AGRICULTURAL AND BIOLOGICAL SCIENCES

AN ASSESSMENT OF EARTHWORM POPULATIONAND SOIL FACTORS IN AMURUM FOREST RESERVE OF JOS, PLATEAU STATE, NIGERIA

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ABSTRACT

This study examined and compared the properties of soil inside and outside the Amurum Forest Reserve in Jos, Nigeria. Earthworms and soil samples were collected from 300 randomly laid 1x1m quadrats. Soils were analyzed for total nitrogen, available phosphorous and soil organic matter. Soil moisture retention capacity and pH were also measured. Other variables measured included percentage litter cover, and percentage grass cover. Earthworm abundance did not significantly differ between the reserve and outside the reserve. Available phosphorous and organic matter contents were significantly higher outside the reserve than inside the reserve. Percentage litter cover and percentage grass cover related positively with earthworm occurrence and abundance. Earth worm occurrence significantly related to litter cover. The earthworms sampled in this study were epigeic species which live in the litter and top soil. The significantly higher available phosphorous and organic matter contents in the surrounding areas of the reserve as compared to the reserve could be attributed to the grazing activities in the surrounding areas of the reserve. Protected areas as well as unprotected areas are important for the conservation of biodiversity.

Keywords: *Amurum Forest Reserve, biodiversity, earthworm, epigeic, grass cover, litter cover*

INTRODUCTION

Since 1990, the world's protected areas have increased in number by 58% and in their extent by 48%. In terms of terrestrial area, protected areas are now one of the most important land-use allocations on the planet (UN 2012 as reported by Bertzky *et al.*, 2012). Today, well managed protected areas support not only healthy ecosystems and threatened species, but they also provide multiple benefits to people, which include a wide range of ecosystem services such as clean water provision, food security, disaster risk reduction and climate regulation (Sritharan and Burgess, 2012). Many studies (Mosallam, 2007; Dhaou *et al*., 2010) in some parts of the world have shown that protected areas can be a successful way of maintaining natural and semi-natural habitats and preventing their degradation (Bruner *et al.*, 2001).

Ecologists are interested in investigating species composition and interactions in natural and anthropogenically influenced communities (Ilorkar and Khatri, 2003; Shameem and Kangroo, 2011). Soil is an essential component that influences species composition and ecosystem function in a landscape (Chapin III *et al*., 2002). Soil nutrient availability influences species distribution and community composition (Chapin III et al., 2002; Toledo *et al*., 2012).

Many species of invertebrates play important roles in altering the structure and fertility of soil (Fabricius, *et al*., 2003). Of these, earthworms are a key taxon for soil functioning (Fonte, *et al*., 2009). They participate in litter decomposition, mix organic and mineral matter, create and maintain soil structure by digging burrows and modifying aggregation, regulate microbial diversity and activity, and protect plants against pests and diseases (Lavelle *et al.*,2006). They develop very complex interactions with other soil biota (Lavelle, 1997). They have been referred to as 'soil engineers' (Brossard *et al.*, 2007, Brown *et al.*, 2000) and have been shown to affect availability of nitrogen (N) and phosphorous (P), the main growth-limiting nutrients. Numerous studies have shown increases in plant growth in the presence of earthworms (Atiyeh *et al*., 2000, Buckerfied and Webster, 1998, Orozco *et al.*, 1996). Earthworm density is influenced by the intensity of and number of soil disturbance events like tillage and traffic, the abundance and quality of food sources, the chemical environment of the soil, and soil microclimate (Donahue, 2001).

Soil and vegetation have a complex interrelationship. Soil properties influence the vegetation and vice versa. A central question in ecology is how species and communities respond to variation in environmental conditions. There have been attempts to describe and explain the relationships between soils and vegetation (Chen *et al*., 1997, Ilorkar and Khatri, 2003, Shameem and kangroo, 2011) although no generalities are possible. Soil is the medium of plant productivity. Kubota *et al*., (1998) suggest that both vertical and horizontal variations of soil characteristics are imperative in vegetation distribution, composition and biomass.

The Amurum Forest Reserve in Jos, Nigeria was established in 2001. Prior to this time, the local community in the area who own the forest used part of it as farmlands and it was also a continuous source of fuel wood (Mwansat *et al*., 2011). Outside the reserve, habitat degradation is evident from along the boundaries of the reserve with the savanna giving way to more open and degraded grazing and arable land (Stevens, 2010).

Amurum Forest Reserve is a vulnerable site of conservation concern because of its small size and proximity to the urban community of Jos. Though the reserve is a protected area, there are still a few sporadic cases of wood cutting and, grazing and setting of fire (Agaldo, 2010).

The aim of this study was to assess theearthworm population and soil factorsof Amurum Forest Reserve of Jos, Plateau state,Nigeria.

The study aimed at measuring and comparing the abundance of earthworms in the reserve and its surrounding, the nitrogen and phosphorous concentration and moisture retention capacity, organic matter concentration, pH of the soil and its surrounding areasand the determination of the relationship between earthworm abundance and other vegetation variables.

MATERIALS AND METHODS

The study was carried out at the Amurum Forest Reserve (9°53'N, 8°59'E) located 15 km northeast of Jos in north-central Nigeria. It is a $2km^2$ fragment which holds the last remnants of natural Guinean savannah vegetation on the Jos Plateau, Nigeria. It is made up of three habitat types - rocky outcrops, gallery forest and savannah scrub (Yessoufou, *et al.*, 2012). The area has an average rainfall of about 1400mm per annum and daily temperatures range between 20 – 25^{o}C. The soil is, for the most part brick red laterite around gullies and a mixture of sand and clay in the savannah. The reserve is protected against anthropogenic disturbance. The reserve is one of the Important Bird Areas (IBA) of Nigeria (Ezealor 2002), because it houses many bird species including the endemic LagonostictasanguinodorsalisPayne (Rock Firefinch) and Viduamaryae Payne (Jos Plateau Indigo Bird).In one hundred $100m^2$ study plots already established inside and outside the reserve, three 1x1m quadrats were established at random in each plot by throwing an object (a stick) whilst standing at the edge of the plot and facing away, giving a total of 300 quadrats.

Earthworms and soil samples were collected from these quadrats and other variables were also measured.Earthworms were searched for and hand sorted from soil dug to a depth of 10cm. The earthworms were taken to the laboratory and stored in 0.5% formaldehyde. Soil samples were collected to a depth of 15cm using a cylindrical core. Composite samples were generated from the 1x1m quadrats in each 10x10m plot making a total of one hundred soil samples. The samples were taken to the laboratory, dried and sieved. The samples were analyzed for total nitrogen and phosphorous concentrations and moisture and organic matter contents. The pH of each soil sample was also measured using a pH meter.Total nitrogen was determined by using the Kjeldahl method (Rutherford *et al.*, 2007). TheAvailable phosphorous was determined by Bray II method (Bray and Kurtz, 1945). Thirty grams (30g) of each of the aggregate fractions were weighed into rubber bands (rings). These were used to determine the water content of aggregate fractions at 1.5Mpa (15 bar) and 0.01 MPa (0.1 bar), using the pressure-plate apparatus.

Organic carbon was determined using the Walkley and Black method (Walkley, 1947) as modified by Allison (1965). Organic matter was then determined by multiplying the percentage organic carbon by the conventional "Van Bemmelen factor" of 1.724. Soil pH was determined in water using water to soil ratio of 1:2.5. After stirring for 30 minutes, the pH values were read off using a Beckman zeromatic pH meter.

Other variables measured in the 1x1m quadrats were percentage grass cover and percentage litter cover. All data collected was compiled using Microsoft Excel 2007® and analyzed using R version 2.15 (R Development Core Team, 2012).Mann-Whitney U test was used to evaluate the difference in the abundance of earthworms between the reserve and its surrounding areas.Independent sample t-test was carried out to compare nitrogen, phosphorous, moisture, organic matter content and pH between the soils of the reserve and that outside the reserve.

The relationship between earthworm occurrence and earthworm abundance with other soil variables were also assessed using generalized linear models with a binomial error distribution and poisson error distribution.

RESULTS AND DISCUSSION

The abundance of earthworms in the reserve and outside the reserve was not significantly different (Mann-Whitney's U test, W = 1238.5, p-value = 0.9393) but the mean number of earthworms recorded per plot was higher outside the reserve (5.08±0.63, N=50) than inside the reserve (4.66±0.47, N=50) (Figure 2). Earthworms were present in 86% of the sample plots and mean abundance of earthworms was 5/plot which was very low. This could be because the soil was dry at the time of data collection. Earthworms live in moist environments and so are more abundant during the rains. Earthworm abundance is best known to correlate with soil texture and soil organic matter (Krück *et al.*, 2006), soil moisture (Eggleton *et al.*, 2009), soil organic carbon content (Mainoo *et al.*, 2008), plant residue management (Fonte *et al.*, 2009) and amount of litter for breakdown (Owa *et al.*, 2003). Soil organic matter content was higher outside the reserve as compared to inside the reserve (table 1). This agrees with studies done by Whalen (2004), Nair *et al*. (2005) and Rossi et al. (2006). In this present study, earthworm abundance was shown to correlate with percentage litter cover where plots with higher percentage of litter cover had higher number of earthworms. This could be because the earthworms sampled in this study are epigeic which are "litter dwellers" so more litter would increase the chances of finding them. A study by Iordache and Borza (2010) in Romania relating chemical indices of soil and earthworm abundance under chemical fertilization recorded humus (mainly from litter) and total nitrogen as the greatest positive influence on earthworm abundance and biomass.

Independent sample t-tests showed significant difference between phosphorous concentration (t=-2.02, df= 98 and p=0.023) and organic matter content (t=-2.54, df=98, p=0.006) of soil within the reserve and soil outside the reserve (Table 1). There was no significant difference between the nitrogen concentration (t=-0.23, df=98 and p=0.408), pH (t=2.02, df= 98 and p= 0.977) and moisture retention capacity (t=-1.11, df= 98 and p= 0.135) of the soil within the reserve and soil outside the reserve (Table 1). Bulk nutrient concentrations have been recorded to differ between protected and unprotected sites (Mossalam, 2007; Rawat *et al.*, 2009). In this study, the soil outside the reserve had significantly higher amounts of organic matter and available phosphorous (Table 1) than the soil in the reserve. This agrees with a study carried out by Mosallam (2007) which showed that organic matter was relatively higher in the soils of the grazed flats when compared with that in the soils of the protected flats in Sudera, Taif, Saudi Arabia. This may be as a result of trampling and lying of standing dead materials by grazing animals. Also, there are studies where native landscapes have much lower nutrients than the outside and concluded that whenever nutrients are available in protected areas, they are immediately taken up. Total nitrogen, moisture retention capacity and soil pH of the reserve and its surrounding areas did not differ significantly between the reserve and its surrounding areas (Table 1). Moreira (2000) in a study in Brazil recorded that physical and chemical soil properties did not differ significantly between protected and unprotected sites and attributed fire protection as the major factor differentiating the two sites. In contrast, Rawat *et al*., (2009) recorded significant differences between soil nutrient concentrations in protected and unprotected areas with the protected areas having higher nutrient concentrations.

The probability of finding earthworms increased significantly (glm, F=11.15, df=1, p=0.001) with increasing percentage litter cover (Figure 3). There was also an increase in the probability of finding earthworms in plots with higher percentage grass cover (Figure 4) but this was marginally significant (glm, F=3.07, df=1, p=0.083). Earthworm abundance also increased significantly (glm, F=14.54, df=1, p<0.001 and glm, F=7.12, df=1, p=0.009 respectively) with increasing percentage litter cover and percentage grass cover (Figures 5 and 6). Earthworm occurrence significantly related to percentage litter cover (Figure 3) with plots containing higher percentage litter cover having higher probability of earthworm occurrence. Earthworm abundance was significantly related to percentage litter cover and percentage grass cover (Figures 5 and 6) with plots containing higher percentages of litter cover and grass cover having higher earthworm abundance. Litter cover was a better predictor of earthworm abundance. The earthworms sampled in this study were epigeic species which are favoured by the accumulation of litter or by grass vegetation. Changes in the distribution and the quality of litter, soil climate and water availability are known to affect the composition of earthworm communities (Gerard, 1967; McLean *et al.*, 1996).’

CONCLUSION

The study shows that earthworm abundance, and soil nutrient characteristics except organic matter and available phosphorous concentrations are the same for Amurum Forest Reserve and its surrounding areas. The study also infers that earthworm occurrence and abundance is influenced by litter cover and grass cover but as earlier stated, the earthworms sampled in this study are epigeic species. The study suggests that areas lying outside fully protected zones may be of great importance for conservation of broad spectrum biodiversity.

Further investigation of soil properties in different landscapes is recommended

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REFERENCES

Agaldo, J. A. (2010). Factors determining the abundance of Lantana camara L. (Verbanaceae) in Amurum Forest Reserve, Plateau State. M.Sc. *Thesis in Conservation Biology*, University of Jos, Nigeria. Pp.69

Allison, L.E. (1965). Organic carbon. In: Methods of Soil Analysis, Part 2, C.A. Black *et al*., Ed. *Agronomy*. 9:1367-1378. American Society of Agronomy., Inc., Madison, WI.

Atiyeh, R. M., Subler, S., Edwards, C. A., Bachman, G., Metzger, J. D. and Shuster, W. (2000): Effects of vermicomposts and composts on plant growth in horticultural container media and soil. *Pedobiologia*, 44: 579-590.

Bertzky, B., Corrigan, C., Kemsey, J., Kenney, S., Ravilious, C., Besancon, C. and Burgess, N. (2012) Protected Planet Report 2012: Tracking progress towards global targets for protected areas. IUCN, Gland, Switzerland and UNEP-WCMC, Cambridge, UK. Pp1-20.

Bray, R. H. and Kurtz, L. T. (1945). Determination of total, organic and available forms of phosphorous in soils. *Soil Science*, 59:39-45.

Brossard, M., Lopez-Hernandez, D., Lepage, M. and Leprun, J. C. (2007). Nutrient Storage in soils and nests of mound-building Trinervitermes Termites in central Burkina Faso: consequences for soil fertility. *Biology and Fertility of soils,* 43: 437-447.

Brown, G. G., Barois, I. and Lavelle, P. (2000) Regulation of soil organic matter dynamics and microbial activity in the driloshphere and the role of interactions with other edaphic functional domains. *European Journal of Soil Biology,* 26:177-198.

Bruner, A. G., Gullison, R. E., Rice, R. E. and Fonseca, G. A. B. (2001). Effectiveness of parks in protecting tropical biodiversity. Science, 291:125-128.

Buckerfield, J. C. and Webster, K. A. (1998) Worm-worked waste boosts grape yields: prospects for vermicompost use in vineyards. *Australian and New Zealand Wine Industry Journal,* 13:73–76.

Chapin III, F. S., Matson, P. A. and Mooney, H. A. (2002): Geology and Soils. In: Principles of Terrestrial Ecosystem Ecology. Springer-Verlag New York, Inc.Pp 46-67.

Chen, Z. S., Hsieh, C. F., Jiang, F. Y., Hsieh, T. H. and Sun, I. F. (1997). Relations of soil properties to topography and vegetation in a subtropical rain forest in southern Taiwan. *Plant Ecology*, 132:229-241.

Dhaou, S. O., Abdallah, F., Belgacem, A. O. And Chaieb, M. (2010). The protection effects on floristic diversity in a North African pseudo-savanna. *Pak. J. Bot*., 42(3):1501-1510.

Donahue, S. (2001) Agricultural management effects on earthworm populations. Soil quality-Agronomy Technical Note No. 11.

Eggleton, P., Inward, K., Smith, J., Jones, D.T. and Sherlock, E. (2009) A six year study of earthworm(Lumbricidae) populations in pasture woodland in southern England shows their responses to soil temperature and soil moisture. *Soil Biology and Biochemistry,*41:1857–1865.

Ezealor A. U. (2002). Amurum Woodlands (Taboru). In: Critical sites for biodiversity conservation in Nigeria. Nigerian Conservation Foundation, Lagos, Pp 65.

Fabricius, C., Burger, M. and Hockey, P. A. R. (2003): Comparing biodiversity between protected areas and adjacent rangeland in xeric succulent thicket, South Africa: arthropods and reptiles. *Journal of Applied Ecology,*40: 392-403.

Fonte, S. J, Winsome, T. and Six, J. (2009): Earthworm populations in relation to soil organic matter dynamics and management in California tomato cropping systems. *Applied Soil Ecology,* 41:206-214.

Gerard, B. M. (1967). Factors affecting earthworms in pastures, *Journal of Animal Ecology*, 36:235-252.

Ilorkar, V. M. and Khatri P. K. (2003). Phytosociological study of Navegaon National Park, Maharashtra. *Indian Forester*, 129(3): 377-387.

Iordache, M. and Borza, I. (2010). Relation between chemical indices of soil and earthworm abundance under chemical fertilization. *Plant Soil Environ*., 56(9):401-407.

Krück, S., Joschko, M., Schultz-Sternberg, R., Kroschewski, B. and Tessmann, J. (2006) A classification scheme for earthworm populations (Lumbricidae) in cultivated agricultural soils in Brandenburg, Germany. *Journal of Plant Nutrition and Soil Science,*169:651–660.

Kubota, D., Masunaga, T., Hermansah, Rasyidin, A., Hotta, M. Shinmura, Y. and Wakatsuki, T. (1998). Soil environment and tree species diversity in tropical rain forest, West Sumatra, Indonesia In: Soils of Tropical Forest Ecosystems, Springer Berlin Heidelberg pp159-167.

Lavelle, P. (1997). Faunal activities and soil processes: Adaptive strategies that determine ecosystem function. *Advanced Ecological Resources,* 27:93-132.

Lavelle, P., Decaens, T., Aubert, M., Barot, S., Blouin, M., Bureau, F., Margerie, P., Mora, P., and Rossi, J.P. (2006) Soil invertebrates and ecosystem services. *European Journal of Soil Biology,4*2: S13-S15.

Mainoo, N-O. K., Whalen, J. K. and Barrington, S. (2008). Earthworm abundance related to soil physical, chemical and microbial properties in Accra, Ghana. *African Journal of Agricultural Research*, 3(3): 186-194.

McLean, M. A., Kolodka, D. U. and Parkinson, D. (1996). Survival and growth of Dendrobaena octaedra (Savigny) in pine forest floor materials. *Pedobiologia,*40:281-288.

Moreira, A. G. (2000). Effects of fire protection on savanna structure in Central Brazil. *Journal of Biogeography,* , 27:1021-1029.

Mosallam, H. A. M. (2007). Comparative study on the vegetation of protected and non-protected area, Sudera, Taif, Saudi Arabia. *International Journal of Agriculture and Biology*, 9(2):202-214.

Mwansat, G. S., Lohdip, Y. N. and Dami, F. D. (2011): Activities of the A. P. Leventis, the West African foremost ornithological research center. *Science World Journal,*6 (1):9-12.

Nair, G. A., Youssef, A. K., El-Mariami, M. A., Filogh, A. M. and Briones, M. J. I. (2005). Occurrence and density of earthworms in relation to soil factors in Benghazi, Libya. *African Journal of Ecology*, 43:150-154.

Orozco, F. H., Cegarra, J., Trujillo, L. M. and Roig, A. (1996): Vermicomposting of coffee pulp using the earthworm Eiseniafetida: effects on C and N contents and the availability of nutrients. *Biology and Fertility of Soils*, 22:162–166.

Owa, S. O., Dedeke, G. A., Marafa, S. O. A. and Yeye, J. A. (2003). Abundance of earthworms in Nigerian ecological zones: implications for sustaining fertilizer-free soil fertility. *African Zoology*, 38(2):235-244.

R Development Core Team (2012). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Rawat, N., Nautiyal, B. P. and Nautiyal, M. C. (2009): Litter production pattern and nutrients discharge from litter in a Himalayan alpine ecosystem. *New York Science Journal* 2(6):54-67.

Rossi, J-P., Huerta, E., Fragoso, C. and Lavelle, P. (2006). Soil properties inside earthworm patches and gaps in a tropical grassland (la Mancha, Veracruz, Mexico). *European Journal of Soil Biology*, 42:S284-S288.

Rutherford, P. M., McGill, W. B., Arocena, J. M. and Figueiredo, C. T. (2007). Total Nitrogen. Soil Sampling and Methods of Analysis. CRC Press, Taylor & Francis Group. Pp126

Shameem, S. A. and Kangroo, I. N. (2011) Comparative assessment of edaphic features and phytodiversity in lower Dachigam National Park, Kashmir Himalaya, India. *African Journal of Environmental Science and Technology,* 5(11):972-984.

Sritharan, S. and Burgess, N. D. (2012) Protected area gap analysis of important bird areas in Tanzania. *African Journal of Ecology,*50:66–76.

Stevens, M. C. (2010): Life history trade-offs between survival, moult and breeding in a tropical season environment. PhD Thesis submitted to the University of St. Andrews, Scotland, UK. Pp 20-21.

Toledo, M., Porter, L., Pena-Claros, M., Alarcon, A., Balcazar, J., Leano, C., Licona, J. C. and Bongers, F. (2012). Distribution pattern of tropical woody species in response to climatic and edaphic gradients. *Journal of Ecology* 100:253-263.

Walkley, A. (1947). A Critical Examination of a Rapid Method for Determination of Organic Carbon in Soils - Effect of Variations in Digestion Conditions and of Inorganic Soil Constituents. *Soil Science*, 63:251-257.

Whalen, J. K. (2004). Spatial and temporal distribution of earthworm patches in cornfield, hayfield and forest systems of south western Quebec, Canada. *Applied Soil Ecology*, 27:143-151.

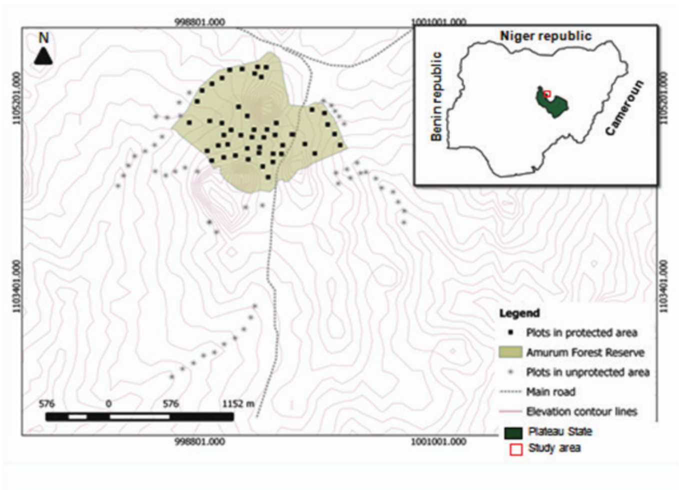
Yessoufou, K., Michelle Van Der, B., Abalaka J, And Daru B. H. (2012) Evolution of fig-Frugivore interactions in West Africa. *Israel Journal of ecology and evolution*, V.58, Pp.39-51

Table 1: Mean and Standard Error (SE) of soil properties of soil within the reserve and soil outside the reserve

	Soil inside reserve			Soil outside reserve			t	df	p
Soil properties	N	Mean	±SE	N	Mean	±SE			
N (%)	50	0.13	0.01	50	0.13	0.01	-0.23	98	0.408
P(mg/kg)	50	4.99	0.08	50	5.26	0.10	-2.02	98	0.023
OM (%)	50	1.60	0.06	50	1.87	0.09	-2.54	98	0.006
MC (%)	50	0.53	0.04	50	0.60	0.05	-1.11	98	0.135
Ph	50	6.41	0.10	50	6.15	0.09	2.02	98	0.977

OM stands for Organic matter and MC stands for Moisture retention capacity. Significant P values in bold.

Figure 1: Map of study area showing points where plots were made inside and outside Amurum Forest Reserve



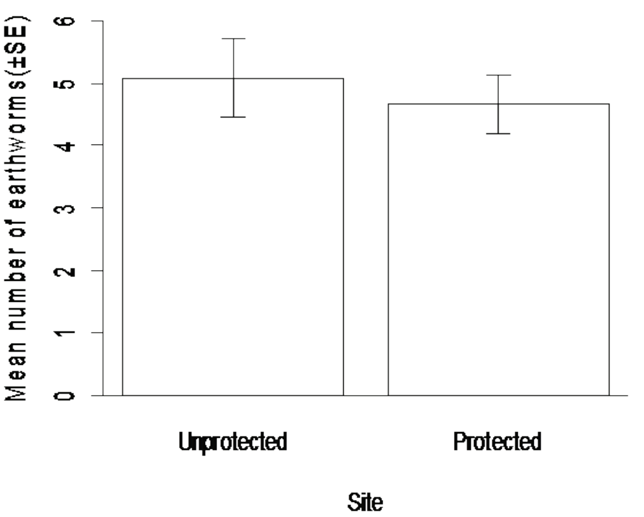


Figure 2: Mean number of earthworms within and outside Amurum Forest Reserve (within=protected, outside=unprotected)

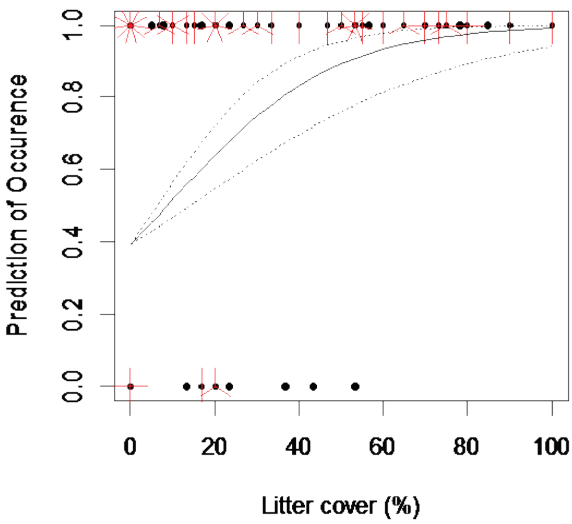


Figure 3: Earthworm occurrence (95%CL) in relation to percentage litter cover

(The fitted line represents the predicted probability of the presence of earthworms in plots with higher percentage litter cover and the dashed lines represent the upper and lower confidence limits. Lines on sunflower plots represent overlapping of plots where multiple points of plots are stacked)

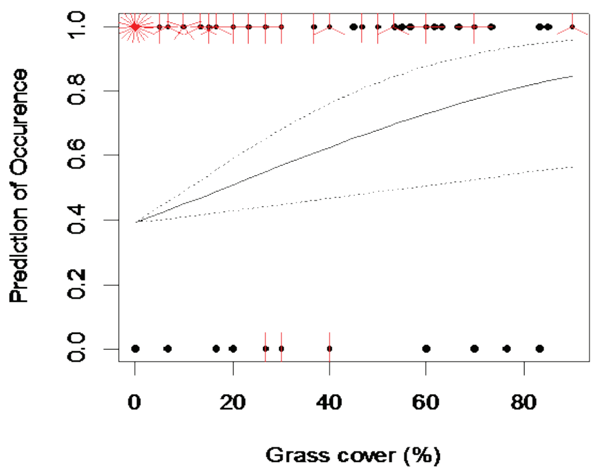


Figure 4: Earthworm occurrence (95%CL) in relation to percentage grass cover

(The fitted line represents the predicted probability of the presence of earthworms in plots with higher percentage grass cover (not significant) and the dashed lines represent the upper and lower confidence limits. Lines on sunflower plots represent overlapping of plots where multiple points of plots are stacked)

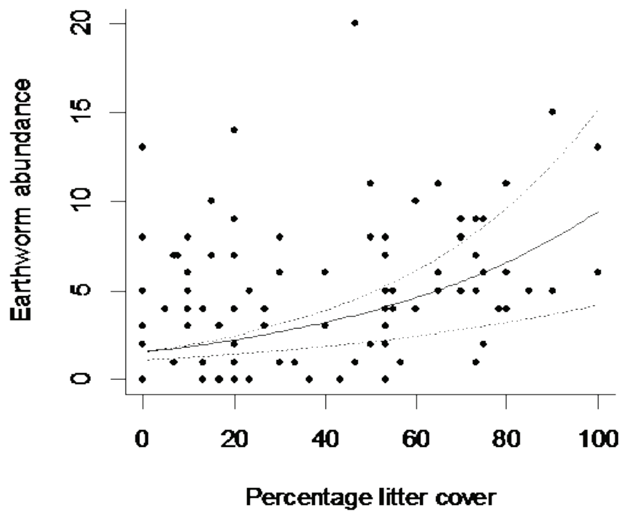


Figure 5: Relationship between earthworm abundance and percentage litter cover (95% CL)

(The fitted line represents predicted earthworm abundance in plots with higher percentage litter cover and the dashed lines represent the upper and lower confidence limits)

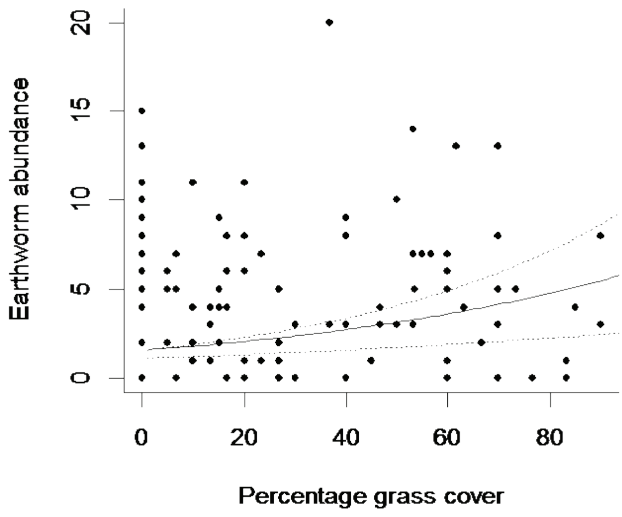


Figure 6: Relationship between earthworm abundance and percentage grass cover (95% CL)

(The fitted line represents predicted earthworm abundance in plots with higher percentage grass cover and the dashed lines represent the upper and lower confidence limits)