Metadata of the chapter that will be visualized online

Chapter Title	Taxonomic and Functional Response of Arbuscular Mycorrhizal Fungi to Land Use Change in Central Argentina	
Copyright Year	2016	
Copyright Holder	Springer International Publishing Switzerland	
Corresponding Author	Family Name	**Silvana**
	Particle	
	Given Name	**Longo**
	Suffix	
	Division	
	Organization/University	Instituto Multidisciplinario de Biología Vegetal (IMBIV), CONICET, Universidad Nacional de Córdoba
	City	Córdoba
	Country	Argentina
Author	Family Name	**Noelia**
	Particle	
	Given Name	**Cofré**
	Suffix	
	Division	
	Organization/University	Instituto Multidisciplinario de Biología Vegetal (IMBIV), CONICET, Universidad Nacional de Córdoba
	City	Córdoba
	Country	Argentina
Author	Family Name	**Florencia**
	Particle	
	Given Name	**Soteras**
	Suffix	
	Division	

Q1

Q2

	Organization/University	Instituto Multidisciplinario de Biología Vegetal (IMBIV), CONICET, Universidad Nacional de Córdoba
	City	Córdoba
	Country	Argentina
Author	Family Name	**Gabriel**
	Particle	
	Given Name	**Grilli**
	Suffix	
	Division	
	Organization/University	Instituto Multidisciplinario de Biología Vegetal (IMBIV), CONICET, Universidad Nacional de Córdoba
	City	Córdoba
	Country	Argentina
Author	Family Name	**Monica**
	Particle	
	Given Name	**Lugo**
	Suffix	
	Division	
	Organization/University	Diversidad e Interacciones Fúngicas, IMIBIO-CONICET, Universidad Nacional de San Luis
	City	San Luis
	Country	Argentina
Author	Family Name	**Carlos**
	Particle	
	Given Name	**Urcelay**
	Suffix	
	Division	
	Organization/University	Instituto Multidisciplinario de Biología Vegetal (IMBIV), CONICET, Universidad Nacional de Córdoba
	City	Córdoba
	Country	Argentina

Abstract	It has been predicted that land use change will pose the main threat to biodiversity worldwide (Sala et al. 2000). A recent meta-analysis shows that, at local scale, conversion and degradation of habitats promote on average a global decline of 8.1 % of species richness and 10.1 % of abundance (Newbold et al. 2015). These human-mediated changes in biodiversity strongly affect ecosystem stability (Hautier et al. 2015). Given the importance of biodiversity on ecosystem functions and services, studies on the effects of land use on species assemblages are highly relevant in current global context.
Keywords (separated by " - ")	Glomeromycota - Life history strategies - Biodiversity - Disturbance

AUTHOR QUERIES

Q1 Please provide email address for the corresponding author.

Q2 "Longo Silvana" has been set as the corresponding author. Please check and advise if correct.

Chapter 7
Taxonomic and Functional Response of Arbuscular Mycorrhizal Fungi to Land Use Change in Central Argentina

[AU1]
[AU2]
[AU3]

Longo Silvana, Cofré Noelia, Soteras Florencia, Grilli Gabriel, Lugo Monica, and Urcelay Carlos

7.1 Introduction

It has been predicted that land use change will pose the main threat to biodiversity worldwide (Sala et al. 2000). A recent meta-analysis shows that, at local scale, conversion and degradation of habitats promote on average a global decline of 8.1 % of species richness and 10.1 % of abundance (Newbold et al. 2015). These human-mediated changes in biodiversity strongly affect ecosystem stability (Hautier et al. 2015). Given the importance of biodiversity on ecosystem functions and services, studies on the effects of land use on species assemblages are highly relevant in current global context.

Despite that soil is an important reservoir of biodiversity (van der Heijden et al. 2008) and that belowground communities are important drivers of aboveground communities and ecosystem processes (Wardle et al. 2004), soil biota is generally underrepresented in studies linking land use–biodiversity–ecosystem processes.

Arbuscular mycorrhizal fungi (AMF) (Phylum Glomeromycota) are one of the main components of the soil biota. They are present in most terrestrial ecosystems and establish obligate symbiosis with more than the 80 % of land plants (Smith and Read 2008). These fungi depend on plant photosynthetic carbon while providing

---

L. Silvana (✉) • C. Noelia • S. Florencia • G. Gabriel • U. Carlos
Instituto Multidisciplinario de Biología Vegetal (IMBIV), CONICET,
Universidad Nacional de Córdoba, Córdoba, Argentina

L. Monica
Diversidad e Interacciones Fúngicas, IMIBIO-CONICET, Universidad Nacional de San Luis,
San Luis, Argentina

M. Pagano (ed.), *Recent Advances on Mycorrhizal Fungi*, Fungal Biology 0,
DOI 10.1007/978-3-319-24355-9_7

them with soil nutrients, among other benefits (Smith and Read 2008). The outcome of the plant–fungus interaction highly depends on the fungal and plant identity and the environmental context.

It has been widely documented that AMF affects plant community structure (e.g., van der Heijden et al. 1998) and ecosystem processes such as productivity (e.g., Klironomos et al. 2000), decomposition (e.g., Urcelay et al. 2011), and soil aggregation (e.g., Rillig and Mummey 2006). Then, local decline of AMF diversity under land use would have consequences on plant communities and ecosystem functioning.

It has been recognized that not only richness or diversity per se but also functional traits of species are important for understanding the response of biotic communities to land use change as well as their impacts on ecosystem processes and services (e.g., Díaz et al. 2007). This trait-based approach has also been recognized as a useful framework to understand fungal ecology (e.g., van der Heijden and Scheublin 2007; Koide et al. 2014; Aguilar-Trigueros et al. 2014).

The functional characteristics of AMF are considered phylogenetically fairly conserved (Hart and Reader 2002; Powell et al. 2009; Maherali and Klironomos 2012). Based on C–S–R triangle (competitor, stress tolerator, ruderal) framework (Grime 1979), Chagnon et al. (2013) recently assigned life history strategies to the three main lineages of AMF (Gigasporaceae, Glomeraceae, and Acaulosporaceae). Accordingly, Gigasporaceae are considered “competitors” characterized by high soil hyphal densities, late production of spores in the growing season, and higher nutritional benefits to hosts. In contrast, Glomeraceae are “ruderals” characterized by higher growth rates, higher intraradical colonization, early production of spores, and low soil hyphal densities. The higher intraradical colonization rates and lower soil hyphal densities imply less nutritional benefits to hosts (e.g., Maherali and Klironomos 2007). In turn, Acaulosporaceae is considered “stress tolerators” with low growth rates, long-lived mycelium, resistance to acidity and low temperature among other stressors, and probably more investment in constitutive defense (Chagnon et al. 2013). These life history strategies could also be useful to explain fungal assemblages in successional dynamics and their response to disturbances imposed by land use change (Chagnon et al. 2013).

In central Argentina (Fig. 7.1), land uses such as fire, grazing, and forest fragmentation are among the most important environmental changes (Zak et al. 2004). In the last 15 years, some studies were performed to assess the impact of those anthropogenic activities on AMF communities. Here we review those studies to analyze the response of AMF to land use. We particularly aimed to assess whether grazing, fire, and forest fragmentation (a) promote a decline of AMF taxonomic diversity and (b) negatively affect Gigasporaceae and Acaulosporaceae lineages' spore abundance and Glomeraceae remains unaffected as predicted by the C–S–R framework (Fig. 7.2). [AU4]

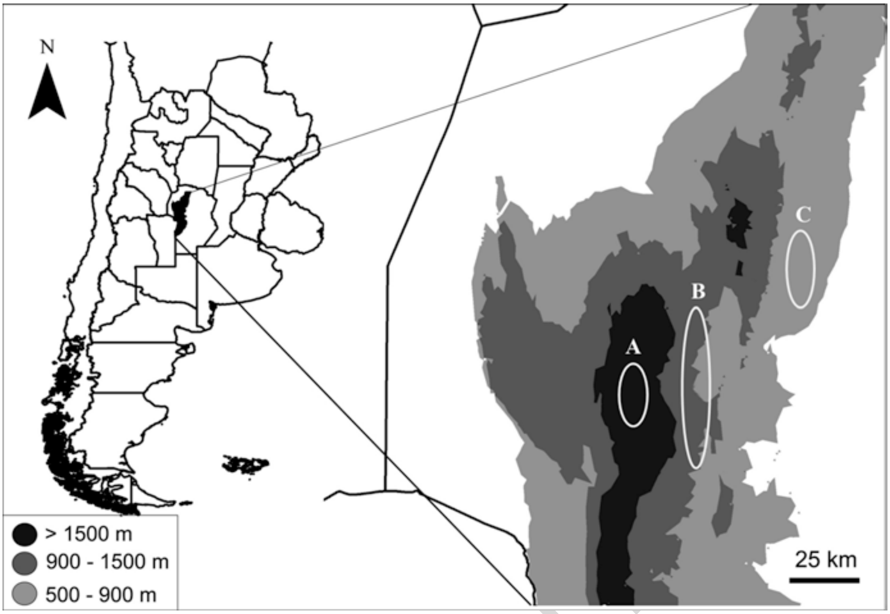

Fig. 7.1 Location of studied areas with each land use in Córdoba, central Argentina. (**a**) Mountain Grasslands (grazing). (**b**) Chaco Serrano Forests (fire). (**c**) Chaco Forests (forest fragmentation)

7.2 Effects of Land Use on Diversity and Abundance of AMF Spores

To evaluate the effect of grazing on AMF spore communities, Lugo and Cabello (2002) conducted a study located in altitudinal grasslands in central Argentina. Six sampling sites were selected: three grazed and three ungrazed for a minimum of 20 years. Samplings were carried out over four seasons. The main findings of this study revealed no differences in spore richness, diversity, and abundance.

Instead, Longo et al. (2014) found that fire severely affects AMF diversity. In this landscape-level study, five locations were selected in Chaco Serrano Forests. In each location, five nearby burned and unburned sites were studied in two seasons (autumn and spring). Results showed that diversity, richness, and evenness of AMF spores consistently decreased in the five burned sites and in some cases nearly half. However, spore abundance was not significantly affected by the fire.

It has been widely documented that habitat loss promoted by human-mediated forest fragmentation strongly affects biological community's dynamics (e.g., Saunders et al. 1991). In this context, area size is an important factor affecting [AU5] biodiversity (Haddad et al. 2015). Grilli et al. (2012) aimed to evaluate the relationship between area size of forest remnants and AMF spore communities at the

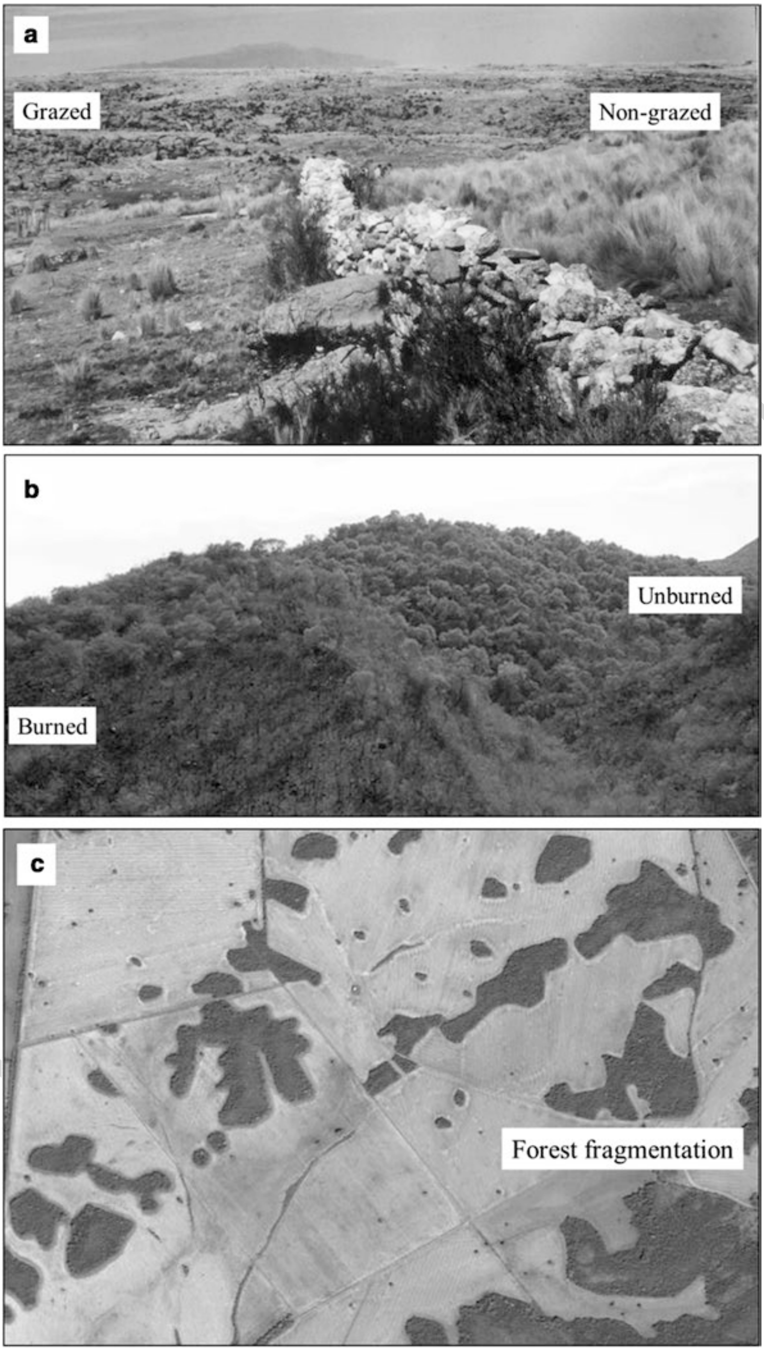

Fig. 7.2 Photographs of the three studied land uses. (**a**) Grazing in mountain grasslands; (**b**) fire in Chaco Serrano forests; (**c**) forest fragmentation in Chaco

landscape level. To this end, eight forest fragments with different sizes (0.86–1000 ha) immersed in an agricultural matrix in the Chaco region were selected. In this study, diversity of spores decreased with decreasing area size, while abundance marginally did it.

In Table 7.1 we summarized the direction of the response of each species (positive, neutral, or negative) to each land use *per* sampling season in those studies. Two species occurred in more than one study: *Entrophospora infrequens* and *Scutellospora biornata*. They were negatively affected in one case (by fire in spring) but not affected in the other five. The remaining species were analyzed within each particular study.

Grazing significantly decreased the abundance of *Scutellospora* sp. in one out of four seasons (winter). In contrast, the following species increased in response to grazing in one season: *Acaulospora laevis* (winter), *A. mellea* (autumn), and *Glomus* sp. (autumn). The remaining species showed neutral response to grazing.

Fire significantly decreased the abundance of several species. *Acaulospora rehmii*, *A. scrobiculata*, *Gigaspora gigantea, Gigaspora* sp. 1*,* and *Gigaspora* sp. 3 consistently decreased their abundance in burned sites in both seasons. In turn, *Ambispora jimgerdemannii*, *Entrophospora infrequens, Dentiscutata heterogama, Scutellospora biornata,* and *Scutellospora* sp. declined with fire in spring, while *Racocetra gregaria* and *Acaulospora* sp. 1 did it in autumn. In contrast, *Septoglomus constrictum* consistently increased in abundance in burned sites over both seasons, while *Glomus* sp. 4 and *Glomus* sp. 5 only did it in spring.

In fragmented forest, three unidentified species of *Glomus* significantly declined their abundance with decreasing area size. The remaining species were not affected.

These results show that the response of AMF depends on the land use type. While fire and reduction of area size seem to strongly decrease AMF diversity, no important differences between grazed and non-grazed sites were observed.

In comparison to fire and forest size reduction, grazing might not strongly affect soil properties and plant diversity. Indeed, despite that livestock grazing removes plant biomass they increase plant diversity in the studied mountain grasslands (e.g., Pucheta et al. 1998). In contrast, fire imposes great impacts to soils such as reduction or elimination of the aboveground and belowground biomass, loss of soil organic horizon, and increase in soil temperature and ash deposition (Neary et al. 1999; Certini 2005), at least in the short term (Neary et al. 1999). Regarding forest fragmentation, it has been shown in the studied area that reduction in area size is accompanied by a decrease in plant diversity (Cagnolo et al. 2006). Then, different impacts on soil properties and plant communities might explain the differential response of AMF communities to the studied land uses.

[AU6]

When looking at particular AMF, several species were not affected by land use while others consistently decreased or increased. Examples of these last cases are some *Gigaspora* species that decreased their abundance in burned sites in both seasons, while *Septoglomus constrictum* behaved in the opposite way (Table 7.1). These species could be considered as indicators of land use in the studied region (Oehl et al. 2003).

Table 7.1 Response of AMF spore species to land use (+: increased, −: decreased, and =: did not change)

Land use type							
	Fire spring	Fire autumn	Grazing summer	Grazing autumn	Grazing winter	Grazing spring	Area size
Acaulosporaceae							
Acaulospora alpina							
A. bireticulata							
A. cavernata	=	=					
A. excavata							
A. foveata							
A. lacunosa							
A. laevis			=	=	+	=	
A. mellea			=	+	=	=	
A. rehmii	–	–					
A. rugosa							
A. scrobiculata	–	–					
A. spinosa							
A. undulata							
Ambisporaceae							
Ambispora appendicula							
A. jimgerdemannii	–						
A. leptoticha							
Claroideoglomeraceae							
Claroideoglomus claroideum	=	=					
C. luteum							
Entrophosporaceae							
Entrophospora infrequens	–	=	=	=	=	=	
Gigasporaceae							
Dentiscutata heterogama	–	=					
Gigaspora gigantea	–	–					
G. margarita							
G. rosea							
Racocetra gregaria	=	–					
Scutellospora biornata	–	=	=	=	=	=	
Glomeraceae							
Funneliformis badium							
F. geosporum							
F. mosseae							

(continued)

Table 7.1 (continued)

Land use type							
	Fire spring	Fire autumn	Grazing summer	Grazing autumn	Grazing winter	Grazing spring	Area size
Glomus aggregatum	=	=					
G. brohultii							
G. dimorphicum			=	=	=	=	
G. fuegianum			=	=	=	=	
Rhizophagus clarus							
R. intraradices							
Sclerocystis coremioides	=	=					
Sclerocystis rubiformis			=	=	=	=	
Septoglomus constrictum	+	+					
Unidentified (Longo et al. 2014)							
Glomus sp. 1	=	=					
Glomus sp. 2	=	=					
Glomus sp. 3	–	=					
Glomus sp. 4	+	=					
Glomus sp. 5	+	=					
Glomus sp. 6	=	=					
Glomus sp. 7	=	=					
Glomus sp. 8	=	=					
Glomus sp. 9	=	=					
Glomus sp. 10	=	=					
Glomus sp. 11	=	=					
Claroideoglomus sp.	–	=					
Acaulospora sp. 1	=	–					
Acaulospora sp. 2	=	=					
Acaulospora sp. 3	=	=					
Gigaspora sp. 1	–	–					
Gigaspora sp. 2	=	=					
Gigaspora sp. 3	–	–					
Scutellospora sp.	–	=					
Unidentified (Grilli et al. 2012)							
Glomus sp. 1							=
Glomus sp. 2							–
Glomus sp. 3							=
Glomus sp. 4							=
Glomus sp. 5							=

(continued)

Table 7.1 (continued)

Land use type							
	Fire spring	Fire autumn	Grazing summer	Grazing autumn	Grazing winter	Grazing spring	Area size
Glomus sp. 7							–
Glomus sp. 8							=
Glomus sp. 9							=
Glomus sp. 10							=
Sclerocystis sp.							–
Gigaspora sp. 1							=
Gigaspora sp. 2							=
Unidentified (Lugo and Cabello 2002)							
Acaulospora2			=	=	=	=	
Acaulospora3			=	=	=	=	
Glomus spp.			=	+	=	=	
Glomus sp. 7			=	=	=	=	
Glomus sp. 3			=	=	=	=	
Scutellospora sp.			=	=	–	=	

7.3 Effects of Land Use on AMF Spores: A Functional Group Approach

Arbuscular mycorrhizal fungi were grouped into three functional groups according to their traits (*sensu* Chagnon et al. 2013): Gigasporaceae, Acaulosporaceae (Acaulosporaceae + Ambisporaceae + Entrophosporaceae), and Glomeraceae (Cl aroideoglomeraceae + Glomeraceae + Pacisporaceae). Then, the number of cases in each functional group that evidenced negative, neutral, or positive response to land use was computed and a Chi-square analysis on absolute frequency was applied (Table 7.2).

The AMF functional groups were differentially affected by land use ($X_2 = 37.69$; $p = 0.0001$). Specifically, Glomeraceae was mainly unaffected (84 % of analyzed cases) and the few positive and negative responses were equally distributed in the remnant cases. In turn, 74 % of Acaulosporaceae revealed neutral responses, while 20 % and 6 % were negative and positive, respectively. In contrast, Gigasporaceae showed 58 % of neutral and 42 % of negative response cases.

It is worth to highlight that Glomeromycota as a whole seem to be fairly resistant to land use since spore abundance was mostly unaffected. Nevertheless, there were clear differences between functional groups.

In line with the C–S–R framework for strategies in AMF (see Fig. 1.1 in Chagnon et al. 2013), Gigasporaceace and Glomeraceae represented opposite trends in their response to land use. This is consistent with the competitor–ruderal life history axis,

Table 7.2 Number of positive, neutral, and negative response cases regarding the spore abundance of species belonging to three AMF functional groups

Functional group	Land use effect		
	Positive	Neutral	Negative
Glomeraceae	5	53	5
Acaulosporaceae	2	26	7
Gigasporaceae	0	15	11
Total	7	94	23

Glomeraceae includes Claroideoglomeraceae, Glomeraceae, and Pacisporaceae. Acaulosporaceae includes Acaulosporaceae, Ambisporaceae, and Entrophosporaceae; see Table 7.1 for more details

[AU7] closely related to environmental conditions caused by disturbance intensity. In turn, Acaulosporaceae showed to be in mid position of the axis. This is not fully consistent with the scheme adapted by Chagnon et al. (2013).

The majority of Glomeraceae seems to be resistant to disturbance posed by land use such as fire, grazing, and forest fragmentation. This is consistent with their "ruderal" life strategy which is characterized by rapid growth, capacity to fuse hypha and restore integrity of the mycelium in soil, and earlier investment in spore production (Chagnon et al. 2013). On the other hand, an important proportion of cases in Gigasporaceae reveal that this group is particularly sensitive to disturbance and would behave as "competitors." They need to allocate large quantities of carbon to extraradical mycelia for soil exploration and sporulate later in the growing season (Chagnon et al. 2013). These traits make this functional group fairly incompatible with the disturbances generally associated with land use. The results suggest that Acaulosporaceae have traits situated in between "ruderal–competitor" axis, but this remains to be explicitly measured.

Overall, these results reveal that trait-based approaches, in particular the C–R–S framework, provide useful insight for ecological understanding of AMF ecology in face of global change.

7.4 Conclusions and Future Directions

Altogether, the results analyzed here reveal that land uses in central Argentina (grazing, fire, and forest fragmentation) tend to negatively affect AMF diversity, mainly those human activities that involve severe soil damaging and decrease plant diversity such as fire and forest fragmentation. When considering AMF functional groups, Glomeraceae seems to be resistant to these land uses, while Gigasporaceae seems to be fairly sensitive. It could be predicted that these changes in AMF taxonomic diversity and functional traits would have consequences on successional dynamics and ecosystem processes. For example, it has been shown that Glomeraceae invests more in intraradical colonization than extraradical mycelium and this may imply less nutritional benefits to plant hosts. In contrast, Gigasporaceae largely invests in extraradical mycelium allowing for better exploitation of soil resources, particularly P, thus enhancing benefits to plant hosts (Maherali and Klironomos 2007). In addition, the large amounts of soil mycelium might promote better soil aggregation through glomalin secretion by these fungi (Rillig and Mummey 2006).

Further studies using trait-based approaches would be useful to test hypothesis regarding the AMF-mediated effects of land use on successional dynamics. This seems to be a fruitful way forward to gain knowledge for making predictions about the consequences of global changes on plant community dynamics and ecosystem functioning.

Acknowledgments This work was supported by Secyt (UNC) and Agencia Córdoba Ciencia. We thank CONICET and the Universidad Nacional de Córdoba (Argentina), both of which supported the facilities used in this investigation.

[AU8]

References

Aguilar-Trigueros CA, Powell JR, Anderson IC, Antonovics J, Rillig MC (2014) Ecological understanding of root-infecting fungi using trait-based approaches. Trends Plant Sci 19(7):432–438

Cagnolo L, Cabido M, Valladares G (2006) Plant species richness in the Chaco Serrano Woodland from central Argentina: ecological traits and habitat fragmentation effects. Biol Conserv 132:510–519

Certini G (2005) Effects of fire on properties of forest soils: a review. Oecologia 143:1–10

Chagnon PL, Bradley RL, Maherali H, Klironomos JN (2013) A trait-based framework to understand life history of mycorrhizal fungi. Trends Plant Sci 9:484–491

Díaz S, Lavorel S, de Bello F, Quétier F, Grigulis K, Robson TM (2007) Incorporating plant functional diversity effects in ecosystem service assessments. Proc Natl Acad Sci USA 104(52):20684–20689

Grilli G, Urcelay C, Galetto L (2012) Forest fragment size and nutrient availability: complex responses of mycorrhizal fungi in native–exotic hosts. Plant Ecol 213:155–165

Grime JP (1979) Plant strategies and vegetation processes. Chichester, Wiley

Hart MM, Reader RJ (2002) Taxonomic basis for variation in the colonization strategy of arbuscular mycorrhizal fungi. New Phytol 153:335–344

Hautier Y, Tilman D, Isbell F, Seabloom EW, Borer ET, Reich PB (2015) Anthropogenic environmental changes affect ecosystem stability via biodiversity. Science 348(6232):336–340

Jansa J, Erb A, Oberholzer HR, Smilauer P, Egli S (2014) Soil and geography are more important determinants of indigenous arbuscular mycorrhizal communities than management practices in Swiss agricultural soils. Mol Ecol 23:2118–2135

Klironomos JN (2002) Feedback with soil biota contributes to plant rarity and invasiveness in communities. Nature 417:67–70

Klironomos JN, McCune J, Hart M, Neville J (2000) The influence of arbuscular mycorrhizae on the relationship between plant diversity and productivity. Ecol Lett 3:137–141

Koide RT, Fernandez C, Malcolm G (2014) Determining place and process: functional traits of ectomycorrhizal fungi that affect both community structure and ecosystem function. New Phytol 201(2):433–439

Longo S, Nouhra E, Goto BT, Berbara RL, Urcelay C (2014) Effects of fire on arbuscular mycorrhizal fungi in the Mountain Chaco Forest. For Ecol Manag 315:86–94

Lugo M, Cabello MN (2002) Native arbuscular mycorrhizal fungi (AMF) from mountain grassland (Cordoba, Argentina) I. Seasonal variation of fungal spore diversity. Mycologia 94:579–586

Maherali H, Klironomos JN (2007) Influence of phylogeny on fungal community assembly and ecosystem functioning. Science 316:1746–1748

Maherali H, Klironomos JN (2012) Phylogenetic and trait-based assembly of arbuscular mycorrhizal fungal communities. PLoS One 7, e36695

Neary DG, Klopatek CC, DeBano LF, Ffolliott PF (1999) Fire effects on belowground sustainability: a review and synthesis. For Ecol Manag 122:51–71

Newbold T, Hudson LN, Hill SLL, Contu S, Lysenko I, Senior RA, Börger L, Dominic Bennett DJ, Choimes A, Collen B, Day J, De Palma A, Díaz S, Echeverria-Londoño S et al (2015) Global effects of land use on local terrestrial biodiversity. Nature 520:45–50

Oehl F, Sieverding E, Ineichen K, Mäder P, Boller T, Wiemken A (2003) Impact of land use intensity on the species diversity of arbuscular mycorrhizal fungi in agroecosystems of Central Europe. Appl Environ Microbiol 69:2816–2824

Powell JR, Parrent JL, Hart MM, Klironomos JN, Rillig MC, Maherali H (2009) Phylogenetic trait conservatism and the evolution of functional tradeoffs in arbuscular mycorrhizal fungi. Proc Biol Sci 276:4237–4245

Pucheta E, Cabido M, Díaz S, Funes G (1998) Floristic composition, biomass, and aboveground net plant production in grazed and protected sites in a mountain grassland of central Argentina. Acta Oecol 19(2):97–105

Rillig MC, Mummey DL (2006) Mycorrhizas and soil structure. New Phytol 171:41–53

Sala OE, Chapin FS III, Armesto JJ, Berlow E, Bloomfield J, Dirzo R, Huber Sannwald E, Huenneke LF, Jackson RB, Kinzig A, Leemans R, Lodge DM, Mooney HA, Oesterheld M, Poff NL, Sykes MT, Walker BH, Walker M, Wall DH (2000) Global biodiversity scenarios for the year 2100. Science 287:1770–1774

Saunders DA, Hobbs RJ, Margules CR (1991) Biological consequences of ecosystem fragmentation: a review. Conserv Biol 5:18–32

Smith SE, Read DJ (2008) Mycorrhizal symbiosis, 3rd edn. Academic, London

Urcelay C, Vaieretti M, Perez M, Díaz S (2011) Effects of arbuscular mycorrhizal colonization on shoot and decomposition of different species and species mixtures. Soil Biol Biochem 43:466–468

van der Heijden MG, Scheublin TR (2007) Functional traits in mycorrhizal ecology: their use for predicting the impact of arbuscular mycorrhizal fungal communities on plant growth and ecosystem functioning. New Phytol 174:244–250

van der Heijden MG, Klironomos JN, Ursic M, Moutoglis P, Streitwolf-Engel R, Boller T, Wiemken A, Sanders IR (1998) Mycorrhizal fungal diversity determines plant biodiversity, ecosystem variability and productivity. Nature 396:69–72

van der Heijden MG, Bardgett RD, van Straalen NM (2008) The unseen majority: soil microbes as drivers of plant diversity and productivity in terrestrial ecosystems. Ecol Lett 11:296–310

Wardle DA, Bardgett RD, Klironomos JN, Setälä H, van der Putten WH, Wall DH (2004) Ecological linkages between aboveground and belowground biota. Science 304:1629–1633

Zak MR, Cabido M, Hodgson JG (2004) Do subtropical seasonal forests in the Gran Chaco, Argentina, have a future? Biol Conserv 120(4):589–598

Author Queries

Chapter No.: 7 0002626632

Queries	Details Required	Author’s Response
AU1	Please check if the affiliations are presented correctly.	
AU2	Please provide email address for the corresponding author.	
AU3	“Longo Silvana” has been set as the corresponding author. Please check and advise if correct.	
AU4	Missing citation for “Fig. 7.3” was inserted here. Please check if appropriate.	
AU5	“Haddad et al. 2015” is cited in text but not given in the reference list. Please provide details in the list or delete the citation from the text.	
AU6	“Neary et al. 1995” has been changed to “Neary et al. 1999” as per the reference list, here and in subsequent occurrences. Please check if okay.	
AU7	Please note that the “*” has been removed from “Table 7.2” footnote.	
AU8	“Jansa et al. 2014; Klironomos 2002” have been provided in the reference list but their citations in the text/body are missing. Please advise location of their citations. Otherwise, delete them from the reference list.	