Agriculture, Ecosystems and Environment 145 (2011) 1–4

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Understanding species and community response to environmental change – A functional trait perspective

Camilla Wellstein[a,*], Boris Schröder[b,c], Björn Reineking[d], Niklaus E. Zimmermann[e]

[a] Department of Biogeography, University of Bayreuth, 95447 Bayreuth, Germany
[b] Institute of Earth and Environmental Sciences, University of Potsdam, 14476 Potsdam, Germany
[c] Leibniz Centre for Agricultural Landscape Research (ZALF e.V.), 15374 Müncheberg, Germany
[d] Biogeographical Modelling, University of Bayreuth, 95447 Bayreuth, Germany
[e] Research Unit Landscape Dynamics, Swiss Federal Research Institute WSL, 8903 Birmensdorf, Switzerland

ARTICLE INFO

Article history:
Received 25 May 2011
Received in revised form 14 June 2011
Accepted 23 June 2011
Available online 22 July 2011

Key words:
Functional traits
Functional diversity
Database
Land use
Management
Climate change
Landscape
Ecosystem function
Clonal plants
Dispersal
Plant growth
Orthoptera

1. Introduction

1.1. The use of trait-based approaches in ecology

The need to understand and project how species, communities and ecosystem functioning respond to environmental change, especially land use and climate change, is increasingly emphasized and is calling for trait-based approaches in ecology (e.g., Bernhardt-Römermann et al., 2011; De Bello et al., 2010; Klimešová et al., 2011; Suding et al., 2008; Walck et al., 2011; Webb et al., 2010; and this issue). These trait-based approaches characterize organisms in terms of multiple biological attributes that describe the organisms' functional response to the abiotic and biotic environment. Thereby, these approaches combine taxonomy, species occurrence (from local assemblages up to biogeographical scales), and functional ecology; in some cases, phylogenetic relatedness of co-occurring species is also taken into account (e.g., Mayfield et al., 2009). While currently in most studies, likewise in this issue, the taxonomic resolution is at the species level, investigations of intraspecific variability and its genetic background represent new promising research directions (e.g., Albert et al., 2010; Nicotra et al., 2010).

Following the functional response and effect trait framework (Lavorel and Garnier, 2002; Suding et al., 2008), research can be designed to test for response traits (that respond, e.g., to a certain environmental change), for effect traits (i.e., quantifying the effect of certain traits on certain ecosystem functions like e.g., net primary productivity), or for both. In this context, functional diversity, defined as 'the value and range and relative abundance of functional traits present in a community' (Tilman, 2001), is likely to be one of the major factors affecting ecosystem functioning (Hooper et al., 2005; Petchey and Gaston, 2006). However, only few studies are dealing with this challenging issue to date (Lavorel et al., 2007).

Parallel to new empirical studies, the use of increasingly available long-term and large-scale community datasets and trait databases points to the importance of eco-informatics and offers the possibility to contribute to answering ecologically and socio-economically relevant questions related to on-going

* Corresponding author. Tel.: +49 921 552299; fax: +49 921 552315.
E-mail address: camilla.wellstein@uni-bayreuth.de (C. Wellstein).

0167-8809/$ – see front matter
doi:10.1016/j.agee.2011.06.024

environmental change (e.g., Cornelissen et al., 2003; Kleyer et al., 2008; Klimešová and de Bello, 2009).

In the following chapter on 'methodological issues', we highlight recurrent ecological and methodological themes of this special issue. Against this theoretical backdrop we present a summary of 'key findings', organized by main study topics.

1.2. Methodological issues

Within this issue, the spatial scales range from single ecosystem to the landscape, the temporal scales explicitly address time spans from almost a decade up to a century. Furthermore, several studies operate with the issues of landscape history in order to either study design or interpretation of research results. The studies refer to animal and plant species, communities, and ecosystem functioning mainly of arable land, grassland, heathland, woodland and floodplain areas. The investigated environmental change considers change in land use, mainly manifested in alterations of disturbance regimes and nutrient supply, change in weather, climate and pathogen infestation.

The studies analyse these changes applying experiments as well as monitoring and modelling approaches. For statistical analyses a range of methods is used, including ordination, RLQ and fourth corner analysis (i.e., procedures to analyse the linkage between three matrices – species × sites, sites × environmental conditions, species × traits, cf. Dray and Legendre, 2008), uni- and multivariate analysis of variance including linear mixed-effects models as well as recursive partitioning (see the papers of this issue for details on the various methods).

In detail, sources of variation (i.e., environmental factors, explanatory variables) refer to published evidence and ecological expert knowledge with reference to the respective study context. The same holds true for the selection of functional traits, i.e., a priori selections are based on published evidence and expert knowledge on response and/or effect traits enabling the link to ecosystem functions. With the RLQ and fourth corner analyses the functional response groups are then evaluated based on both, the similarity of traits and their response to the environmental conditions.

From the ecosystems under study, contributions either use all present vascular plant species (in case of forests those of the understory vegetation), or they use dominant or most frequent plant species, or selected functional groups, or they focus on key/model species otherwise. Contributions using animal taxa focused on the order of Orthoptera, a group of terrestrial insects, on which grasshopper communities and bush-crickets as key/model species were investigated. Contributions analysing the community-level deal with species presence/absence data, weight species by their abundance/frequency or with their total cover. The resolution of organisms' traits is always at the species level, measured either directly within the investigated habitats or acquired from trait databases. Here, authors paid attention to ensure the applicability of traits, e.g., when dealing with leaf nutrient content, traits have to be measured in ecosystems with comparable nutrient levels (e.g., Doležal et al., 2011).

Between one (e.g., macropterism in Orthoptera) and 25 traits of interest are used per analysis. The effects of the investigated environmental change are studied for species richness, species composition, trait abundance, trait composition, emerging functional groups, functional diversity, and lastly by testing for species survival and extinction as well as for effects on ecosystem functioning.

By following the species' and community's response to environmental change with the functional trait perspective, all studies within this issue contribute to understanding the mechanisms behind the observed dynamics. From a scientific point of view, this special issue may contribute to getting on step further towards what was described as the Holy Grail (Lavorel and Garnier, 2002; Lavorel et al., 2007).

2. Key findings

Our overview is organized along three main topics, namely the effects of intermediate and long-term environmental change on species and community functional diversity, the effects on ecosystem functioning, and the relevance of the landscape context.

2.1. Intermediate- and long-term effects of changes in land-use, weather and climate

One study on intermediate-term, i.e., eight years, effects of weather impact on an Orthoptera species' reports changes of functional type densities. This key finding implies that the shift may affect dispersal capability and consequently influence the species' response by climate driven range expansion (Poniatowski and Fartmann, 2011).

The experimental and monitoring studies on longer-term effects of land use change, i.e., decades to centuries, report changes in community functional trait states caused by shifts in abundance as well as by species turnover, or changes in functional group abundance and functional group composition.

In a species-rich oligotrophic mountain meadow in the Czech Republic, mulching represented a management alternative that prevents plant community degradation after abandonment of traditional land use practices. In particular, mulching has promoted species and functional diversity by facilitating heliophilous forbs and legumes with more acquisitive strategies in resource use and release, e.g., higher foliar N and P content. This occurred at the expense of tall grasses (with resource-retentive strategies, e.g., high leaf dry matter content), which dominate the mown and fallow plots (13 years study context, Doležal et al., 2011).

In search of the driving forces behind the species' compositional changes after management alterations in a species-rich calcareous grassland in Southwest Germany, new equilibria of functional group composition were still not reached even after 30 years. Mowing has best maintained the functional group composition of the original grazing treatment, and the emerging functional group of competitive species profited most from alternative management treatments to grazing. (30 years study context, Drobnik et al., 2011).

In mountain beech forests of the Central Italian Apennine, the trait–environment relationships of a species-rich understory vegetation changed mainly 14 years after abandonment of coppicing. The increasing correlation between traits and environmental factors later on during succession indicates that the trait–environment relationship has stabilized (90 years study context, Campetella et al., 2011).

In a conceptual modelling study the authors explored the combined effects of a century of climate and habitat change on species survival based on selected functional types (Jeltsch et al., 2011). The authors were able to show that responses may differ among functional types, and that habitat restoration may be a successful conservation strategy under climate change.

2.2. Effects on ecosystem functioning

Environmental change may alter community abundance, structure, and composition implying functional changes that may lead to alterations in ecosystem functions. Since trait-linked plant-life processes such as, e.g., gas exchange, biomass production and hydraulic lift inherently contribute to ecosystem processes and services, shifts in trait alterations may represent mechanisms and causes for shifts in ecosystem functions. Deductive conclusions on ecosystem effects from measured trait-changes depend on the comparability of the ecological contexts in which effect traits were evaluated and are applied, and on the extent of intraspecific variability of the respective traits.

In general and when using this approach, results of research papers on functional response traits often point to some of the biological mechanisms controlling functions and services of ecosystems (e.g., Lienin and Kleyer, 2011). In particular, specific effect traits of the dominant species might strongly influence ecosystem functions. This is often referred to as the "biomass ratio hypothesis" (Grime, 1998). In this context, the comparison of different approaches of weighting traits by abundance is particularly interesting. Such a comparison was carried out by Bishop et al. (2011). They use a deductive approach to analyse functional linkages that became effective after the introduction of a forest pathogen in woodlands of the Southwest Australian Floristic Region. This environmental change substantially altered the trait composition indicating potential shifts in key ecosystem functions such as productivity, carbon storage, and hydrology over an ecologically short time period.

In oligotrophic grasslands (Doležal et al., 2011) measure ecosystem functioning, namely productivity, directly together with changes in functional traits and moreover in functional diversity. Measurement results for abandoned sites suggest that over the course of certain years productivity is positively related, e.g., with specific leaf area and leaf nutrient content. A positive relation between productivity and functional diversity exists, e.g., in phenology and seed dispersal traits.

2.3. Functional responses in the landscape context

Several studies explicitly addressed the landscape-level complexity due to natural heterogeneity (e.g., by topography, geology and hydrology) and/or heterogeneity in land use (e.g., by farming systems, land use intensity, or abandonment) when analysing trait–environment relationships. The environmental factors considered in these studies all represent different disturbance regimes, e.g., regimes of agricultural and silvicultural land use, and flooding. Two layers of impact on community functional characteristics can be distinguished: First, the site-scale impact that is influenced by local environmental and land-use differences of habitats, e.g., manifesting in disturbance intensity at a site. Second, the landscape-scale impact linked to the spatial landscape characteristics, e.g., manifesting in the fraction of intensively used land vs. semi-natural/natural habitats such as woodlands.

In particular, José-María et al. (2011) demonstrated effects of agricultural intensification on the distribution of plant functional traits in cereal fields in the Mediterranean Central Catalonia. They report that farming system affected growth form and pollination vector distributions, while the within-field disturbance gradient affected the abundance distribution of life forms. Furthermore, simple landscapes, with more open areas, may favour wind-dispersed species (José-María et al., 2011).

In the temperate Northwest Germany, Lienin and Kleyer (2011) determined trait–environment relationships for agricultural ecosystems. They find that plant leaf economics and reproductive investment respond to gradients of land use intensity: traits were strongly related to soil resources that co-varied with disturbance, emphasizing the relevance of local scales (Lienin and Kleyer, 2011).

In mountain beech forests of the Mediterranean Apennines (Italy), succession stand age proved to be more important in explaining trait variability than natural heterogeneity in e.g., elevation, inclination and bedrock (Campetella et al., 2011).

In floodplains of the Elbe River (North Germany), Dziock et al. (2011) studied Orthoptera communities along a land use and flood disturbance gradient and identified two complementary life history strategies: high active dispersal-low reproduction strategy in intensive land use situations, and high passive dispersal-high reproduction strategy in areas with high flood disturbance.

In a conceptual modelling framework, Jeltsch et al. (2011) show that correlated changes between habitat and climatic conditions can accelerate (in case of habitat loss or degradation) or slow down (in case of habitat gain or improvement) regional species extinction; the strength of such effects depend on the overall landscape capacity of the species, local turnover at the patch level, and the species' dispersal characteristics.

This special issue comprises a broad array of studies on functional traits. The contributions highlight the continuous challenge of understanding the dynamics of biodiversity and the linkage of biodiversity and ecosystem functioning. The knowledge gained in this research field promises to be a valuable basis for the development of adaptation strategies to environmental change.

Acknowledgement

We are grateful to the authors for their contributions and to all reviewers for their valuable comments on the manuscripts of this special issue. The special issue was initiated at the 39th annual meeting of the Ecological Society for Germany, Austria and Switzerland (GfÖ). Camilla Wellstein and Björn Reineking thank the Bavarian Ministry of Science, Research and Art for funding within the FORKAST project. Niklaus E. Zimmermann acknowledges funding from FP6 (ECOCHANGE, GOCE-CT-2007-036866) and FP7 (MOTIVE, ENV-CT-2009-226544). Boris Schröder was supported by the German Science Foundation (grant no. SCHR 1000/3-1 and SCHR 1000/4-1).

References

Albert, C.H., Thuiller, W., Yoccoz, N.G., Douzet, R., Aubert, S., Lavorel, S., 2010. A multi-trait approach reveals the structure and the relative importance of intra- vs. interspecific variability in plant traits. Funct. Ecol. 24, 1192–1201.

Bernhardt-Römermann, M., Gray, A., Vanbergen, A., Bergès, L., Bohner, A., Brooker, R.W., De Bruyn, L., De Cinti, B., Drinböck, T., Grandin, U., Hester, A.J., Kanka, R., Klotz, S., Loucougaray, G., Lundin, L., Matteucci, G., Meszaros, I., Oláh, V., Preda, E., Prevosto, B., Pykälä, J., Schmidt, W., Taylor, M.E., Vadineanu, A., Waldmann, T., Stadler, J., 2011. Functional traits and local environment predict vegetation responses to disturbance: a pan-European multi-site experiment. J. Ecol. 99, 777–787.

Bishop, C.L., Williams, M.R., Wardell-Johnson, G.W., 2011. A forest pathogen drives change in plant functional trait composition in the Southwest Australian Floristic Region. Agric. Ecosyst. Environ. 145, 59–66.

Campetella, G., Botta-Dukat, Z., Wellstein, C., Canullo, R., Gatto, S., Chelli, S., Mucina, L., Bartha, S., 2011. Patterns of plant trait–environment relationships along a forest succession. Agric. Ecosyst. Environ. 145, 38–48.

Cornelissen, J.H.C., Lavorel, S., Garnier, E., Diaz, S., Buchmann, N., Gurvich, D.E., Reich, P.B., ter Steege, H., Morgan, H.D., van der Heijden, M.G.A., Pausas, J.G., Poorter, H., 2003. A handbook of protocols for standardised and easy measurement of plant functional traits worldwide. Aust. J. Bot. 51, 335–380.

De Bello, F., Lavergne, S., Meynard, C.N., Lepš, J., Thuiller, W., 2010. The partitioning of diversity: showing theseus a way out of the labyrinth. J. Veg. Sci. 21, 992–1000.

Doležal, J., Mašková, Z., Lepš, J., Steinbachová, D., de Bello, F., Klimešová, J., Tackenberg, O., Zemek, F., Květ, J., 2011. Positive long-term effect of mulching on species and functional trait diversity in a nutrient-poor mountain meadow in Central Europe. Agric. Ecosyst. Environ. 145, 10–28.

Dray, S., Legendre, P., 2008. Testing the species traits–environment relationships: the fourth-corner problem revisited. Ecology 89, 3400–3412.

Drobnik, J., Römermann, C., Bernhardt-Römermann, M., Poschlod, M., 2011. Adaptation of plant functional group composition to management changes in calcareous grassland. Agric. Ecosyst. Environ. 145, 29–37.

Dziock, F., Gerisch, M., Siegert, M., Hering, I., Scholz, M., Ernst, R., 2011. Reproducing or dispersing? Using trait based-habitat templet models to analyse Orthoptera response to flooding and land use. Agric. Ecosyst. Environ., accepted, in this issue.

Grime, J.P., 1998. Benefits of plant diversity to ecosystems: immediate, filter and founder effects. J. Ecol. 86, 902–910.

Hooper, D.U, Chapin, F.S., Ewel, J.J., Hector, A., Inchausti, P., Lavorel, S., Lawton, J.H., Lodge, D.M., Loreau, M., Naeem, S., Schmid, B., Setala, H., Symstad, A.J., Vandermeer, J., Wardle, D.A., 2005. Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. Ecol. Monogr. 75, 3–35.

Jeltsch, F., Moloney, K.A., Schwager, M., Körner, K., Blaum, N., 2011. Consequences of correlations between habitat modifications and negative impact of climate change for regional species survival. Agric. Ecosyst. Environ. 145, 49–58.

José-María, L., Blanco-Moreno, J.M., Armengot, L., Sans, F.X., 2011. How does agricultural intensification modulate changes in plant community composition? Agric. Ecosyst. Environ. 145, 77–84.

Kleyer, M., Bekker, R.M., Knevel, I.C., Bakker, J.P., Thompson, K., Sonnenschein, M., Poschlod, P., Van Groenendael, J.M., Klimeš, L., Klimešová, J., Klotz, S., Rusch, G.M., Hermy, M., Adriaens, D., Boedeltje, G., Bossuyt, B., Dannemann, A., Endels, P., Götzenberger, L., Hodgson, J.G., Jackel, A.-K., Kühn, I., Kunzmann, D., Ozinga, W.A., Römermann, C., Stadler, M., Schlegelmilch, J., Steendam, H.J., Tackenberg, O., Wilmann, B., Cornelissen, J.H.C., Eriksson, O., Garnier, E., Peco, B., 2008. The LEDA Traitbase: a database of life-history traits of Northwest European flora. J. Ecol. 96, 1266–1274.

Klimešová, J., de Bello, F., 2009. CLO-PLA: the database of clonal and bud bank traits of Central European flora. J. Veg. Sci. 20, 511–516.

Klimešová, J., de Bello, F., Herben, T., 2011. Searching for the relevance of clonal and bud bank traits across floras and communities. Folia Geobotanica 46, doi:10.1007/s12224-010-9088-z, in this issue.

Lavorel, S., Garnier, E., 2002. Predicting changes in community composition and ecosystem functioning from plant traits: revisiting the Holy Grail. Funct. Ecol. 16, 545–556.

Lavorel, S., Díaz, S., Cornelissen, J.H.C., Garnier, E., Harrison, S.P., McIntyre, S., Pausas, J.G., Pérez-Harguindeguy, N., Roumet, C., Urcelay, C., 2007. Plant functional types: are we getting any closer to the Holy Grail? In: Canadell, J.G., Pataki, D., Pitelka, L. (Eds.), Terrestrial Ecosystems in a Changing World. The IGBP Series. Springer, Berlin/Heidelberg, pp. 149–160.

Lienin, P., Kleyer, M., 2011. Plant leaf economics and reproductive investment are responsive to gradients of land use intensity. Agric. Ecosyst. Environ. 145, 67–76.

Mayfield, M.M., Boni, M.F., Ackerly, D.D., 2009. Traits, habitats, and clades: identifying traits of potential importance to environmental filtering. Am. Nat. 174, E1–E22.

Nicotra, A.B., Atkin, O.K., Bonser, S.P., Davidson, A.M., Finnegan, E.J., Mathesius, U., Poot, P., Purugganan, M.D., Richards, C.L., Valladares, F., van Kleunen, M., 2010. Plant phenotypic plasticity in a changing climate. Trends Plant Sci. 15, 684–992.

Petchey, O.L., Gaston, K.J., 2006. Functional diversity: back to basics and looking forward. Ecol. Lett. 9, 741–758.

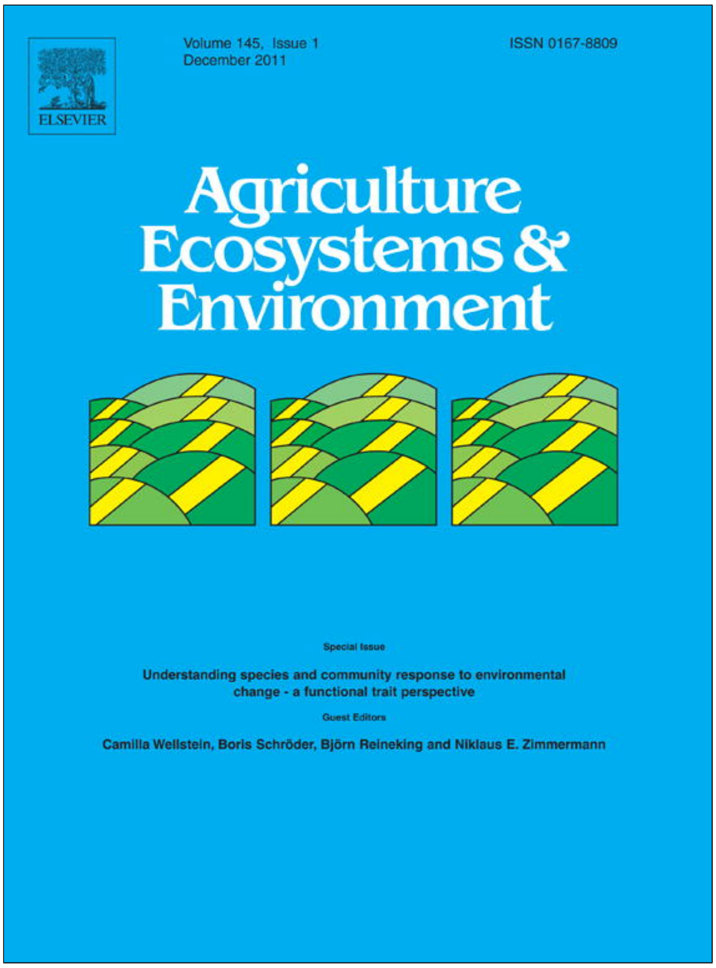
Poniatowski, D., Fartmann, T., 2011. Weather-driven changes in population density determine wing dimorphism in a bush-cricket species. Agric. Ecosyst. Environ. 145, 5–9.

Suding, K.N., Lavorel, S., Chapin, F.S., Cornelissen, J.H.C., Diaz, S., Garnier, E., Goldberg, D., Hooper, D.U., Jackson, S.T., Navas, M.L., 2008. Scaling environmental change through the community-level: a trait-based response-and-effect framework for plants. Global Change Biol. 14, 1125–1140.

Tilman, D., 2001. Functional diversity. In: Levin, S. (Ed.), Encyclopaedia of Biodiversity, vol. 3. Academic Press, San Diego, pp. 109–120.

Walck, J., Hidayati, S.N., Dixon, K.W., Thompson, K., Poschlod, P., 2011. Climate change and plant regeneration from seed. Global Change Biol. 17, 2145–2161.

Webb, C.T., Hoeting, J.A., Ames, G.M., Pyne, M.I., Poff, N.L., 2010. A structured and dynamic framework to advance traits-based theory and prediction in ecology. Ecol. Lett. 13, 267–283.


Volume 145, Issue 1
December 2011
ISSN 0167-8809
ELSEVIER
Agriculture Ecosystems & Environment
Special Issue
Understanding species and community response to environmental change - a functional trait perspective
Guest Editors
Camilla Wellstein, Boris Schröder, Björn Reineking and Niklaus E. Zimmermann