SPECIES DENSITY AND DIVERSITY ALONG GEOMORPHIC GRADIENT IN GASHAKA-GUMTI NATIONAL PARK (GGNP), NIGERIA

*MUBI, A.M. and TUKUR, A.L.

http://dx.doi.org/10.4314/ejesm.v5i4.S11

Received 20th June 2012; accepted 10th October 2012

Abstract

The relevance of geomorphic forms to the conservation and protection of plant species and their territorial habitats in the Gashaka-Gumti National Park (GGNP) Nigeria was examined. The study analyzed and stratified the geomorphic features of the Park and observed species types, density and diversity distribution pattern. The variation between the landscape features and species distribution were investigated at 0.095% test level. Remotely acquired data, field investigation, Geographical Information System (GIS), and statistical approaches were adopted for the study. Data was collected on morphologic form, altitude, gradient, soil types and physical properties, species types, density and diversity from 103 units of 625m² quadrants. Results of the analysis show low species densities of 16, 14 with corresponding low diversities of 3, 3, per 625m² on high altitudes whereas high densities of 60, 55 and corresponding high diversities of 11, 6 exist on middle altitudes. The plains and the riparian areas have mean density of 47 and corresponding diversity of 10 per 625m². Uapaka togoensis, Crossopteryx februfuga, Brachystigia eurycoma Andria enermis are some of the species within low altitude stratum (240-599m). The middle strata 600-959m and 960-1319m are characterized by species such as Danielia oloveri, Hymonocadia acida, Terminalia glaucocens while at the upper strata (1320- 1679 and 1680-1885) Combrutum spp, Entanda africana, and Lanea shamperi are the notable examples. Assessment of the physical features and species variation between geomorphic strata variables revealed (except for gradient), significant variation. The 'F' values show F = 27.87 altitude value, F= 4.32 for gradient, F= 4.80 for density and F= 9.13 for diversity. Variation in soil properties, altitude, hydrology and slope gradient in order of importance were noted as the causal factors for the observed variation in species distribution.

Key words: *Gashaka-Gumti, geomorphic, habitat, landscape, species, density, diversity*

Introduction

Among the goals and requirements of modern conservation is the need for better understanding of the dynamics of the physical systems that is to understand and predict the spatial distribution and composition of species over the landscape (Jones, *et al.*, 1998; Bridge and Johnson, 2000; Kenneth and Blanca, 2007; Adrian, *et al.*, 2009; Mubi, 2010a; Mubi, 2010b; Newbold, 2010). The emphasis is on the importance of landforms and running water as interrelated and interacting elements of the environment that basically produce ecological patterns and processes on the one hand and plant and animal species on the other hand. Relevance of geomorphic forms in nature conservation as buttressed by Ono (2002) that landforms provide templates for the development of species habitats and landforms change is likely to cause habitat loss including decline in biodiversity. Jensen (2000) observed that, landscape patterns provide a set of indicators such as pattern, shape, dominance, connectivity, configuration among others that can be used to assess ecological state and trends at a variety of scales. Such landscape approach he noted permits two important types of comparisons:1) to compare conditions within and across landscape, 2) to compare conditions across different types of risks. Such ecological risks are known to include the risk of erosion, loss of soil productivity, loss of biological functions and loss of biodiversity.

The influence of landscape attributes and maps on species distribution have been well documented (Warren, 2001; Franklin *et al.*, 2004; Nemoto and Libeiro, 2006; Zheng *et al.*, 2006; Ferreira-Junior *et al.*, 2007; Yoshiyuki and Hajime, 2007; Wehling and Diekmann, 2008; Mubi, 2008; Wevill, 2010; and Duccio *et al.*, 2010). Therefore, effective and efficient conservation and management of species habitats in National Parks necessitate an elaborate data and understanding of the physical features as well as the complex links and interactions between the physical features

Department of Geography, Modibbo Adama University of Technology P. M. B. 2076, Yola Adamawa State, Nigeria
**Corresponding author:* ammubi@yahoo.com

and the population composition of plant species, if species and their habitats are to be managed in a way that can conserve their diversity. It is against this background that this paper examined the geomorphic forms and species types, density and diversity distribution in the Gashaka-Gumti National Park (GGNP) along geomorphic gradient. This is with a view to providing baseline information for explaining, monitoring and mitigating problems arising out of plant species population, distribution, conservation and management in the park.

Study area

The relief features of the park vary considerably between the northern and southern sectors. The northern Gumti sector is characterized by lowland of undulating plains and flood plains dotted with isolated hills and mountains. The southern Gashaka sector on the other hand, is more hilly and mountainous with numerous water courses. The relief/altitude is high and rugged and is dominated by steep slopes, deep plunging valleys, precipitous escarpments and long winding ridges (Figure 2).

Four principal soil groups, Leptisols, Acrisols, Luvisols, and Ferrisols are distinguished in the study area. The Leptisols occur alongside the Acrisols with the Acrisols amid the Leptisols and are found in the central southern sector of the park on altitude 1400m and about. The Ferrisols are associated with upper slopes on high elevations up to 1600m and above restricted within the southern part. The Luvisols however, dominate the entire northern sector of the park. Rainfall varies from mean annual of 1,500mm in the drier lowland northern sector to mean annual of 2,033mm at the higher wetter southern sector. Temperatures fluctuate between mean annual minimum of 20^{o}C to mean annual maximum of 31.7^{o}C. Drainage system is characterized by high densities and diverse types of dendrite, trellis and radial in their nature and distribution patterns.

The study was carried out of species distribution along geomorphic gradient in Gashaka-Gumti National Park, one of the Nigerian eight (8) National Parks rich in biodiversity. Covering an area of 6,660km^2, the park is a unique area of high nature conversation value, located in the sub-tropical zone of eastern high lands of the savannah area of Nigeria. It lies between latitude 6^o 55' and 8^o 05' North and between11^o 11' and 12^o 13' longitude East (Figure 1).

Figure 1 Location of Study Area

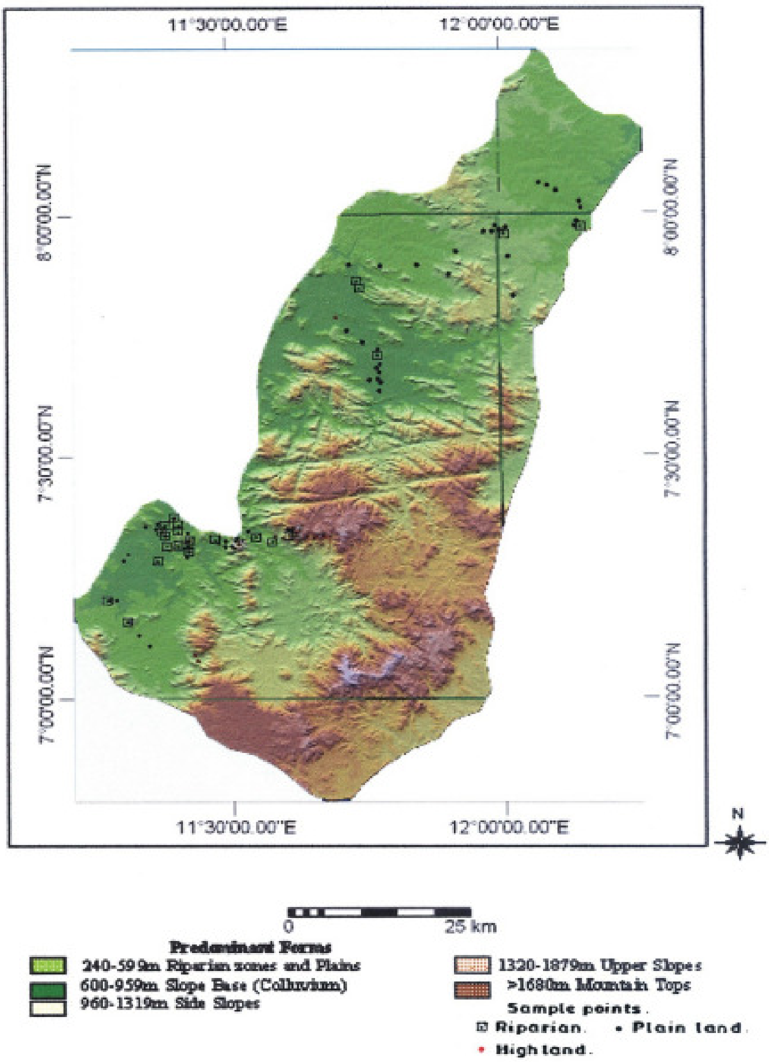

Figure 2: Digital Terrain Model (DTM) of Gashaka-Gumti National Park
Source: Analyzed from topographical sheets 1:100, 000, of 1970
using ILWIS Academic version 3a

Over twenty streams have their sources from the park and flow through the park while several others rise from the highlands drained through the park down to reaches beyond the boundaries of the park.

Materials and Methods

A base line Digital Terrain Model (DTM Figure 2) of the study area was produced from the topographical sheets of the study area. The topographic sheets were scanned into the computer and were then merged into a copy using Adobe Photoshop Elements Version 3.0 to obtain a mosaic relief of the study area. The mosaic copy was then digitized from their analogue paper maps into a digitized format. The scanned map was geo-referenced to the Universal Traverse Marcato (UTM) grid ellipsoid datum 84 (Nigerian data are referenced to). Integrated Land and Water Information System (ILWIS) Academic, Version 3.2a was used in transforming the latitude and longitude coordinates on the topographical sheets to metric (UTM) system. Boundary of the study area, contours, settlements (segments) were created after the geo-referencing. Each layer was digitized after going through the various initiation stages of creating map name and domain. The contour (segments) lines were interpolated to generate elevation values. Thus, the resulting raster map is Digital Elevation Model (DEM), illustrating the landscape in its Two Dimensional Form (2D). The application of Z values (XYZ coordinates) to the 2D produced the landscape in its Three Dimensional Form (3D), (DTM Fig. 2). The DTM was stratified into five (5) relief/geomorphic form classes based on altitude and, thus constituted the sample strata from which sample units for detailed survey were drawn. Stratification of the study area into relief layers was deemed essential because in ecological studies, stratification is believed to increase the reliability of data relative to un-stratified studies of similar nature. Data collection was based on sample geomorphic strata. Jones *et al.,* (1998) outlined the goals of using landscape (geomorphic form) approach to the study of protected areas and these include:

(i) estimate on aerial basis and within known confidence, the current status, trends and changes in selected indicators of important landscape;

(ii)estimate with known confidence the geographic coverage and extent of the landscape patterns and types;

(iii) seek associations between selected indicators of natural and anthropogenic stresses and indicators of landscape condition; and

(iv) provide statistical summaries and periodic assessment of the condition of the landscape.

Gashaka-Gumti National Park is a large, diverse and complex environment with varied morphological and climate types thus, the stratification and use of geomorphic features for detailed survey. The detail field survey collected data from a total of 103 sample units delineated 25m x 25m ($625m^2$) distributed across the five strata. Information sourced include: sample unit coordinates and altitude using Global Positioning System (GPS) Garmin 12, gradient with the aid of hand held Abney level, while species type, density and diversity were observed in the field. Information on soil is limited to map source and field checks.

Results and Discussion

The general pattern in the distribution within the park is initial increase in species density and diversity with elevation, followed by a peak and then a decline with further increased elevation. Along valley bottoms and slopes (600–959m stratum) species mean density and mean diversity are as high as 60 and 11 per $625m^2$ unit of land respectively. On the riparian and plains (240–599m) stratum and along lower valley slopes (960–1319m) means density and means diversity are 47, 10 and 55, 6 per unit of land (Figure 3). Low mean density of 14 and diversity of 3 per unit area are associated with heights above 1320m, on exposed bare surfaces and precipitous scarp slopes (Table 1). This indicates that the middle latitudes are the most diversified and dense while the high altitudes are the least.

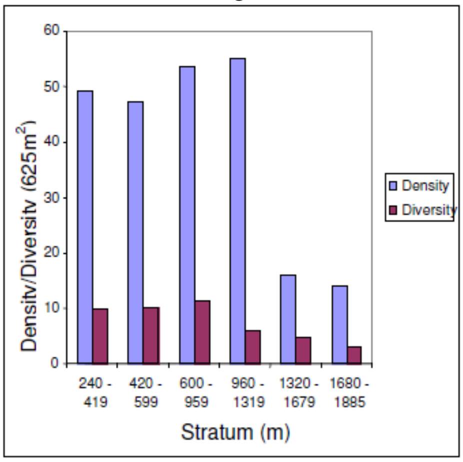

Figure 3 Mean species density/diversity distribution between geomorphic strata

The observed pattern in Gashaka-Gumti National Park is similar to the established findings that, species composition in the low Várzea forest differed significantly from that of upland Varzea forest (Florian *et al*., 2006); those found of Tree-line changes along Andes that, morphological plasticity is a common trait that dominates all tree lines (Young and León, 2007); the hump-shaped distribution with species richness in the middle elevation in Hubei Province Chaina (Hua, 2008); species responded clearly to environmental gradients in lowland Bolivia, for most (65%) climate, soil explained $r^2 > 0.50$ of the variation in the occurrence (Marisol, *et al*., 2012). The obvious reason for the significant variation in species density and diversity in the park like in the case of Vàrzea forests and the Andes environment is attributed to the wide range in the elevation standing at an altitude between 240m-2400m (Figure 2). The variation in elevation gave rise to different climates which support both montane and lowland forest types (Mubi, 2008). Test of the degree of variation in geomorphic factors and species distribution between geomorphic strata for the study area show 'F' results which indicate except for gradient, significant variations in altitude, species density and diversity. The calculated F values revealed for altitude F=27.87, gradient F=4.32, density F=4.80 and diversity F=9.13.

Table 1 Species density and diversity distribution between geomorphic strata in the study area

Stratum (m)	**DGF**	**SMG**	**SLT**	**NSS**	**SMDN ($625m^2$)**	**SMDV ($625m^2$)**	***DSS***	**VGTT**
240 – 599	Riparian landscape and plains flat bottom	0.6^0	Luvisols/Leptesols Alluvium along riparian and fine/coarse sand on the plains	85	47	10	*Uapaka togoensis* *Crossopteryx febrifuga* *Piliostigma thonningii* *Terminalia glaucoscens* *Nauclea latifolia* *Anogeissus leocarpus* * *Vitex doniana* * *Brachystigia eurycoma* * *Andiria enermis*	GLF WDL/ GRS
600 – 959	Slope base (colluvium) Valley bottom (alluvium) Concave base	3^o	Mainly Leptesols Fine grain colluviums and alluvium along streams	8	60	11	*Annona senegalensis* *Daniela oliveri* *Hymonecadia acida* *Crossopteryx febrifuga* *Ficus spp* *Bredelia ferruginea*	GLF LLF WDL/ GRS
960 – 1319	Deep valley side slopes	4^o	Mainly Leptesols and patches of Acrisols Coarse grain colluviums (Sand, talus, boulders)	1	55	6	*Diospyros spp* *Anogessus leocarpus* *Terminalia glaucoscens* and grass	MGR GLF
1320 – 1679	Upper straight slopes	3^o	Ferrasols Fine reddish/orange soil with precipitous rock surface/ boulders	5	16	3	*Combretum spp* *Combretum molle* *Lanea shamperi* *Annona senegalensis* and grass	MGR GLF MFR
1680 – 1885	Upper convex scarp slopes	10^o and >	Ferrasols Fine reddish/orange color soil with exposures of Rock outcrop, bare surfaces	4	14	3	*Combretum spp* *Entanda africana* *Combretum molle* and grass	MGR MFR

•DGF – Dominant geomorphic forms •SMG – Stratum mean gradient •SLT – Soil Type •NSS – Number of Sample Units in Stratum •SMDN – Species mean density •SMDV – Species mean diversity •DSPPS – Dominant species in a Stratum •VEGTT – Vegetation Types •GLF – Gallery Forest •WDL/GRS – Woodlands/grass •LLF – Lowland forest •MGR – Montane grassland •MFR – Montane Forest *Mainly found in riparian landscape.

Table 2 The abundant and frequency occurring species in the sample units (103) of the northern/southern sectors and the entire Park

Northern Sector 39			Southern Sector 64			Entire Park 103		
SPPT	FSU (625m2)	SMDU (625m2)	SPPT	FSU (625m2)	SMDU (625m2)	SPPT	FSU (625m2)	SMDU (625m2)
Uapaka togoensis	*13*	*8*	*Uapaka togoensis*	*32*	*16*	*Uapaka togoensis*	*45*	*13*
Monetis kestingii	*3*	*35*	** Diospyros spp*	*21*	*16*	** Diospyros spp*	*24*	*13*
Terminalia glaucoscens	*26*	*5*	*Hymenocardia acida*	*25*	*7*	*Hymenocardia acida*	*38*	*7*
Hymonecardia acida	*13*	*7*	*Crossopteryx februfuga*	*24*	*6*	*Crossopteryx februfuga*	*42*	*5*
Isoberlinia tomentosa	*8*	*10*	*Annona senegalensis*	*28*	*5*	*Annona senegalensis*	*41*	*5*
Burkia Africana	*12*	*6*	*Nauclea latifolia*	*24*	*3*	*Terminalia glaucoscens*	*40*	*7*
Psedocidiria koschyel	*9*	*8*	** Vitex doniana*	*29*	*2*	*Piliostigma thonningii*	*37*	*4*
Danielia oliveri	*9*	*7*						

•SPPT-Species type •FSU – Frequency of species per unit •SMDU – Species mean density per unit *Mainly riparian.

The most frequently and least occurring species in the 103 units surveyed are *Terminalia glaucoscens* 26 (67%), *Monitis kestingii* 3 (8%) in the northern sector, *Uapaka togoensis* 32 (50%), *Diospyros spp* 21 (33%), and *Uapaka togoensis* 45 (44%), *Diospyros spp* 24 (23%) in the southern and the entire park respectively (Table 2). This result corroborate Yoshiyuki and Hajime (2007) findings of occurrence frequency range from 66.8% of *Thalassia hemprichii* to 4.5% that of *Enhalus aacoroides* species distribution to multiple physical environmental factors. Results in Table 2 further revealed that, species density per unit area (625m^2) is not related to its frequency of occurrence in the park, examples are the environment specific species such as *Monestis kestingii, Nauclea latifolia, Piliostigma thonningii, Vitex doniana* and *Diospyros spp*. This finding also support Marisol *et al.* (2012) of species relationship per number of plots in which species is found to exhibit weak correlation, which challenges the view that most tropical forests are dominated at large scale by few common species. Generally, species like *Brachystigia eurycoma, Andria enermis* and *Vitex doniana* favor riparian landscapes, while *Crossopteryx februfuga Uapaka togoensis, Anonna senegalensis, Anogeisus leocarpus,* and *Nauclia latifolia* thrive well on the drained plains. On the slopes of high lands, *Combrutum spp* and *Entanda africana* are notable examples. The variation in species density and diversity could largely be attributed to the variation in geomorphic/hydrologic factors (altitude, gradient, soil properties and accessibility to moisture supply) and the processes operating (links/interactions between the elements) at different scales of the geomorphic units and the resultant soil products. Runoff facilitates the removal to some extent, transportation and deposition of the geomorphic products (soils) over the landscapes, which then creates suitable habitats for the observed dense and diverse species.

Conclusion and Recommendations

The study concluded that, the factors which determine species habitats variability, species types, density and diversity distribution are many, complex and interrelated and spatially varied over the park landscape. The middle altitudes are found to be the most diverse and dense while the high altitudes are the least. Therefore, in order to effectively conserve and manage the dense and diverse plant species and their habitats in the GGNP, maintain and protect resilience of prevailing morphologic conditions in the different strata under which the diverse species are preserved, there is need to obtain comprehensive data remotely acquired and analyzed. The findings provide broader and more integrative understanding of species nature and their habitats. Such an understanding and knowledge is essential and desirable in the following areas: It aids to understand the physical land characteristics, of species habitat base on their requirements; Knowledge of special requirements will help to promote, preserve, enhance, protect and manage the bio-diversity of species of fauna and flora of the area, some of which are rare, endangered, or at the verge of extinction. The knowledge obtained can be transferred to another environment with similar characteristics for improvement on conservation and management of such site. Such knowledge could also be beneficial for rehabilitation of depleted environment that was once characterized by similar condition.

References

Adrian, C.N., Ross, A.H., Cristian, E., Duncan, G., Jose, M.R.B., Luis, C. and Shelley, A.H. (2009), Remote Sensing and the future of landscape ecology. *Progress in Physical Geography,* 3, 528-546

Bidge, S.R.J. and Johnson, E.A. (2000), Geomorphic principles of terrain organization and vegetation gradients *Journal of Vegetation Science,* 11, 57-70.

Duccio, R., Joaquin, H., Szabolcs, L., Jorge, M.L., Alberto, J., Carlo, R., Giovanni, B. and Alessandro, C. (2010), Accounting for uncertainty when mapping species distribution: The need for maps of ignorance. *Physical Geography in Progress,* 35, 211-226.

Florian, W., Jochen, S., Juen, C.M., Thomas, M., Wolffng, J.J., Maria, T.F.R., Helder, L.Q. and Martin, W. (2006), Tree species composition and diversity gradients in White-water forest across the Amazon Bazin *Journal of Biogeography.* Blackwell Publishing Ltd.

Franklin, S.B., Kupter, J.A, Grubaugh, J.W. and Kennedy, M.L. (2004), Biotic diversity of natchez trace state forest, western Tennessee. *Environmental Monitoring and Assessment* 93, (1-3) 30-34.

Ferreira-Júnior, W.G., Silva, A.F., Schaefer, C.E.G.R., Meira-Neto, J.A.A., Dias, A.S., M lgnácio, Medeiros, M.C.M.P (2007), Influence of soils and topographic gradients on tree species distribution in a Brazilian Atlantic Tropical Semideciduous Forest *Edinburgh Journal of Botany,* 64, 137-157.

Yu Hua, Y. (2008), Distribution of plant species richness along elevation gradient in Hubei Province, Chaina http://www.maweb.org/documents/bridging/papers/hua.yu.pdf retrieved 30. 06. 2012

Jensen, J.R. (2000), Remote sensing of the environment*: An earth resource perspective. Pearson Education*, Singapore.

Jones, K.B., Ritters, H.R., Wickhnm, J.D., Tankersley, R.D., O'Neill, R.V., Chslovd, D.J., Smith, E.R. and Neale, A.C. (1998), An ecological assessment of the United State:Mid–Atlantic Region; An Atlas, EPA/600/R-79/130. Las Vegas, NV: U.S. Environmental Protection Agency. http://www.epa.gov/emap/htm/pubs/docs/groupdocs/landeol/atlas/ma atlas.html (Date: 21.07.2007).

Kenneth, R.Y. and Blanca León (2007), Tree-line changes along the Andes: implication for spatial patterns and dynamics. Philos Trans R Soc B *Bio Sci* 362 (478) 263-272.

Marisol, T., Marielos, P., Fraans, B., Alfredo, A., Julio, B., José, C., Claudio, L., Juan, C.L. and Lourens, P. (2012), Distribution pattern of tropical woody species in response to climate and edaphic gradients. *Journal of Ecology* 100, 253-263.

Mubi, A.M. (2008), An analysis and mapping of the physical land characteristics for the conservation and management of flora of Gashaka-Gumti National Park, Nigeria. PhD thesis submitted to the Department of Geography, Bayero University Kano, Nigeria.

Mubi, A.M. (2010a), Remote Sensing-GIS supported land cover analysis of Gashaka-Gumti National Park, Nigeria. *FUTY Journal of the Environment* 5(1), 15-28.

Mubi, A.M. (2010b), Assessment of Tree Species Distribution in Gashaka-Gumti National Park, Nigeria: A Regression Based Model Approach. *The Zaria Geographer,* 18, 11-13.

Nemoto, M. and Libeiro, J.F. (2006), Factors determining the habitat of Drosera sessillifolia in the humid zone of the Brazilain cerrado *Ecological Research,* 21, 1 150-156.

Newbold, T. (2010), Applications and limitations of museum data for conservation of ecology with particular attention to species distribution models *Progress in Physical Geography,* 34, 1 3-22.

Ono, Y. (2002), Landform conservation and flood control: Issue of the chitose diversion channel project in Hokkaido *Japan-Australian Geographical Studies,* 40, 2 143-154 12 Blackwell Publishing.

Yoshiyuki, T. and Hajime, K. (2007), Relationship of species composition of tropical seagrass meadows to multiple physical environmental factors *Ecological Research,* 22, 1 87-96. Springer, Tokyo.

Warren, A. (2001), Valley-side slopes In: Warren A and French J. R. eds *Habitat Conservation: Managing and Physical Environment* John Wiley and Sons New York.

Wevill, T. and Read, J. (2010), Fine-scale pattern in the distribution of semi-arid species at Wyperfield National Park, Southern Australia- The potential roles of resource gradients vs disturbance. *Journal of Arid Environments,* 74, 4 482-490.

Wehling, S. and Diekmann, M. (2008), Factors influencing the spatial distribution of forest plant species in hedgewows of North-western Germany *Biodiversity and Conservation*, 17, Issue 11 2799-2813

Zheng, Y., Xie, Z., Jang, L., Shimizu, H., Rimmington, G. M. and Zhou, G. (2006), Vegetation response along environmental gradient on the Ordos plateau, Chaina *Ecological Research,* 21(3), 396-404.