Journal of Ecology and the Natural Environment Vol. 4(x), pp. xxx-xxx, xxxx 2013
Available online at http://www.academicjournals.org/JENE
DOI: xxxxxxxxxxxxxxxxx
ISSN 2006 - 9847©2012 Academic Journals

Full Length Research Paper

A new model: Herbaceous species diversity along the environmental gradient in the typical hilly areas of Henan Province

Bing-Hua Liao[1,2,3]*, Pei-Song Liu[1], Zhen-Zhong Wen[1], Sheng-Yan Ding[3], Hai-Long Yu[2], Zhi-Chao Wang[2], Zhong-Kai Li[2], Huan-Xin Chu[2], Wen-Liang Li[2] and Yi Shen[2]

[1]The Key Laboratory of Ecological Restoration in Hilly Areas, Forestry Department of Henan Province, Ping-ding-shan University, Ping-ding-shan, Henan Province,China,467000.
[2]Department of Environment and Geography, Ping-ding-shan, Henan Province, China, 467000.
[3]Institute of Ecological Science and Technology, College of Life Sciences, Henan University, Kaifeng, China, 475001.

Accepted 3rd November, 2012

Ecological model is important. The relationship between biodiversity and disturbance gradient, however, makes it difficult to compare data from different studies and draw general conclusions. These results assessed the relationship between disturbance gradients and herbaceous species diversity in the typical hilly areas on varying spatial scales along the environmental gradient in Henan Province. Using community ecology techniques and quantitative measurements of disturbance, we detected a linear relationship between weighting values of disturbance intensity and herbaceous species diversity (Simpson), which were significantly correlated (*P<0.01*) in the differential ecosystem types along different disturbance gradient. Understanding a linear relationship between herbaceous species dynamics and their causes in the differential type's landscapes is essential for further research of local ecosystem functions reaching the goal of ecosystem sustainable development in the context of biodiversity conservation. These results indicate that weighting values of disturbance are the most important environmental factors affecting the herbaceous species diversity in building a model of the ecosystem. This model may help policy makers formulate better ecological conservation and restoration plans with ecosystem.

Key words: Model, herbaceous species diversity, disturbance gradient, significantly, the typical hilly areas.

INTRODUCTION

Ecosystems are typically filled with large numbers of plant species along environmental gradient, making species-centered studies of systemic processes and functions extremely difficult, if not outright impossible, to carry out (Liao et al., 2010; Liao et al., 2011a, 2011b). The intermediate disturbance Hypothesis (IDH) suggests that species diversity will be maximal at intermediate levels of disturbance (Connell, 1978). Moreover, many experiments have assessed the relationship between plant species biodiversity and disturbance intensity from IDH perspective along different disturbance gradients in theoretical ecology (Biswas et al., 2010; Boutin et al., 2008; Leis et al., 2005). For example, Leis et al. (2005) found that disturbance up to intermediate levels can be used to maintain biodiversity by enriching the plant species pool. Further, Biswas et al. (2010) suggested that plant species richness and diversity, functional richness and diversity reached peaks at moderate disturbance intensity in riparian and upland plant communities.

Therefore, the relationship between plant species diversity and intermediate disturbance intensity has many

*Corresponding author. E-mail: lbh@henu.edu.cn. Tel: 086-13839962027.

Abbreviation: IDH, Intermediate disturbance hypothesis.

Table 1. The relationship between IDH and biodiversity from the different perspectives.

The relationship between IDH and biodiversity from the different perspectives	Author
Water level fluctuations, fire and grazing are essential for maintaining plant diversity.	Keddy, 2005.
Increased diversity at intermediate disturbance was due primarily to increased evenness.	Aronson, 1995.
Diversity and soil properties were best at intermediate disturbance levels.	Zhang et al., 2010.
The IDH pattern was obtained for low frequency dependence and low immigration.	Cordonnier et al., 2006.
Generate a period-bubbling bifurcation structure and population dynamics that are most variable at intermediate disturbance frequencies.	Reluga, 2004.

real world applications in the field of ecological conservation and restoration (Table 1). Here, using plant community ecology techniques, this study analysis asked three key questions regarding the relationship between herbaceous species diversity and intermediate disturbance levels in the differential ecosystem types. First, this study asked if the IDH facilitate human understanding of the contribution of the relationship between herbaceous species diversity dynamics and disturbance gradient to different ecosystem types, and if these relationships are more useful than others. Next, this study asked if the large set of the relationship between herbaceous species diversity dynamics and disturbance gradient from IDH perspective can be compressed into a general model that is universally applicable to ecosystem studies. Finally, this study asked how the links between herbaceous species diversity and disturbance along disturbance gradient can be applied to real world scenarios in order to prevent biodiversity loss and ecosystem manage degrading or degraded ecosystems.

MATERIALS AND METHODS

The ecosystems of the typical hilly areas are results of the historical natural and anthropogenic activities in the Henan Province. Quantitative assessments mainly depended on disturbance of human-driven and season driven changes in herb biodiversity and were based on a careful choice of landscape scenarios (Table 2).

Using community ecology techniques, we examined the influences of different disturbance on dynamics of herbaceous species diversity and disturbance interactions along the different disturbance gradient along elevations gradient on the northern slope of the *Fu-Niu* Mountain Natural Reserve in August, 2011. Several plots (e.g. typical hilly ridge areas, typical hilly boundary areas and typical hilly center areas) were established per 1 × 1 km area. A total of 20 plots were set. Each study plot, consisted of one 20 × 20 m tree layer quadrate, five (the center and four corners of the study plot) 2 × 2 m shrub layer quadrates and five 1 × 1 m herbaceous layer quadrates. Thus, these plots include 100 herbaceous layer quadrates and 100 shrub layers in the typical hilly center areas in August, 2011 (Tables 1 to 4).

Traditional indices

This is the most widely used indices, Simpson's index (Simpson, 1949). Simpson's index of diversity is generally calculated as the complement of D:

$$1-D=1-\sum_i (p_i)^2$$

Where, p_i is the proportion of the sample belonging to the ith species.

RESULTS AND DISCUSSION

Dynamics in the dominant/companion tree species along disturbance gradient at pulsed field gradients (PFGs) levels

The results show that disturbance is an important environmental factor affecting weed species diversity in anthropogenic activities in the typical hilly areas center / the typical hilly boundary areas / the ridge of the typical hilly areas. The relationship between values of weighting disturbance and the weed species diversity investigated vary significantly in the herbaceous layer along the environmental gradient on varying disturbance scales along the different disturbance intensity gradient in the typical hilly areas (Figures 2 to 4).

The results indicate that herb diversity (e.g. Simpson indicator) is expected to increase when weighting values of disturbance is reduced along disturbance gradients in the typical hilly areas of Henan Province (Figures 2 to 4). Second, herbaceous diversity (e.g. Simpson indicator) is expected to decrease when weighting values of disturbance is increased along disturbance gradients in the typical hilly areas of Henan Province. Thus, our result implies that weak disturbance should lead to higher herbaceous species diversity in the typical hilly areas of Henan Province.

These results suggest that herb species diversity (e.g. Simpson indicator) is expected to increase when weighting values of disturbance is reduced along disturbance gradients in the farmland boundary areas and the ridge in the typical hilly areas (Figures 1 to 5). In addition, herb species diversity is expected to decrease when weighting values of disturbance is increased along disturbance gradients in the typical hilly areas boundary areas and the ridge in the typical hilly areas (Figures 3 to 4). Therefore, this result implies that weak disturbance should lead to higher herbaceous species diversity in the typical hilly areas of Henan Province. To do this, the

Table. 2. The physical geographic conditions of *Fu-Niu* Mountain nature reserve.

Location	Climatic							Elevation (m) †	Area (hm^2)	Vegetation
	Precipitation (mm)	Mean temperature (ºC)								
		Annual Mean		Maximum		Minimum				
		South slope	North slope	South slope	North slope	South slope	North slope			
Latitude (º): 32.75 - 34.00 Longitude(º): 110.50 - 113.01	800 - 1100	14.1- 15.1	12.1-12.7	26.5-28.5	26.5-28.5	1-2	-1.5 - 2	351 - 1920	56000	Straddling mixed vegetation zones of the subtropical and warm-temperate zones of East China, the *Fu-Niu* Mountain National Reserve is representative of north-south climatic transition zones.

†Above sea level.

Table 3. The selection of the weighting values of disturbance.

Parameter	Differential ecosystem type
Values of weighting of disturbance	
Times of Disturbance	Typical hilly areas center
+ Frequency of Disturbance	/Ridge of the typical hilly areas
+100/ The width of road in the different types	/ Typical hilly areas boundary

Table 4. Investigation Index along the elevation gradient variable.

Investigation	Layer	Community	Species	Height	Crow	Diameter
Community Investigation	Tree/shrub /herbaceous	Coverage/community's age structure	Species/ individual number	Layer's Height	Crow height/ width	Basal diameter

Table 5. The negative correlation between Simpson and weighting values of disturbance.

Differential ecosystem type	Simpson
Typical hilly areas center	-0.962**
Ridge of the typical hilly areas	-0.981**
Typical hilly areas boundary	-0.917**

***P*<0.01

correlation between species biodiversity and the weighting values of disturbance was then analyzed (Table 5).

This results suggest that there is a linear relationship between weighting values of disturbance and herb species diversity (Simpson),

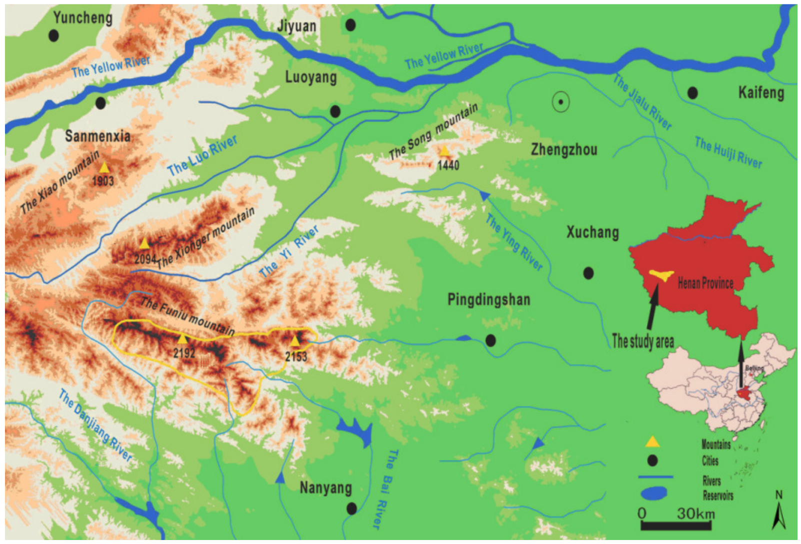

Figure 1. A digital cadastre map in the typical hilly areas of Henan Province.

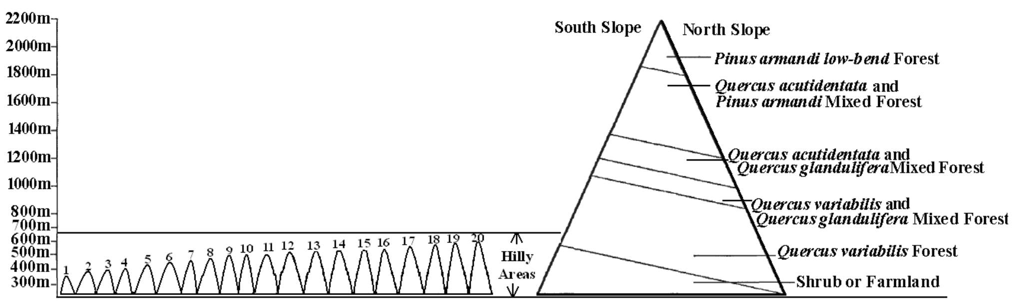

Figure 2. The Southern slope of *Fu-Niu* Mountain vegetations.

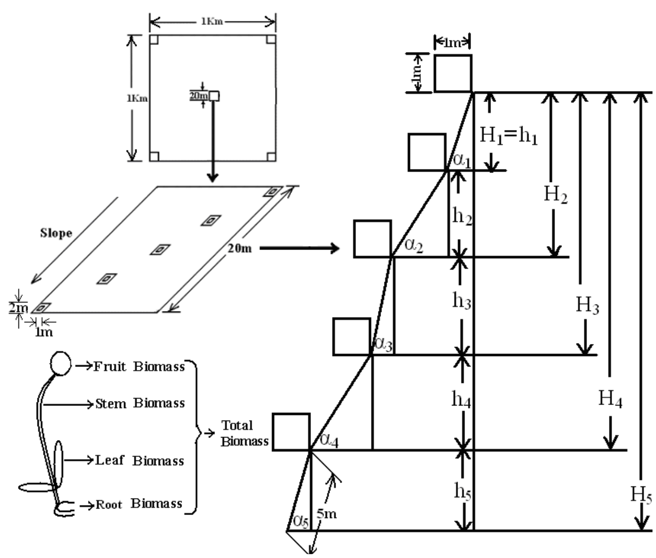

Figure 3. Quadrate settings and research methods. $H_1=h_1=5m \times Sin\alpha_1$; $H_2=h_1+h_2=5\ m \times (Sin\alpha_1+Sin\alpha_2)$; $H_3=h_1+h_2+h_3=5\ m \times (Sin\alpha_1+Sin\alpha_2+Sin\alpha_3)$; $H_4=h_1+h_2+h_3+h_4=5\ m \times (Sin\alpha_1+Sin\alpha_2+Sin\alpha_3+Sin\alpha_4)$; $H_5=h_1+h_2+h_3+h_4+h_5=5\ m \times (Sin\alpha_1+Sin\alpha_2+Sin\alpha_3+Sin\alpha_4+Sin\alpha_5)$.

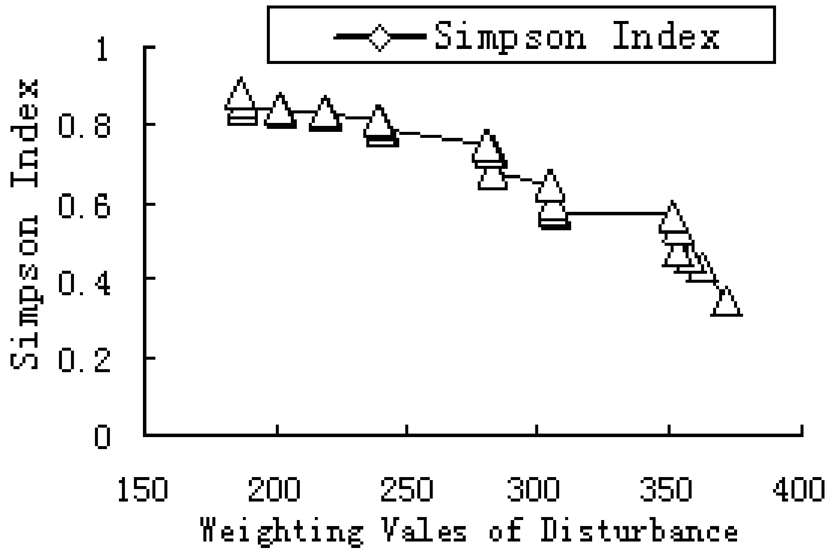

Figure 4. The relationship between Simpson and disturbance in the typical hilly areas boundary areas.

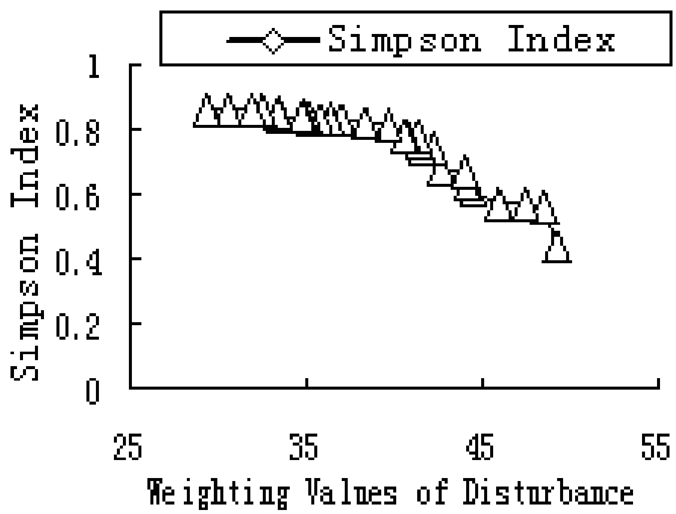

Figure 5. The relationship between Simpson and disturbance in the typical hilly areas center areas.

which were significantly negative correlated (P<0.01). The results indicate that disturbance, largely determined by weighting values of disturbance, are the most important environmental factors affecting the distribution of herb species diversity (Table 5).

The results indicate that elevation and disturbance are important environmental factors affecting the distribution of plant functional groups on southern slope of the *Fu-Niu* Mountain National Nature along elevation gradient, while distributions of individual species differed significantly along different elevation gradient (Figures 1 to 6, Table 6).

A general model of the links between herbaceous species diversity and disturbance gradient from IDH perspective (magnetohydrodynamics (MHD))

The IDH is used as a framework for investigating the linkages between disturbance and species diversity. Unfortunately, the various IDH makes it difficult to compare data from different studies in order to draw general conclusions (Connell, 1978;Aronson et al., 1995). It is therefore important to develop MHD which is

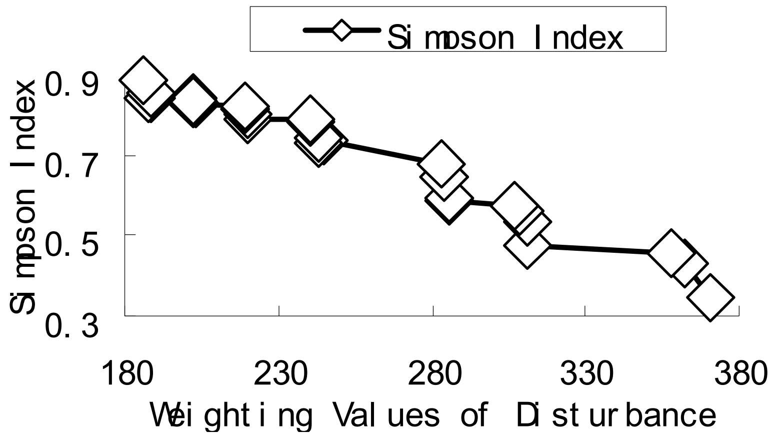

Figure 6. The relationship between Simpson and disturbance in the typical hilly areas.

Table 6. Dynamics of vegetation dominate species on the typical hill areas of the southern slope of the *Fu-Niu* Mountain National Nature at PFGs level along elevation gradient.

Number of site location	Elevation (m) †	South Slope
1	351	*Quercus variabills* and *Castanea mollissima* Mixed Forest
2	370	*Conyza canadensis* Herbs Vegetation
3	419	*Q. variabills* and *Lindera angustifolia* Mixed Forest
4	449	*Q. variabills* and *L. angustifolia* Mixed Forest
5	498	*Q. variabills* and *Cotinus coggygria* Mixed Forest
6	525	*Q.* and *C. mollissima* Mixed Forest
7	537	*Q. variabills* and *L. angustifolia* and *Melia azedarach* Mixed Forest
8	560	*C. canadensis* Herbs Vegetation
9	564	*Q. variabills* and *L. angustifolia* and *M. azedarach* Mixed Forest
10	568	*Populus L.* Forest
11	576	*Q. variabills* and *L. angustifolia* and *M. azedarach* Mixed Forest
12	577	*Phyllostachys glauca McClure* Forest
13	582	*Q. variabills* and *C. coggygria* and *L. angustifolia* Mixed Forest
14	584	*Populus L.* Forest
15	590	*Q. variabills* and *M. azedarach* Mixed Forest
16	602	*Cornus officinalis Sieb. et Zucc.* Forest
17	608	*Q. variabills* and *C. mollissima* and *L. angustifolia* Mixed Forest
18	620	*Q. variabills* and *L. angustifolia* Mixed Forest
19	636	*Pinus tabulaeformis Carr.* Forest
20	667	*Q. variabills* Forest

universally applicable across a range of ecosystems so that the relationship between herbaceous species diversity and disturbance gradient can be more accurately quantified with quantitative measurements of disturbance intensity. Here we proposed the use of a MHD framework that incorporates model (Figures 2 to 5) operating on varying spatio-temporal and disturbance scales for in-depth studies of the relationship between herbaceous species diversity and disturbance gradient (e.g. anthropogenic disturbance and natural disturbance). Such a MHD will facilitate ecosystem studies that apply the links between herbaceous species diversity and disturbance gradient from IDH perspective (Figures 1 to 7, Tables 1 to 6).

The above MHD can help identify the relationship between herbaceous species diversity and disturbance intensity most relevant to tolerating environmental fluctuations or recovering from IDH perspective (Figure

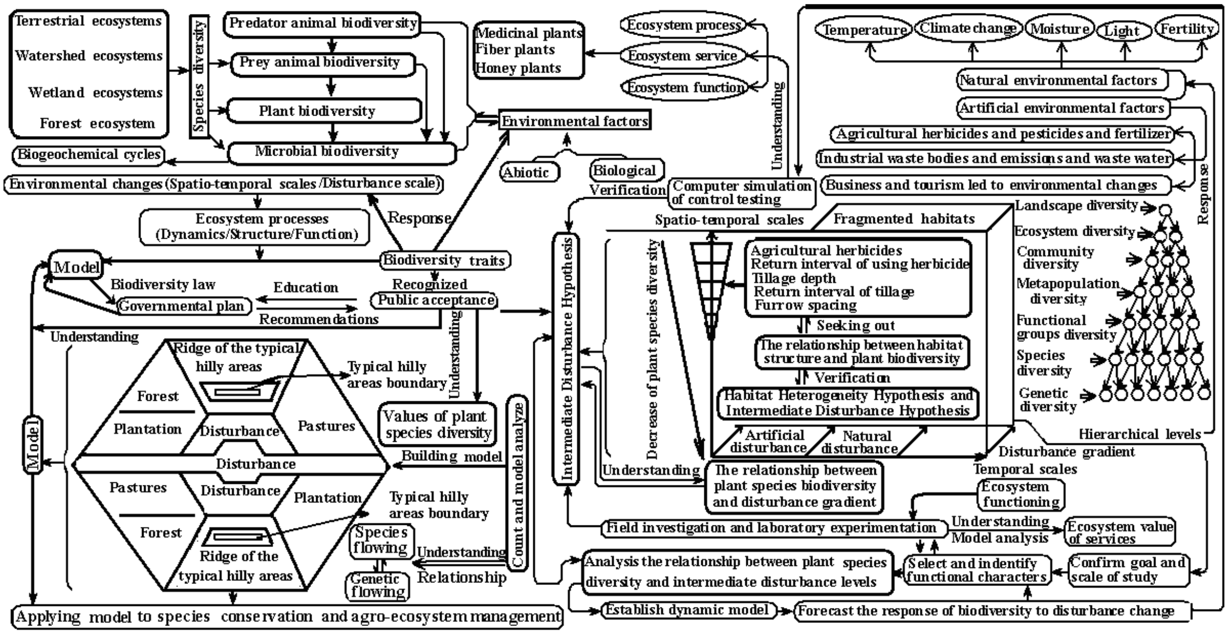

Figure 7. The proposed the framework of relationship between herbaceous species diversity and disturbance gradient that incorporates herbaceous species diversity dynamic from the intermediate disturbance level, and operating on varying spatio-temporal and disturbance scales in the forest ecosystem. The model was based on the study (Liao et al., 2010; 2011a, 2011b).

7). Based on the fact the MHD is useful to achieving the goal of ecosystem, sustainable development in the context of biodiversity conservation is needed. For example, Bartels et al. (2010) explained that whether resource quantity or resource heterogeneity is the determinant of understory plant diversity in individual studies was dependent on stand successional stage(s), presence or absence of intermediate disturbance, and forest biome within which the studies were conducted. Carvalheiro et al. (2011) suggest that presence of weeds allowed pollinators to persist within sunflower fields, maximizing the benefits of the remaining patches of natural habitat to productivity of this large-scale crop.

Applying general model to species conservation and forest ecosystem management

The above MHD can help identify theoretical ecology (e.g. diversity dynamics, species composition, food web structure, diversifying plant-microbial system, ecosystem stability/functioning, organic agriculture, biodiversity law, watershed ecosystem management, assessment of ecosystems and biodiversity, scale dependence) (Liao et al., 2010, 2011a, 2011b; Stutter et al., 2010; Shennan, 2008; Menalled et al., 2001, Bartels et al., 2010; Crowder et al., 2010; Bai et al., 2004; Davis et al., 2007; Bernez et al., 2002; Marris, 2010; Crawley et al., 2001). For instance, Menalled et al. (2001) suggest that ecosystem management systems can have both immediate and long-term effects on weed species density, abundance, and diversity. Shennan (2008) proposed that important elements for understanding biotic interactions include consideration of the effects of diversity, species composition and food web structure on ecosystem processes; the impacts of timing, frequency and intensity of disturbance; and the importance of multitrophic interactions in ecosystem. Stutter et al. (2010) proposed a mechanism whereby the establishment of vegetated buffer strips between cropland and watercourses on previous agricultural land causes a diversifying plant-microbial system. Bartels et al. (2010) explained that whether resource quantity or resource heterogeneity is the determinant of understory plant diversity in individual studies was dependent on stand successional stage(s), presence or absence of intermediate disturbance, and forest biome within which the studies were conducted.

Therefore, it will nonetheless be a substantial challenge to apply this MHD to specific real world policy problems (Gilbert 2010; James et al., 2010; Marris, 2010).

Conclusion

Progress in three key areas will substantially further efforts to gain a rigorous understanding of how the links between herbaceous species diversity and disturbance intensity, and their interactions, influence the response of ecosystem properties to changing biodiversity. First, better understanding of the relationship between herbaceous species diversity and disturbance intensity is correlated, particularly with respect to the predominant forces of human activities. Second, MHD is based on both field investigations of community ecology techniques of 100 herbaceous layer quadrates and scientific analysis, which can use more and more theoretical ecology. Finally, MHD can be useful to understand the plant species diversity and disturbance intensity from IDH perspective. Understanding MHD is essential for further research of local ecosystem functions and the goal of ecosystem sustainable development in the context of herbaceous biodiversity conservation in natural or artificial disturbance ecosystem. Therefore, MHD may help to ameliorate this situation about losses of plant species diversity (e.g. medicinal plants, honey plants, fiber plants, etc).

ACKNOWLEDGEMENT

This work was supported by the Forestry Department of Henan Province Science Foundation of China (No.201004044), the National Natural Science Foundation of China (No. 41071118) and by the many ideas of some researchers of "1st Biotechnology World Congress".

REFERENCES

Aronson RB, Precht WF (1995). Landscape patterns of reef coral diversity: a test of the intermediate disturbance hypothesis. J. Experimental Marine Biol. Ecol. 192(1): 1-14.

Bai YF, Han XG, Wu JG, Chuo ZZ, Li LH (2004). Ecosystem stability and compensatory effects in the Inner Mongolia grassland. Nature. 431: 181-184.

Bartels SF, Chen HY (2010). Is understory plant species diversity driven by resource quantity or resource heterogeneity? Ecology. 91(7):1931-1938.

Bernez I, Haury J, Ferreira MT (2002). Downstream effects of a hydroelectric reservoir on aquatic plant assemblages. Sci. World J. 2:740-750.

Biswas SR, Mallik AU (2010). Disturbance effects on species diversity and functional diversity in riparian and upland plant communities. Ecology. 91(1):28-35.

Boutin C (2008). Evaluating the relationship between floristic quality and measures of plant biodiversity along stream bank habitats. Ecological Indicators. 8(5): 466-475.

Carvalheiro LG, Veldtman R, Shenkute AG, Tesfay GB, Pirk CW, Donaldson JS, Nicolson SW (2011). Natural and within-farmland biodiversity enhances crop productivity. Ecology letters. 14(3):251-259.

Connell JH (1978). Diversity in tropical rain forests and coral reefs. Science. 199(4335): 1302-1310.

Crawley MJ, Harral JE (2001). Scale Dependence in Plant Biodiversity. Sci. 291: 864-868.

Crowder DW, Northfield TD, Strand MR, Snyder WE (2010). Organic agriculture promotes evenness and natural pest control. Nat. 466: 109-112.

Davis SR, Brown AG, Dinnin MH (2007). Floodplain connectivity, disturbance and change: a palaeoentomologi -cal investigation of floodplain ecology from south-west England. The J. Animal Ecol. 76(2): 276-288.

Gilbert N (2010). Biodiveristy law could stymie research. Nat. 463: 598.

James AN, Vorhies F (2010). Green development credits to forest global biodiversity. Nature. 465: 869.

Leis SA, Engle DM, Leslie DM Jr, Fehmi JS (2005). Effects of short- and long-term disturbance resulting from military maneuvers on vegetation and soils in a mixed prairie area. Environmental Management. 36(6): 849-861.

Liao BH, Wang XH (2010). Plant functional group classifications and a generalized hierarchical framework of plant functional traits. Afr. J. Biotechnol. 9: 9208-9213.

Liao BH, Ding SY, Hu Nan et al (2011a). Dynamics of environmental gradients on plant functional groups composition on the northern slope of the *Fu-Niu* Mountain Nature Reserve. Afr. J. Biotechnol.10:18939-18947.

Liao BH, Ding SY, Liang GF et al (2011b). Dynamics of plant functional groups composition along environmental gradients in the typical area of *Yi-Luo* River watershed. Afr. J. Biotechnol.10:14485-14492.

Marris E (2010). UN body will assess ecosystems and biodiversity. Nat. 465: 859.

Menalled FD, Gross KL, Mark H (2001). Weed aboveground and seedbank community responses to agricultural management systems. Ecological Applications. 11:1586-1601.

Shennan C (2008). Biotic interactions, ecological knowledge and agriculture. Philosophical transactions of the Rpyal Society of London. Series B, Biological sciences. 363(1492):717-739.

Simpson EH (1949). Measurement of diversity. Nature. Pp 163: 688.

Stutter MI, Langan SJ, Lumsdon DG (2009). Vegetated buffer strips can lead to increased release of phosphorus to waters: a biogeochemical assessment of the mechanisms. Environmental science & technology. 15;43(6): 1858-1863.