin Island, Philippines

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Abstract: The purpose of the study was to explore large scale patterns of variations in earthworm density along the elevation gradient in the island of Camiguin, Philippines. A total of 360 observations were gathered from 30 samples collected from high elevation, middle and low elevation using twelve environmental variables. These observations were subjected to multivariate statistical technique, primarily the Principal Component Analysis and MANOVA and Kriging to explore which factors affect earthworm density and the significant segregation of samples. Results revealed that elevation contributed large variation in earthworm density (80.45%) followed by potassium (19.44%). These two factors were the new dimensions observed in a large scale study of continuous land.

Key words: Environment; Multivariate landscape; Earthworm; Variation; Principal component analysis

1. Introduction

Earthworms are important in maintaining soil health, fertility and productivity owing to their feeding behavior, burrowing activity and the nutritive cast that it produce. These facts are unequivocal and widespread in literature (Edwards and Fletcher, 1988; Vasanthi and Kumaraswamy, 1999, Arancon et al., 2005; Postma-Blaauw et al., 2006). In a paper presented during the 8th International Symposium on Earthworm Ecology, Monroy et al. (2006) provided evidence on the importance of earthworm in the distribution and increase in diversity of decomposers in terrestrial environment. Lazcano et al. (2006) presented the results of their study emphasizing increase biological activity and enhancement of nutrient cycling and organic matter mineralization. Further, the interactions of earthworms and microorganisms increase plant productivity through the production of Plant Growth Regulators (PGR) coupled with the release of humic acids that act as PGR's (Arancon and Edwards, 2006). These results of studies clearly demonstrate the beneficial effects of earthworms in soil and plant yield, and currently this organism is used as indicator of soil health (Frund et al., 2010). Earthworms occupy space in the landscape; and are present in the farm, forested land, orchard, grass land, river banks, along canals and levees and in garbage areas (Jimenez and Rossi, 2006; Timmerman et al., 2006; Rombke et al., 2009). But since natural landscape displays certain degree of pachiness at all spatial scale (Legendre, 1993), there was then an interest in examining the distribution pattern of the earthworm especially in a continuous field. There was also an interest in exploring the factors influencing such pattern related to soil fertility.

Current literatures show that the distribution of earthworms in a continuous landscape is reported to be in clusters, and much of these reports are based on a small scale studies. Butt et al. (2003) for example used only 1m X 1m grid, Rossi (2003) 10m X 10m grid, Hernandez et al. (2003) used less than 1 ha (8134 sq.m) and Jimenez and Rossi (2006) used 2 ha plot. Among these studies, it appears that different dominant factors are responsible for causing variations in earthworms depending on species; and this has been noted in the review made by Hernandez et al. (2003). Medium scale and large scale studies have not been done so far in earthworms, which may have effect on its density and distribution. Jimenez et al. (2014) recommended that the scale be increase in future studies. Rossi and Halder (2010) found a very strong effect of the spatial scale in the investigation of butterfly biodiversity, and therefore investigation of earthworm density in a larger scale, especially from continuous agricultural land at different altitude and practices may reveal environmental factors associated to it. Finer scale study has so far been having difficulty revealing the association of environmental factors with the distribution and density of earthworms.

In any scale of study, a number of variables have to be measured and variables that vary greatly have to be identified. To accommodate and analyzed these landscape variables altogether, a multivariate technique is identified as the appropriate method. Onweremadu et al. (2007) used the Principal Component Analysis (PCA) – a multivariate tool, to characterize soil using 12 variables and successfully

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identified two variables that contribute large variation in the land. PCA analysis in the current study was complemented with geostatistics to enhance spatial analysis and visualization of earthworm density across the landscape. A specific geostatistical method known as Kriging is commonly used to interpolate data of variables of interest (Jassim and Altaany, 2013). This method utilizes the semivariogram model that is based on spatial autocorrelation of Getis (2010). Spatial autocorrelation captures the variability of the landscape and determined the spatial distribution of organism (Goovaerts, 1997; Rossi et al., 1995), which can be viewed graphically.

The current study explored variation in earthworm density and factors strongly associated to it across a 185 hectare continuous agricultural land. Using non-parametric multivariate technique and kriging method, the study reveals a new dimension strongly affecting the already known factors influencing density of earthworms.

2. Materials and methods

The study site was in Catarman, a portion of Camiguin Island, Philippines. The island is 21 km from the nearest mainland, surrounded by Bohol Sea in the North and West, Butuan Bay in the East and Gingoog Bay and Macajalar Bay in the Southeast and southwest respectively. The site covered an area 1,850,166 sq.m. (185 ha), with elevation gradient from 337.41 m asl down to -4.3 m asl in the coastal area Fig. 1.

Along the slope, three locations were selected: 1) Barangay Itus, characterized as unattended sloping agricultural land with 10% to 15% slope and has an elevation of 257.86 to 337.41 m asl; 2) Barangay Tibakhaw, characterized as agricultural land (7% to 9.6% slope) with elevation of 113.69 to 182 m asl and 3) Barangay Alga, the coastal area with residential housing, relatively flat (1% to 2.4% slope) and having elevation of -4.3 to 56 m asl. These three sampling locations respectively represent the high, middle and low elevation areas.

From each of these locations, ten random samples were collected with distances between samples ranging from 30m to 50 m. Earthworm count and data (moisture and temperature) from each sampling point (a quadrat of 30 cm X 30 cm X 30 cm) were collected; Other on site data were also collected: elevation, coordinates and vegetation type. Representative soil samples were obtained for the analysis of nitrogen, phosphorus, potassium, pH, bulk density and porosity. In each location (high, middle and low elevation), descriptions on landuse and slope were made.

A total of 360 observations from 30 samples collected from the three locations were put in the PAST (Paleontological Statistics) ver.2.03 platform for multivariate statistical analysis. Principal

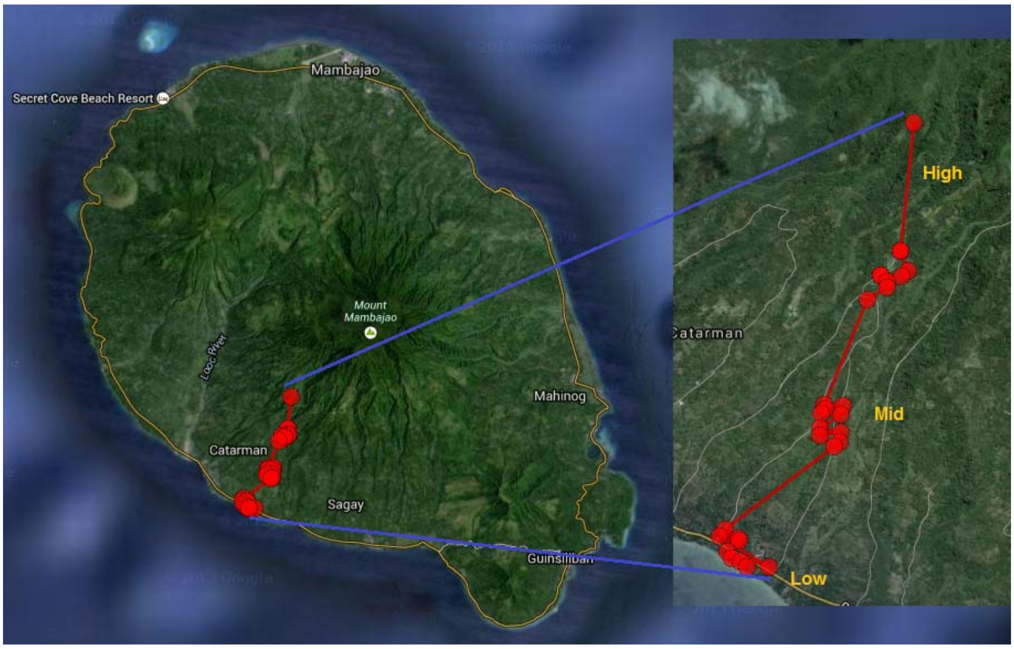

Fig. 1: Satellite image showing sampling points at three locations (High, Middle and Low elevation) in Catarman, Camiguin Island; image generated from GPSVisualizer after loading all coordinates. Total distance from highest point to lowest sampling point is 4.025km

Component Analysis (PCA) was implemented to explore patterns of variations. F test for earthworm density was then implemented using score of Principal Component 1 (PC 1).

The Kriging method was implemented using the North-East coordinates and number of earthworms collected from field to generate an interpolated earthworm population in a 10,000 grids of the 185 hectare.

3. Results

Results revealed that there was a decreasing pattern of earthworm density from high elevation area to low elevation area (coastal area). Such pattern is visualized in Fig. 2 after Kriging operations for the 10,000 grids in 185 hectare land that stretched 4.025 km from the highest sampling point to the lowest sampling point (N 09⁰8'22.6", E 124⁰41'54.8" to N 09⁰06'55.6", E 124⁰41'11.8"). Interpolation of earthworm density data by kriging shows that 29-33 earthworms per cubic feet are confine in a narrow range of 29 m at high elevation.

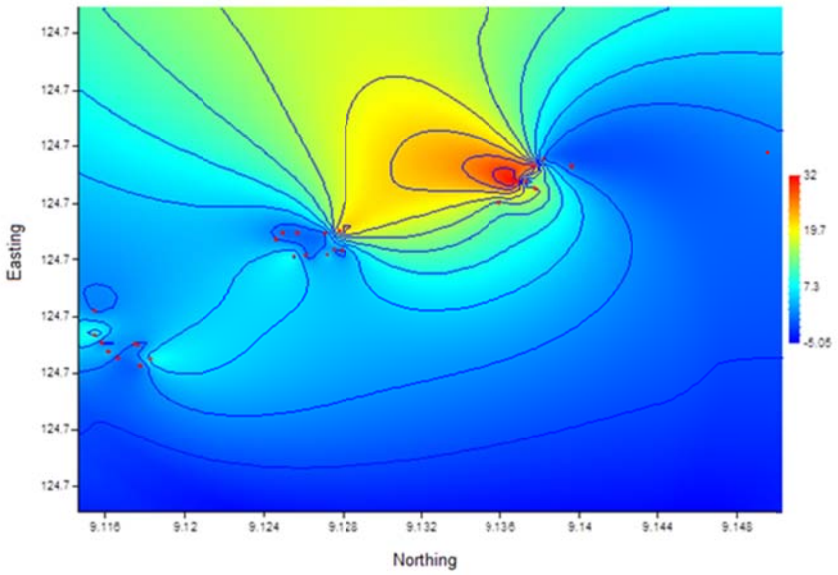

Fig. 2: Earthworm density after Kriging and interpolations of 10,000 grids along north and eastern sections of 185 hectare land in Catarman, Camiguin. The increasing NE coordinates corresponds from low elevation to high elevations areas

These areas (High, Mid and Low elevation) that differ significantly in earthworm density (df=2,27; F=72.71; Pr=0.000) also differ significantly in terms of physico-chemical characteristics after multivariate analysis of variance (MANOVA; df=24,30; F=23.7; Pr=0.000). It also differ significantly in nitrogen levels (df=2,27; F=3.939; Pr=0.033), with the high elevation having large nitrogen content (2,322ppm) than the low elevated area (1,558ppm); but significantly opposite pattern was observed for the phosphorus (df=2,27; F=5.763; Pr=0.009) with the high elevation having low phosphorus content (41,000ppm) than in coastal area (142,755ppm).

Results of Principal Component Analysis (PCA) show that 80.45% of the total variation was contributed by Principal Component 1 (PC 1), and 19.44% was contributed by PC 2. Total variation of 99.9% among samples was attributed to these first two Principal components.

PC 1 and PC 2 correspond to elevation and amount of potassium respectively. In the scatter plot above Fig. 3, the separation of samples along PC 1 axis was due to elevation, and along PC 2 axis was due to potassium. These two variables vary greatly while the rest of the variables have weak contribution to the overall variation; their variance contribution is less than 1 percent.

Although potassium contributes the second largest variation in the 185 ha land, but the pattern of variation did not go along significantly with the elevation. There was so much variation within each of the following sampling area: in the high elevation, mid elevation and low elevation, as depicted in Fig. 4. F test on potassium level on these three sampling areas were not significant (df=2,27; F=0.9835; Pr=0.387).

4. Discussion

There was a decreasing pattern of earthworm density across the continuous 185 ha land, and elevation was the dominant factor revealed to have influenced on this earthworm density after non-parametric multivariate analysis. This factor was not apparent in small scale studies done by Jimenez and Rossi (2006), Rossi (2003), Hernandez (2003), and Araujo and Hernandez (1999). Potassium was another factor that was not observed in previous studies that may also have influence on earthworm density.

Although potassium contributed the second largest variation in PCA, but its concentration among the three sample sites did not differ significantly. The large variation was observed only within each of the sampling site. This pattern is obvious in Fig. 4; the confidence interval of mean was so wide that suggest a highly fragmented landscape in terms of potassium.

The variation contribution by potassium in Principal Component 2 (PC 2) was an overall variation for the entire 185 ha land which include also the within sampling site variation. The contribution of potassium becomes apparent because of the scale that was relatively larger.

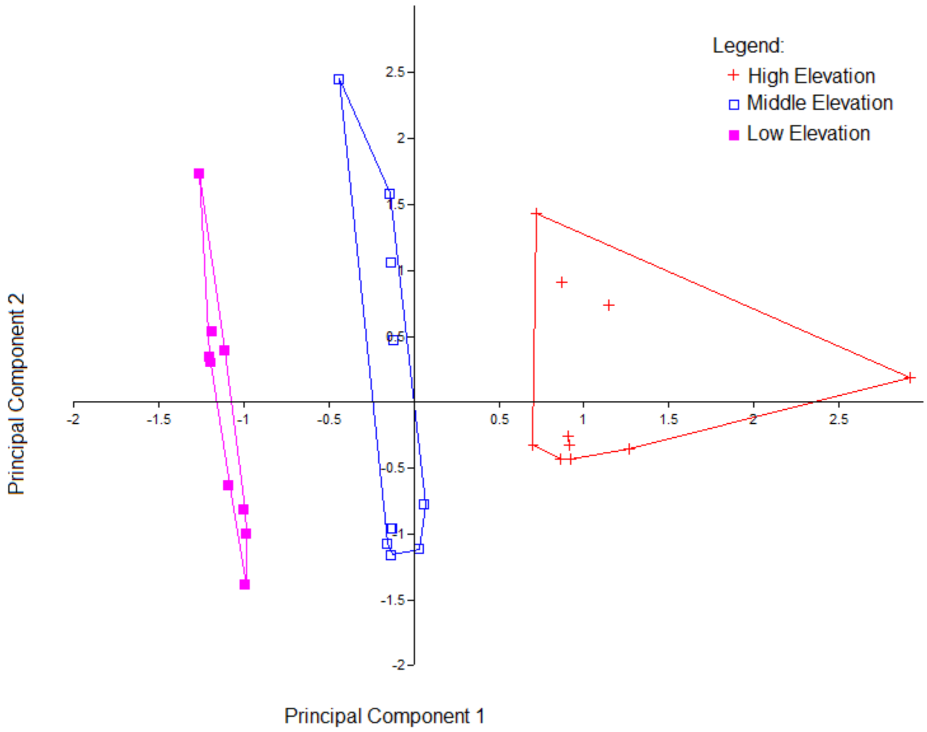

Fig. 3: Result of principal component analysis showing separation of samples along Principal Component 1 (PC1)

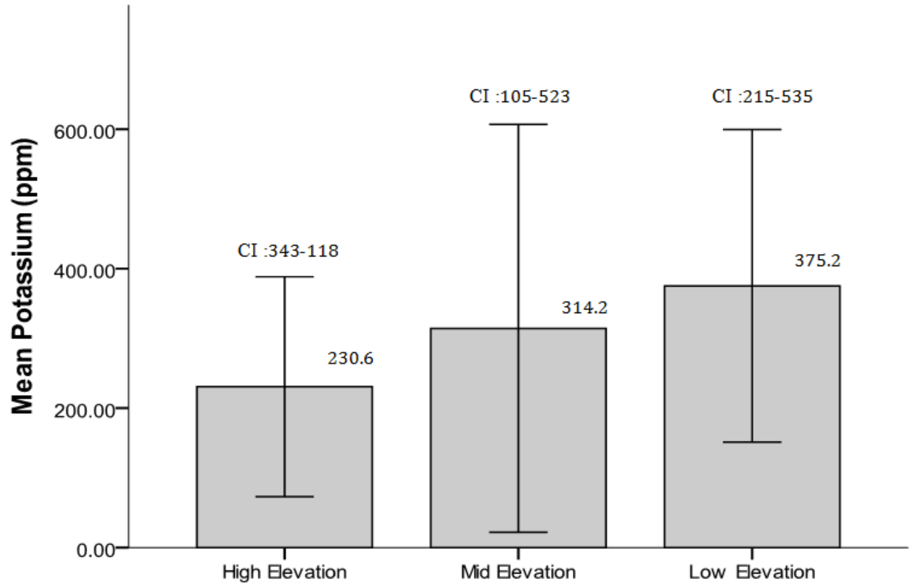

Fig. 4: Average levels of potassium at three sampling areas with corresponding confidence interval

Jimenez et al. (2014) reported that environmental variables associated with spatial distribution of earthworms are not easily detected in very fine scale; but in this large scale study involving 185 ha, this association became apparent.

While pH did not appear as dominant factor in PCA, but there was a pattern of increasing pH towards the coastal areas. A close examination of the correlation matrix of PCA, it can be observed that pH has a strong negative correlation with elevation (r= -0.82). Briones et al. (1995) reported that this was one of the major factors influencing distribution of majority of earthworm species, aside from calcium, magnesium, aluminum, C/N ratio and organic matter; potassium was never reported.

The low elevation area which includes the coastal, where pH is high (pH=6.9) and low earthworm density (3 per cu.ft.), was relatively flat (1% to 2.4% slope) with few coconuts and bananas, and the weed vegetation cover was minimal, mostly composed of grasses and broadleaf weeds but without legumes; more so, there were residential houses.

Mid elevation is a semi agricultural land with secondary type forest. The area vegetation was composed of banana, coconut trees and a few old tropical fruit trees. Land surface under these trees in the area were mostly grasses. The relatively low density of earthworms could be attributed to the type of vegetation. Organic matter from grasses was low in nitrogen compared to legume plants; hence the quality of food for the earthworms is low. The food quality in the mid elevation area could explain the low earthworm density.

The high elevation area in contrast, was sloping (10%-15% slope) and has strongly acidic soil (pH=5.46); earthworm density reached as high as 12 per cu.ft. The relatively high earthworm density could possibly be due to the quality of food – i.e the presence of legumes. The area was predominantly unattended agricultural land mostly planted with coconuts intercropped with few bananas, and on the ground were the legumes (*Centrosema sp*.) and carabao grasses. Nitrogen content in this area was significantly high than the coastal area owing to the presence of legumes.

Organic matter as one important diet and a factor that dictates earthworm distribution was reported by several workers (Briones et al., 1995; Postma-Blaauw et al., 2006; Arancon et al., 2005) but was not obtained in the current study. The decision was based on the assumption that organic matter and nitrogen are anyway strongly and positively correlated, and thus the high nitrogen content environment is related to quality food for the earthworms.

5. Conclusion

In this large scale study, elevation and potassium were the new dimensions that emerged to explain patterns of variation in earthworm density. Elevation in a continuous landscape may explain differences in pH and levels of potassium that affect earthworm density.

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