Chapter 1
Introduction

Abstract Functional diversity is an increasing used concept to address changes in biodiversity. It is an emerging concept which summarizes key properties of ecosystems of special interest in global climate change studies and in the evaluation of the effects of land management in the preservation of ecosystem services for human wellbeing. In this chapter we introduce the main notions associated with functional diversity approach, including definition of functional diversity, ecosystem processes, and ecosystem services and linking these concepts to species traits. We highlight the importance of functional diversity approach using some examples to show the relationship between ecosystem services with species traits.

Keywords Ecosystem services · Functional traits · Functional diversity assessment · Millennium ecosystem assessment · Functional ecology

1.1 Functional Diversity Approach to Quantify the Biodiversity

Functional ecology establishes principles and tools to forge links between the characteristics of communities, and ecosystem functions and services (Cornelissen et al. 2003; Lavorel et al. 2007). For example, the energy and materials flow through the biotic and abiotic components of an ecosystem is directly related to productivity, while resistance and resilience are measures of the ability of a system to respond before the disturbance or adapting to change (Díaz and Cabido 2001).

The functional approach allows simplify the floristic complexity and the effects of vegetation to understand the responses, in terms of key ecological processes. It also provides tools to identify and monitor global change effects and other consequences of human activity, emphasizing ecosystem services (ES). This functional

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approach transcends the descriptive analysis. It can be done in a relatively easy, inexpensive and standardized way, allowing the comparison among communities and between community properties and environmental variables.

According to Grime (1998) three groups of species may be identify related to its contribution to the community performance: dominants, subordinates and transients. Dominant species are the most important species as determinants of ecosystem properties such as productivity, carbon sequestration, water relations, nutrient cycling and storage, litter quality and resistance and resilience to perturbations. Ecosystem functions are likely to be closely predictable from the most abundant species, those which contribute highly to the total plant biomass. This is known as mass ratio hypothesis (Grime 1998). The contributions to ecosystem functions are dictated by the laws of physics and chemistry. They state that the greater the effects of large autotrophs within the ecosystem, there will be a greater participation in processes like photosynthesis, resources inputs, nutrient cycling, and hydrology cycle, among others. This implies that ecosystem properties should be determined mainly by dominants species and some subordinates, and much less by transients' species.

Application of the mass ratio hypothesis is restricted to autotrophs in ecosystem processes. In animals, when attention is turned to trophic elements, like parasites, herbivores, and predators, impact on ecosystem functions is less related to abundance (Grime 1998).

Functional diversity approach using plants is based on the most abundant species, which implies the inclusion of all the species necessary to account for the 80% of the total biomass. When species' biomass is not available, other measures like cover, basal area or abundance may be used as surrogate for biomass (Díaz et al. 2007a; Lavorel et al. 2008). The protocols applied for the functional characterization comply with this recommendation discarding the less represented species in the community.

Ecosystem services are the benefits that humans obtain from ecosystems for support their survival and quality of life. The benefit may be directly associated to survival like food production or to effects indirectly related to quality of life, like energy provision (MEA 2005). ES are also used to link the ecological concept of functional diversity with the social concept of social actor strategies (Díaz et al. 2011). Going deeper into the links among biodiversity, ES, and social actors it is necessary to consider the contributions that biodiversity provides to an ES, the social actors perception, their needs, access, and management capability of the ES (Carpenter et al. 2009).

The ecosystem services depend on ecosystem properties which in turn are determined by ecosystem functions and ecosystem processes. For example, soil fertility (as service that ecosystem provide) depends on textural composition, organic matter accumulation and nutrient cycling. Not all ES depend directly upon ecosystem processes; some are associated to aesthetic or spiritual value of species (Díaz et al. 2007a; de Bello et al. 2010). For example, the aesthetic value of flowers from *Rafflesia arnoldii*, a parasitic species, with flowers up to more than 1 m, the largest in the world, growing in Sumatra (Beaman et al. 1988), or the presence of a relic species of dolphins, *Lipotes vexillifer*, in the Yangtze river in China (Zhou et al. 1998), which is threatened by the dam harbor the largest hydropower plant in the world (López-Pujol 2008).

The ecosystem functions are determined by the role of different species in maintaining ecosystem processes. Changes in species composition and changes in the relative abundance have a direct implication over ecosystem structure in terms of community dynamics. Ecosystem properties related to ES would be referred as a function or process. As emphasis of functional diversity is placed on the services that an ecosystem can provide, we will use ecosystem properties to describe collectively the ecosystem processes and functions.

1.2 Functional Diversity Assessment

Functional diversity is defined as the value, range, distribution and relative abundance of the functional characteristics of organisms in a community (Chapin et al. 2000; Loreau and Hector 2001; Hooper et al. 2005). In contrast to the taxonomic biodiversity, based only on the relative abundance of species in the community, functional diversity summarizes various aspects of the biological composition and hence the role of populations in the community. Functional diversity may be linked directly to the ecosystem services (Díaz et al. 2007c).

As functional diversity states for characteristics of individuals of species in the community, a set of characteristics has to be evaluated. A trait is a well-defined, measurable property of organisms, usually measured at the individual level and used comparatively across species. A functional trait is one that strongly influences organismal performance in the community (Lavorel and Garnier 2002; Cornelissen et al. 2003; Violle et al. 2007). Trait values influence growth, reproduction and survival of organisms, and affect relationship among organisms of different species. These, in turn, drive the properties and services that ecosystem may provide (Luck et al. 2009).

The best subset of traits are those that provided the most complete information related to an ecosystem service under study and that, simultaneously, may be easily measured with the least sample effort and at a low cost. For example, to study photosynthesis capacity, measurement of area and weight of leafs may be used to estimate specific leaf area, meanwhile, maximum high or diameter at breast height registered at two or more times may be used to study growth rate.

There is empirical evidence that specific leaf area is positively correlated with photosynthetic potential and hence growth rates, recruitment and mortality, and negatively correlated with longevity and investment in defenses. For example, Garnier et al. (2004) found that the 58% of variation ($r^2 = 0.58$) of specific above-ground net primary productivity (g kg^{-1} d^{-1}) in 12 plots of vegetation in south France may be estimated using specific leaf area (m^2 kg^{-1}). Also, leaf dry matter content, and leaf tensile strength are negatively correlated with photosynthetic potential and hence growth rates, recruitment and mortality, and are positively correlated with longevity and investment protection and defenses (Almeida-Cortez et al. 1999).

There is international consensus around the importance to follow a protocol to measure traits and there are international efforts to have information on traits values for as many species as possible. The project TRY (www.try-db.org) is an effort to collate existing plant functional trait data set into a communal repository (Kattge et al. 2011a). This initiative have now three million trait records for about 69000 plant species and about 50 scientific projects are using plant trait data via TRY. There are some guidelines to make your own data base part of TRY (Kattge et al. 2011b) and also to use data base from TRY. You may learn more about the data sharing policy within TRY going to the web page.

1.3 Classification of Ecosystem Services

According to the Millennium Ecosystem Assessment (MEA 2003) ecosystem services may be classify in four main groups. The classification differentiates among provisioning services, regulating services, cultural services and supporting services. Production of food, availability of fresh water, provision of fuel-wood, fiber, biochemical and genetic resources are provisioning services. Regulating services refer to the benefits obtained from regulation of ecosystem properties, like climate regulation, disease regulation, water regulation, water purification, pollination. Cultural services join those nonmaterial benefits obtained from ecosystems. Spiritual and religious services, recreation and ecotourism, aesthetic, inspirational, educational, sense of place and cultural heritage are examples of cultural ecosystem services (MEA 2003).

Supporting services, those necessary for the production of all other ecosystem services, like soil formation, nutrient cycling or primary production were considered as the fourth group in Millennium Ecosystem Assessment classification. Some ecosystem services included in this group are nowadays considered as part of the regulating services, or as ecosystem properties like primary production, oxygen production and nutrient cycling (Carpenter et al. 2009; Díaz et al. 2011; Polania et al. 2011).

1.4 Selection of Traits According to Ecosystem Service

To evaluate functional diversity at a community or assemblage, traits associated to main ecosystem properties has to be identify. Several studies identify the traits that have more prediction capability of ecosystem properties. For example, primary productivity, carbon accumulation in vegetation, soil carbon accumulation and decomposition rate are used to evaluate climatic regulation through carbon sequestration. To evaluate these properties we use traits like growth form and growth rate, plant height, plant longevity, wood density, dry matter, lignin, leaf nitrogen content, leaf longevity, toughness of leaves, specific leaf area (SLA) and leaf mass per area (LMA), potential decomposition rate of leaves, and stems and specific root length (Lavorel and Garnier 2002; Díaz et al. 2004, 2009; Wardle et al. 2004; De Deyn et al. 2008).

Ecosystems may provide services to control water erosion. This service depends on water retention in soil and sediment, litter and standing vegetation, and balance between infiltration and runoff, properties that may be evaluate considering traits like growth form and growth rate of the plant, plant longevity, crown architecture, clonality, longevity of leaves, dry matter, lignin and nitrogen content in leaves, potential decomposition rate of leaves and stems, root architecture and deep and underground stems (Brauman et al. 2007).

Production of forage for herbivores like livestock, wild species or symbolic species is an ecosystem process associated with food provision. Traits associated with food provision are growth form and growth rate of the plant, plant longevity, plant high, regrowth, position of the buds of renewal, longevity of leaves, dry matter, lignin and nitrogen content in leaves, phosphorus and active toxic compounds in leaves, leaf toughness, specific leaf area (SLA) and leaf mass per area (LMA), symbiosis with nitrogen fixer microorganisms or insects (Wright et al. 2002; Díaz et al. 2007b; Quétier et al. 2007).

1.5 Functional Diversity Quantification

There are several methods to quantify functional diversity, the preference for one or another relays on type of available information and is related to the aims of research. All methods are based on data of functional traits measured, at least, at species level. The following chapters focus on methods to quantify functional diversity, how to relate functional diversity with environmental variables and its relation with ecosystem services. Numerical examples are analyzed using a free specialized software: FDiversity (Casanoves et al. 2011), which can be downloaded from www.fdiversity.nucleodiversus.org.

One option to quantify functional diversity is to estimate the number of functional groups in the community. This is a measure of functional richness. A functional group is a subset of the species present at the assemblage that shared similar trait profiles. Composition of functional group in a given community may vary according to the service being investigated. Functional groups are identified by cluster analysis of trait's profiles. In Chap. 2 we present this methodology and use one example to defined plant functional groups and other to define bird functional groups (guilds).

Functional diversity may also be summarized using functional indices. These indices are based on traits' values evaluated at species level. They may also incorporate weights by some measure of the species importance in the community. Chapter 3 is entirely dedicated to functional indices definitions. We included taxonomy of the indices based upon the information they used and the output they offer. For each index we will include its definition, the information needed to estimate it, it's statistical and ecological properties, and some reference to explore its application to real cases.

The last chapter of the book, Chap. 4 is a tutorial to estimate the indices using FDiversity (Di Rienzo et al. 2008). Three step by step examples are presented. For each one we calculate the functional diversity indices and compare results from several communities to determine statistical differences among them, or explore the relationship with environmental variables. The data sets and key detailed output of the analysis are available at Springer's Extra Materials website: http://extras.springer.com/.

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