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CONCEPTS & THEORY

Socio-economic, scientific, and political benefits of mycotourism

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Citation: Büntgen, U., J. Latorre, S. Egli, and F. Martínez-Peña. 2017. Socio-economic, scientific, and political benefits of mycotourism. Ecosphere 8(7):e01870. 10.1002/ecs2.1870

Abstract. Rural areas particularly suffer from economic crises where they overlap with long-term negative effects of climate change. Here, we introduce the concept of mycotourism by means of mushroom-related industries in central-northeastern Spain. We describe how this novel branch of eco-tourism can help stabilize social and political structures. Likewise, we illuminate the potential of mycotourism to compensate for some losses related to widespread unemployment and summer drought, as well as to generate unexpectedly fruitful research opportunities. Focussing on Spain's emerging black truffle industry, we recommend a stronger involvement of natural sciences, conservation services, and management strategies in commercial endeavors. We emphasize the relevance of direct and indirect climatic impacts on ecological and societal systems as well as on economic markets. Moreover, we stress the importance of a vital science–policy interface at various scales, with immediate opportunities for sustainable landscape protection and the preservation of biological diversity.

Key words: climate change; economic crisis; Iberian Peninsula; long-term drying; non-wood forest products; Périgord black truffle.

Received 19 April 2017; revised 22 May 2017; accepted 24 May 2017. Corresponding Editor: Debra P. C. Peters.

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INTRODUCTION

Societies are particularly vulnerable if negative effects of climate change coincide with the devastating impacts of economic crises in space and time (Carleton and Hsiang 2016). Similar to California, South Africa, and parts of Australia, many areas of the Iberian Peninsula are currently not only suffering from an exceptionally high rate of unemployment (http://ec.europa.eu/eurostat/), but also experience an unprecedented drying trend since around the mid-1970s until present (Cook et al. 2016). An ending of either circumstance remains unpredictable, let alone both. Adaptation and mitigation strategies therefore become critical for the maintenance of societal structures and political stability in rural areas, as well as for the conservation of ecological and agricultural systems. The ongoing situation of intertwined direct and indirect climatic, economic, and political factors is alarming in many parts of the Mediterranean region (Kelley et al. 2015). However, this condition may also offer unexpected scientific challenges and research opportunities, in tandem with anticipated mutual benefits for a deeper understanding of the functioning and productivity of a diversity of ecological components, as well as for an eminent

improvement of conservation services and related management strategies.

Here, we use an example from central-northeastern Spain to introduce the unconventional, and relatively novel, concept of mycotourism in connection with state-of-the-art fungal ecology research. Mycotourism is herein defined as a specialized product of eco-tourism that attracts individuals across all demographics to harvesting in mushroom-rich forests, and by way of growing sectors of gastronomy and markets, as well as other socio-cultural activities and economic benefits (Latorre Minguell and Martínez-Peña 2016). We use this new branch of mycological-oriented eco-tourism as a prime example to demonstrate how innovative research programs can, synergistically with other social programs, compensate some of the losses due to socio-economic and climatic crises.

About 15 yr ago, mycotourism was established within the Spanish mycological program of Castilla and León (http://www.micocyl.es). Mycotourism has rapidly gained attention, evidenced by popularity now outside of Spain, for example, in Canada and Scotland, and even more informally at restaurants and groceries worldwide offering locally wild, fresh, harvested fungi. Mycotourism is far more connected to the local society of a place than mushroom forays or scientific research ever seem to reach, and thus is of greater applicability to the general public and local economy.

We focus on one of the worldwide mycological icon species, the Périgord black truffle (*Tuber melanosporum*), to advocate a stronger involvement of environmental sciences and conservation strategies into commercial endeavors experiencing drought-induced instability. Moreover, we stress the importance of political attempts to facilitate non-bureaucratic implementation of interrelated ecological research projects and conservation avenues into the growing sector of commercial truffle cultivation. We further address different pathways of improving rural development programs and increasing biological diversity to ultimately support existing and establish new strategies of sustainable landscape and ecosystem services. We target the mycological community to move forward in public awareness, funding opportunities, and socio-economic realities that, ultimately, affect fungal ecology research. Although using examples from central-northeastern Spain, our findings are of relevance for many regions around the globe.

Socio-Economic Benefits

The Spanish Province of Soria, approximately 150 km north of Madrid, exhibits the lowest population density of the entire Iberian Peninsula (8.7 persons/km^2). During the last 15 yr, regional (52%) and national governments (10%), together with the European Union (38%), invested around 8.5 million euros in this rural area to build up a worldwide unique system for ensuring sustainable (ecological) management and (economic) valorization of wild edible mushrooms and its producing forest habitats (Junta de Castilla y León 2014). An exceptional alliance of mycologists, foresters, gastronomes, farmers, and politicians created a wide-ranging program of mushroom-related subjects (Martínez-Peña et al. 2011). Joined forces between communal, national, and even European-wide initiatives boosted public interest in mushroom picking and associated activities (http://www.micocyl.es/). The continuously growing awareness of mycotourism increased local to international interests in this region and enhanced regional gastronomy and the hotel sector (Latorre Minguell 2014, Martínez-Peña et al. 2015).

Today, there are ~160,000 (425,000) hectares of public woodland in Soria (Castilla and León) where mushroom harvesting is strictly regulated by licensing. Between 2013 and 2015, >150,000 harvesting permits in Soria generated a total income of ~755,000 euros. Eleven mycological parks (http://www.micosylva.com/parques) in eight Provinces of Castilla and León are expected to contribute toward sustainable forest management practices. A mycological park represents a protected forest area that is committed to both the protection and utilization of wild mushrooms. Two complementary pathways have therefore been introduced: (1) the improvement of forest management strategies that account for the ecological requirements of fungal communities; (2) the improvement of edible mushroom resources that contribute to economic and socio-cultural developments of the region. None of the established mycological parks conflict with areas of special ecological restrictions, and protected

zones have been rigorously excluded from any mycotouristic activities. Each mycological park further established fungal reserves in which harvesting is strictly permitted.

In utilizing trained mycotourism guides and promoting restaurants that serve the local products, these parks bring a mycological perspective to silviculture (mycosilviculture) so that the region can adapt adequately to a multitude of climate change-related effects, while promoting sustainability and helping conserve biological diversity. Frequently organized mushroom markets (www.mercasetas.es) additionally facilitate sales of an array of fresh and non-perishable, local fungal products, and further help extend commerce to international markets (Fig. 1).

The rural landscape of Castilla and León receives ~251,000 mushroom-related tourists per year, generating an average income of ~32 million euros. Since this value has been constantly increasing during recent years, it translated in a structural development of the nearby rural territories. The average direct spending per mycotourist has been estimated as ~130 euros per year (Latorre Minguell 2014). Spanish middle-aged families from urban areas, such as Madrid, Barcelona, and Bilbao, are mainly attracted by the leisure of harvesting, gastronomy, and cultural activities related to wild mushrooms. In addition to mycotourism, wild edible mushroom forest resources in Castilla and León generate incomes to the agro-food industry, permit authorities, and trade activities. The total value of the mycological sector in Castilla and León accumulates to ~65 million euros per year (Martínez-Peña et al. 2015).

The benefits of mycotourism extend beyond economics. No conflicts with other types of land use and/or tourist activities have been reported, and we anticipate mutual benefits to occur between different components of the tourism sector. Likewise, mycotourism contributes to the conservation of biological and ecological systems, as well as the preservation of cultural habits, through the dissemination of traditional mushroom harvesting practices and ecological scientific

Fig. 1. (A, B) Examples of the newly established mushroom markets (http://www.mercasetas.es/) and (C) the emerging sector of truffle orchards in the Province of Soria, central-northeastern Spain. Both aspects play an important economic role for rural societies and landscapes, with additional benefits for ecological and political systems. While markets and their associated events (http://www.micosylva.com/) may also have a strong educational function, orchards can provide a multitude of unique opportunities for interdisciplinary research projects. The gain and exchange of mycological insights, together with a rising gastronomic interest, will ultimately enhance ecological and societal sustainability, as well as political acceptance.

knowledge to the general public. Note in this context that sustainable management of mycological resources is a primary goal of each mycological park; mushroom harvesting requires a permit, and the number of permits depends on the mycological productivity of each forest and can change from year to year. An official mushroom permit limits each harvester to the collection of specific species. The overall amount and size of the collected fruit bodies per day is also defined. A mycological park further provides mycological guidance for inexperienced tourists, including information about poisonous species. Good practice of harvesting and respect for the environment is a prerequisite in all mycological parks of Castilla and León, where more than 3000 harvesters are controlled by forest wardens every year.

Most edible fungi from this region are cosmopolitan in temperate European regions. Besides the high culinary value of porcini (*Boletus edulis*) and the saffron milk cap (*Lactarius deliciosus*) in this part of Spain (Büntgen et al. 2015*a*), the Périgord black truffle is one of the economically most important species in Spain, France, and Italy (Büntgen et al. 2015*a*). The rapidly emerging truffle hotspots in the Spanish Provinces of Soria and Teruel attract tourists from all over the world. At the same time, the species' belowground lifecycle, symbiotic interaction with host plants, and climate sensitivity are, despite recent scientific advances, still not fully understood (see references herein).

Scientific Benefits

Although the last ~15 yr of mycotourism describe a socio-economic success for large parts of rural central-northeastern Spain, we recommend a stronger involvement of research endeavors, especially in those projects that have either pioneering character and/or high socio-economic, political as well as ecological significance. In addition to the ample ecological insights that emerge from spatiotemporally explicit mushroom fruiting inventories (Büntgen et al. 2015*a*, Andrew et al. 2016), one such case is the plantation of oak seedlings after inoculation with truffle spores (Stobbe et al. 2013). The increasing number of truffle orchards (Fig. 1C), not only in Spain but also in many other countries of similar biogeographic conditions in Europe and elsewhere, provides a unique opportunity for the establishment of experimental settings, management interventions, artificial treatments, as well as long-term observations for better understanding the productivity and phenology of truffles and the behavior of their host trees throughout different phases of forest stand development (Büntgen et al. 2017).

Carefully designed scientific escort of the truffle industry (e.g., research concepts adapted to nurseries and orchards) appears particularly timely under the recent "global climate change" umbrella (Büntgen et al. 2012), because model-based climate projections almost uniformly point to a continuation of western Mediterranean drying (Seager et al. 2014, Fischer and Knutti 2015, Kelley et al. 2015). A drought-induced reduction in seasonal soil moisture availability and a longer-term depression of the groundwater level have been suggested to affect the vitality of truffle host trees (Büntgen et al. 2015*b*). This defines one of the most obvious challenges for an efficient and sustainable irrigation system that would obviously benefit from scientific guidance. Moreover, there is a need to further assess the complex interplay of biotic processes and abiotic drivers of the symbiotic truffle–host interaction, as well as the yet-unknown maturation of truffle fruit bodies (Büntgen et al. 2015*b, 2017*). Cross-disciplinary approaches should also investigate the optimal tree age and plantation density, the risk of invasive species, as well as fungi–host diseases, insect threats, and other pathogens (Rosa-Gruszecka et al. 2017). Although operating on larger spatiotemporal scales, aspects of soil degradation and landscape transformation should be considered equally. Pending myco-ecological research avenues (Büntgen and Egli 2014) should be complemented by the needs of conservationists, not only in Spain but also elsewhere.

The expected impetus should be jointly generated by farmers and researchers (as well as politicians) at the interface of an economically oriented production and a scientifically sound ecological and mycological evaluation. Novel and existing truffle orchards should therefore allow the putative impact of experimental management interventions, such as (host) tree thinning and (orchard) soil processing, to be compared with high-resolution monitoring data of micro-climatic conditions and radial stem growth rates of the plantation trees (Büntgen and Egli 2014, Büntgen

et al. 2015*b*). Isotopic tracing of the fungi–host interaction and source water utilization, together with the investigation of fruit body yield and maturation, may further contribute to the establishment of a protected terroir concept for *Tuber melanosporum* in most of the world's Mediterranean environments (and for other truffle species in other biogeographic zones). Inoculation techniques and nursery processes should be optimized to control and enhance the success rate of mycorrhized host plants (Stobbe et al. 2013), and truffle production systems should be adapted to dynamic business models that incorporate the putative effects of climate change and a sustainable green technology for energy and water use reduction and retention. The main reason why most of these attempts have not yet been implemented (in Spain and elsewhere) is, in our opinion, simply related to a lack of awareness and connection between farmers and scientists (as well as politicians and conservationists).

Involvement of a holistic research agenda is expected to reveal insights into biotic, abiotic, and combined edaphic controls on the growth and ripening of one of the world's most expensive gourmet products. New perceptions are of prime importance, because many components of the species' hidden lifecycle and mutualistic relationship with perennial host plants are still poorly understood (Büntgen et al. 2015*b*). Additional relevance is implied by long-term negative trends in Mediterranean truffle harvest (Büntgen et al. 2012), which have been associated with an unprecedented multi-decadal drying since around the mid-1970s (Cook et al. 2016). In summary, we envision a direct realization of climate change impacts on fungal-plant biology, agricultural industry, and landscape ecology.

Political Benefits

The establishment of a sustainable system of mycotourism and its ample opportunities for scientific involvement will almost certainly translate into political advantages (Fig. 2). Management and service strategies will benefit from socio-economic stability, as well as from the assessment of climate variability and ecosystem vulnerability. Deregulation processes are, however, needed to facilitate a rapid, non-bureaucratic implementation of research projects and conservation schemes into the ongoing and future commercial interests of Spain's emerging truffle sector. While local and regional governments are expected to

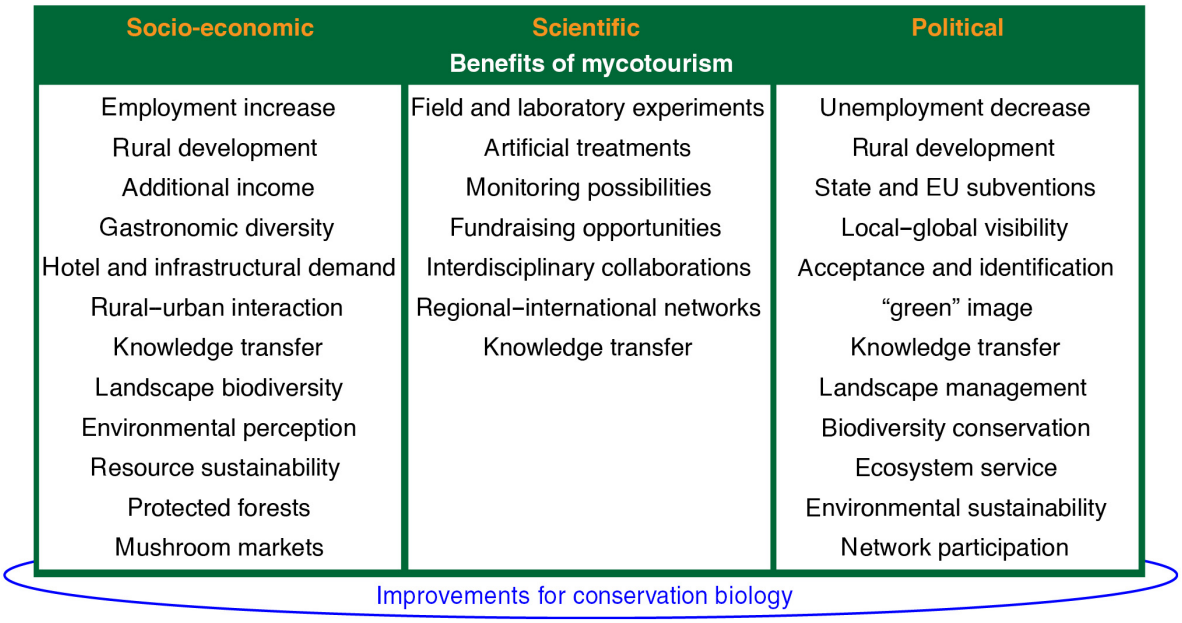

Fig. 2. Socio-economic, scientific, and political benefits of mycotourism, which will further help conserving biological and ecological diversity at various spatiotemporal scales.

directly benefit from a close alliance between mycotourism and science, more indirect gains are foreseen to arise from mycological (and more general biological) resources at national and even higher levels (Gluckman 2016). This accounts for improved rural development programs and newly established landscape conservation strategies, as well as ecosystem services.

Decreased unemployment together with increased income and cutting-edge research technology will enhance the independency and visibility of regional governments, which will further benefit from a stronger involvement of the local population into political processes. A stronger identification with, and appreciation of, the political system can create positive feedback loops also for environmental protection. At the same time, silvicultural management plans and biodiversity conservation strategies should not only be founded on scientific outcome, but should also more actively consider mushroom phenology, productivity, and diversity, as well as a sustained management, green technology, and valorization strategy for mycological resources. Wild edible mushrooms in general and mycotourism in particular therefore perfectly fit into the most recent European funding body for bio-economy (European Commission 2012). Likewise, local and regional governments may profit from several European cooperation initiatives that aim at providing frameworks for the management and valorization of wild edible mushrooms. Based on a sustainable infrastructure of mycotourism, continental-wide innovation programs like the micosylva forest network (http://www.micosylva.com/) will in turn inspire rural areas to improve their green image, and to ponder a ground-up management for policy change.

Acknowledgments

Carrie Andrew provided useful comments and suggestion that helped improving this work. Supported by Micosylva+ (Interreg IVB SUDOE SOE3/P2/E533), the Government of Castilla and León, ARAID, the project Xilva (CGL2011-26654, Economy and Competitiveness Ministry), and the Ministry of Education, Youth and Sports of Czech Republic within the National Sustainability Program I (NPU I), grant number LO1415. U.B. designed the study and wrote the paper together with input from all authors.

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