Antonella Vastola *Editor*

The Sustainability of Agro-Food and Natural Resource Systems in the Mediterranean Basin

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ISBN 978-3-319-16356-7 ISBN 978-3-319-16357-4 (eBook)
DOI 10.1007/978-3-319-16357-4

Library of Congress Control Number: 2015937597

Springer Cham Heidelberg New York Dordrecht London

Printed on acid-free paper

Springer International Publishing AG Switzerland is part of Springer Science+Business Media (www.springer.com)

Preface

This book focuses on the challenges to implement sustainability in diverse contexts such as agribusiness, natural resource systems and new technologies. The project arose from the editor's experience during the International Edamus M.Sc. course on "economics of quality for sustainable development"—the School of Agricultural, Forestry, Food and Environmental Science (SAFE), University of Basilicata, is a partner of the Edamus Mundus Programme. The exchange of ideas and the experience with students from all continents led to the idea to gather in one volume the experiences of researchers at the SAFE of the University of Basilicata in Southern Italy.

Basilicata's production system is mainly based on the agricultural sector and exploitation of natural resources. However, in recent years, it has witnessed industrial development driven by the discovery of oilfields. SAFE research took up the challenge posed by market competition to create value through the sustainable use of the region's renewable and non-renewable resources. Moreover, due to its unique geographical position in the middle of the Mediterranean basin, Basilicata is an excellent field laboratory for testing sustainable solutions adaptable to other Mediterranean areas.

The book offers a broad, multidisciplinary approach to identifying and testing different solutions tailored to the economic, social and environmental characteristics of the region and the surrounding areas. The volume is a collection of multidisciplinary case studies involving SAFE researchers and their scientific partners. It is intended as a stimulating contribution to the debate on the development of sustainable techniques, methods and applications for the Mediterranean regions. Last, but not least, a global event like Expo 2015 represents a unique opportunity to present the volume.

The book consists of three parts, with agro-food systems examined in Part I, natural resource systems and the environment in Part II and new technologies in Part III.

The first part includes the case studies related to experiences in the agro-food system. The first article addresses food security in the southern Mediterranean, providing readers with an overview of important factors to achieve more inclusive, integrated and efficient food systems. Thus, after setting the scene, the next two articles deal with crop production from the twin angles of sustainability and healthy food production. The next five articles are case studies related to livestock production typical of the Mediterranean including goats, sheep but also buffaloes and Podolian cattle. The focus is on a more sustainable rearing method but also on enhancing the products obtained from the milk of these species; the last article in this group describes the innovative uses of donkey milk. This is followed by two studies dealing with sustainable agricultural practices in protecting traditional crops in southern Italy from disease: the cherry tomato and the PGI-labelled Sarconi bean. To follow, there is the experience of the Turkish Cypriot community's adoption of pomegranate farming. Last, but not least, is a contribution on the role of women in the wine industry.

The second part explores issues relevant to the sustainability of natural resource systems and the environment. The first four case studies analyse the effects of climate change and the use of non-renewable resources in relation to the region of Basilicata. Of considerable interest is the case study on the allocation of oil royalties from the presence of oilfields that have to coexist with the extensive agricultural and forestry resources of the region. The next article addresses the role of soil variability on potential groundwater pollution and recharge in a Mediterranean agricultural watershed. The last three articles discuss biodiversity from original standpoints such as the use of native grasses for turfgrass, hypogeous fungi and the role of grazing for biodiversity conservation on a Nature 2000 network site.

The third part pools experiences in the use of new technologies such as geographical information systems as a tool for landscape modelling and three-dimensional analysis; satellite technologies to apply precision farming; technologies for extending the shelf life of fresh fruit and vegetables; cost-effective and non-invasive geophysical techniques for near-surface investigation; the use of electrolysed water as the disinfecting agent in the food industry.

I wish to thank my colleagues Michele Perniola and Severino Romano, as former and current SAFE Head, who believed in and supported the idea and its execution. I would like also to thank all the authors, with special thanks going to Aysen and Fabio who joined the team despite everything. Finally, I would like to express my gratitude to Fabio Massimo and Nicolò for their unwavering encouragement and for sharing the "sunny and cloudy" moments during the realisation of this book.

Potenza, Italy
January, 2015

Antonella Vastola

Introduction

Sustainability and Sustainable Development: The Background and the Current Perspectives

The roots of the concept of sustainability can be found, according to various scholars, in two contributions, both published in 1972: a book by Meadows et al., namely *The Limits to Growth*, which modelled the dynamics of the human presence on the planet, and an article by Goldsmith et al., *A Blueprint for Survival*, which forecast "*the breakdown of society and the irreversible disruption of the life-support systems on this planet*" without profound social changes. Both agreed that "*if current trends are allowed to persist*" (Goldsmith et al. ibidem) the actual growth model is bound to collapse within a century and that a consensus has to be found at the global level involving governments, the private sector and public opinion leaders. Such statements underline the fact that sustainability, defined literally as the ability to maintain or support and, more broadly, as the ability to continue a certain behaviour indefinitely, can be used as a key concept for the definition of development models to be pursued.

Since the 1980s the term *sustainability* has been applied to the human capacity to live on the planet. It was the energy crisis in the 1970s which underlined the fragility of global economic development, after which awareness of sustainability issues began to grow slowly. In 1987, the UN World Commission on Environment and Development (WCED), commonly known as the Brundtland Commission, gave in its report *Our Common Future* the first—and most widely quoted—official definition of sustainable development, which "... *is development that meets the needs of the present without compromising the ability of future generations to meet their own needs*". This broader definition emphasises the importance of people's aspirations for a better life, of global preservation and the essential relevance of future generations to the goals of current actions.

From this definition there emerged the widely accepted idea that sustainable development is based on three pillars: economic, social and environmental.

Economic sustainability concerns the capacity of an economy to support a certain level of economic production. Environmental sustainability is the ability of the environment to support a certain level of natural resource extraction rates. Finally, social sustainability is related to the ability of a social context to function at a certain level of social well-being and harmony.

At this point, a final remark has to be made to clear the field for all the following considerations that will be based, directly or indirectly, on the concept of sustainable development. Indeed, as many scholars have noted, the Brundtland Commission did not define sustainability but stated a definition of sustainable development as the "solution" to the problem of sustainability.

In 1992 in Rio de Janeiro, the UN Conference on Environment and Development defined the so-called Agenda 21, which is a broad action plan to implement sustainable development on a global, national and local level with the widest involvement of local stakeholders. Agenda 21 included 40 separate chapters, setting out actions related to the social and economic dimensions of sustainable development (e.g. poverty, health, demographics), conservation and management of natural resources (e.g. air, forest, water, chemicals), strengthening the role of major groups (e.g. women, young people, the elderly, NGOs, farmers) and means of implementation (e.g. information, training, international cooperation, finance).

In 2001, the UNESCO's Universal Declaration on Cultural Diversity added a fourth pillar: culture, as an element that shapes economic development and people's behaviour. The UNESCO initiative is twofold: one side focuses on the development of the cultural sector itself (e.g. creativity, cultural tourism, heritage), while the other deals with the proactive role that culture should have in shaping public policies—first of all, those regarding education followed by the environment, science and so forth.

In more recent years, due in particular to the financial crisis that has had global repercussions, albeit of different intensity between countries and industries, the concept of sustainable development as well as the set of tools to approach it has changed. In 2005, the UN World Summit which led to the definition of the Millennium Development Goals (MDGs) restated that development is a central goal in itself and that sustainable development calls for a convergence between the three pillars of economic development, social equity and environmental protection. The driving principles are: reducing poverty and hunger, improving health and well-being and creating sustainable production and consumption patterns.

The literature underpinning the MDGs identified a series of requirements for sustainable development: equity, poverty alleviation, a better use of non-renewable resources and integrating economic, environmental and social issues in decision making. Finally, a last but not least consideration—while the challenge of sustainable development is a shared one, countries have to adopt different strategies to advance sustainable development goals.

Given that the MDGs are only valid until 2015, in 2012 the Rio+20 Conference with the report *The Future We Want* proposed a set of sustainable development goals (SDGs) that updated MDGs to the 2015–2030 scenario.

Box 1. Sustainable Development Goals—*The Future We Want*

Goal 1. End poverty in all its forms everywhere.
Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture.
Goal 3. Ensure healthy lives and promote well-being for all at all ages.
Goal 4. Ensure inclusive and equitable quality education and promote life-long learning opportunities for all.
Goal 5. Achieve gender equality and empower all women and girls.
Goal 6. Ensure availability and sustainable management of water and sanitation for all.
Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all.
Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.
Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation.
Goal 10. Reduce inequality within and among countries.
Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable.
Goal 12. Ensure sustainable consumption and production patterns.
Goal 13. Take urgent action to combat climate change and its impacts.
Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development.
Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification and halt and reverse land degradation and halt biodiversity loss.
Goal 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.
Goal 17. Strengthen the means of implementation and revitalise the global partnership for sustainable development.

Recent years have witnessed a rising global alert due to the steady increase of global warming, mainly caused by increases in greenhouse gas (GHG) emissions generated by production systems as well as lifestyle models with too high an impact on the environment. Rio+20 reaffirmed that the ultimate objective under the United Nations Framework Convention on Climate Change is to stabilise GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.

The stable functioning of earth systems is a precondition for a decent level of global development. This means that for the SDGs to be feasible, they have to take into account the effects of increasing human pressure on the planet (the human population is expected to top nine billion by 2050), like water shortages, extreme weather, deteriorating conditions for food production, ecosystem loss, ocean acidification and sea level rise. These are real dangers that could threaten development and trigger humanitarian crises across the globe (Griggs et al. 2013).

A criticism of the system proposed by SDGs is the large number of goals, rising from six MDGs to 17 SDGs. This would not appear to simplify the framework of measures adoptable. This consideration holds especially if one thinks of the set of indicators that must be put in place. Indeed, another criticism levelled at the MDG/SDG complex is the appropriateness of indicators measuring actions and hence the assessment of their effectiveness. Managing the sustainable development process requires a much strengthened evidence base and the development and systematic use of robust sets of indicators and new ways of measuring progress. Taking into account these considerations, Griggs and colleagues (2013) proposed to set a medium-term horizon and some provisional targets (less ambitious than the SDGs) to accomplish. Results achieved with respect to these targets should be quantified in order to review them and to achieve the expected results in 2030.

It seems that the latest UN Secretary-General's synthesis report *The Road to Dignity by 2030* (2014) is going in the above-mentioned direction. In presenting the vision for the post-2015 sustainable development agenda, the 17 goals have been rearranged in a focused and concise manner that enhances the necessary global awareness and allows implementation at the country level. The report proposes a set of six essential elements underpinned by rights, with people and the planet at the centre.

Box 2. Sustainable Development Goals—*The Road to Dignity by 2030*

1. Dignity: to end poverty and fight inequality.
2. People: to ensure healthy lives, knowledge and the inclusion of women and children.
3. Prosperity: to grow a strong, inclusive and transformative economy.
4. Planet: to protect our ecosystems for all societies and our children.
5. Justice: to promote safe and peaceful societies and strong institutions.
6. Partnership: to catalyse global solidarity for sustainable development.

Given this scenario, the basic commitment is related to the capacity to act with solutions that lead to an inclusive growth for all countries and all communities. Particular attention is given to planetary needs in terms of climate stability, biodiversity loss and unsustainable land use. This means that, to implement a sustainable agenda, finance, technology, science and investments in capacities should be included, while to monitor and review implementation, the report proposes the use of new and non-traditional data sources, enhancing data capacity, availability, disaggregation, literacy and sharing.

Since the beginning of the new millennium, as evidenced by the above framework, the concept of sustainable development has been closely linked to that of well-being. In the last decade the economic crisis has affected all countries, albeit to a varying degree. This has shown that the measurement of welfare or well-being cannot be reduced to a single indicator such as Gross Domestic Product (GDP). Many scholars and international organisations have been involved in drawing up a measure that does not use only economic performance to assess the wealth and social progress of a country. Although this issue lies somewhat beyond the scope of this analysis, it is instructive to see that it is closely linked to sustainability. In its final remarks, the Commission on the Measurement of Economic Performance and Social Progress (CMEPSP)—generally referred to as the Stiglitz-Sen-Fitoussi Commission (created in 2008 on the French government's initiative)—did not identify a new indicator but, on the contrary, drafted a set of 12 recommendations (Stiglitz et al. 2009), three of which deal with sustainability: (1) GDP is "an inadequate metric to gauge well-being over time particularly in its economic, environmental and social dimensions, some aspects of which are often referred to as *sustainability*" (ibidem, p. 8); (2) environmental sustainability—including the destruction of resources and the risks of climate change—is a component of growth; (3) well-being has a multidimensional nature which involves material living standards (income, consumption and wealth) but also health, education, the quality of governance, social networks, the environment (present and future conditions) and insecurity (economic and physical aspects).

Sustainability in the Agro-Food System

Agriculture has a vital role to play as the planet's food provider, but it also uses a wealth of non-renewable resources. This makes it one of the best fields to study the application of sustainable development.

Given the current high levels of hunger and malnutrition—805 million chronically hungry people in the period 2012/2014—and increasing food demand—over nine billion people will have to be nourished in 2050—the challenge for agricultural production coincides with the goals of sustainable development. Food security is achieved "*when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life*" (FAO 1996).

The linkage between the goal of food security and the path towards a sustainable development model is evident: in order to achieve a decent level of nutrition for all people, responsible environmental stewardship is required as well as greater equity in food management. This applies to agricultural and food systems at global, national and local levels.

A recent FAO report states "*sustainable agriculture must nurture healthy ecosystems and support the sustainable management of land, water and natural resources, while ensuring world food security. To be sustainable, agriculture must meet the needs of present and future generations for its products and services, while ensuring profitability, environmental health and social and economic equity. The global transition to sustainable food and agriculture will require major improvements in the efficiency of resource use, in environmental protection and in systems resilience*" (FAO 2014). The above-mentioned report sets out five key principles that balance the social, economic and environmental dimensions of sustainability: (1) improving efficiency in the use of resources; (2) conserving, protecting and enhancing natural ecosystems; (3) protecting and improving rural livelihoods and social well-being;

(4) enhancing the resilience of people, communities and ecosystems and (5) promoting good governance of both natural and human systems.

As emphasised in the FAO reports and by several other international institutions, the different components of sustainability cannot be considered separately because they are strongly interrelated and need to be analysed using an integrated, holistic approach given the complexity of agro-food systems. This means considering the close interdependence of different aspects of food production and consumption.

A review of different reports about the sustainable path of agro-food systems suggests that, regardless of the perspective of the analysis, the main goals of a sustainable agro-food system concern: (a) sustainable production systems; (b) sustainable consumption guidelines; (c) biodiversity protection; (d) combating climate change; (e) developing local economies and small-scale production. Last but not least, each goal must be set and pursued as part of an overall strategy that takes all the other elements into account simultaneously.

Without exploring every single goal in depth, it would be useful to highlight some of their aspects. Given that the food production model concerns both industrial production as well as small and medium-scale production systems, sustainable food production is facing a challenge that can be summarised with the statement "*in order to grow, agriculture must learn to save*" (FAO 2013a). This means that, given the increasing food demand, the effects of climate change and the competition for resources such as land water and energy, farmers around the world have to look at a new paradigm: sustainable crop production intensification (SCPI) which "*produces more from the same area of land while conserving resources, reducing negative impacts on the environment and enhancing natural capital and the flow of ecosystem services*" (FAO ibidem). An example of this paradigm is conservation agriculture, which minimises tillage, protects the soil surface and sows crops in rotations that enrich the soil; moreover, it helps to reduce water needs by 30 % and energy costs by up to 60 %. With regarding to water management, the SCPI paradigm requires the use of precision technologies for irrigation and farming practices that use ecosystem approaches to conserve water. To increase crop productivity, a best practice is minimisation of chemical fertilisers, given the impact that nitrates and phosphates have in terms of GHGs.

Today more than ever the paradox of food is increasingly evident: on the one hand, there are people who are overweight or obese—2.1 billion across the world—and whose social cost is $2 trillion each year, and on the other there are one billion people suffering from hunger and another two billion suffering from micronutrient deficiencies. In all countries, especially in the developed world, and in those that are experiencing new conditions of well-being, a sustainable consumption model must be developed from the concept of sustainable diets.

Box 3. Sustainable Diets

Sustainable diets are those diets with low environmental impacts, which contribute to food and nutrition security and to healthy lives for present and

(continued)

future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy, while optimising natural and human resources (FAO 2010).

The spread of a food model that is based on sustainable diets allows the conservation of biodiversity to be enhanced through the raw materials that are used as ingredients. Moreover, it can provide nutrient recommendations to consumers and have positive effects on their awareness vis-à-vis the positive repercussions of an environmentally sustainable food chain.

The last, but not the least, effect of the above-mentioned food paradox is the increasing phenomenon of food losses and waste. Recent estimates indicate that each year approximately one-third of all food produced for human consumption in the world is lost or wasted (FAO 2013b). The phenomenon occurs in both high- and low-income countries. In the first case, the food is largely wasted at the consumption stage while in low-income countries, it is lost mostly during the early and middle stages of the food supply chain.

Food waste represents an evident inefficiency and a missed opportunity to improve global food security, but also to mitigate environmental impacts and resource use. Given that the food and agriculture sectors together generate 30 % of total GHGs, appropriate solutions have to be found. In developed countries, programmes are under way to increase consumer awareness of food waste and energy use in food products, as well as regulations mandating reductions in organic waste management. In low-income countries, options include promoting low-cost farm storage facilities as well as upgrading transport and processing facilities (FAO 2011).

The search for better food chain efficiency is another key element of the sustainable development model. The importance of logistics systems, their management and how they can improve sustainability lies at the heart of the recent concept of green logistics. The premise is that optimisation of logistic operations across the supply chain has positive results in terms of: reduction of post-harvest losses, savings in energy, reduction of the environmental footprint and more competitive market positioning. In order to remain competitive, agro-food agents need rapid access to emerging technologies and, in addition, to be profitable their activities have to meet environmental standards and regulations, as well as deal, directly or indirectly, with consumers.

To define the elements of sustainability and a framework for assessing trade-offs and synergies among all dimensions of sustainability, an international reference tool has been developed, the Sustainability Assessment of Food and Agriculture system (SAFA). SAFA is an assessment of economical, environmental, social and governance sustainability. The field of application is the entire food supply chain from the site of primary production (agriculture, fisheries, forestry) to the retail outlet. Its main purpose is to support effective sustainability management of a company or production site.

The SAFA framework identifies four dimensions of sustainability: good governance, environmental integrity, economic resilience and social well-being. For each of these four dimensions, SAFA outlines essential elements of sustainability through 21 high level themes (Fig. 1). These are applicable at any level of development, for instance at the national level, or commodity-specific. The themes are further divided into 58 sub-themes that are tailored to food and agriculture supply chains and thus are not well suited for policy development (FAO 2013c).

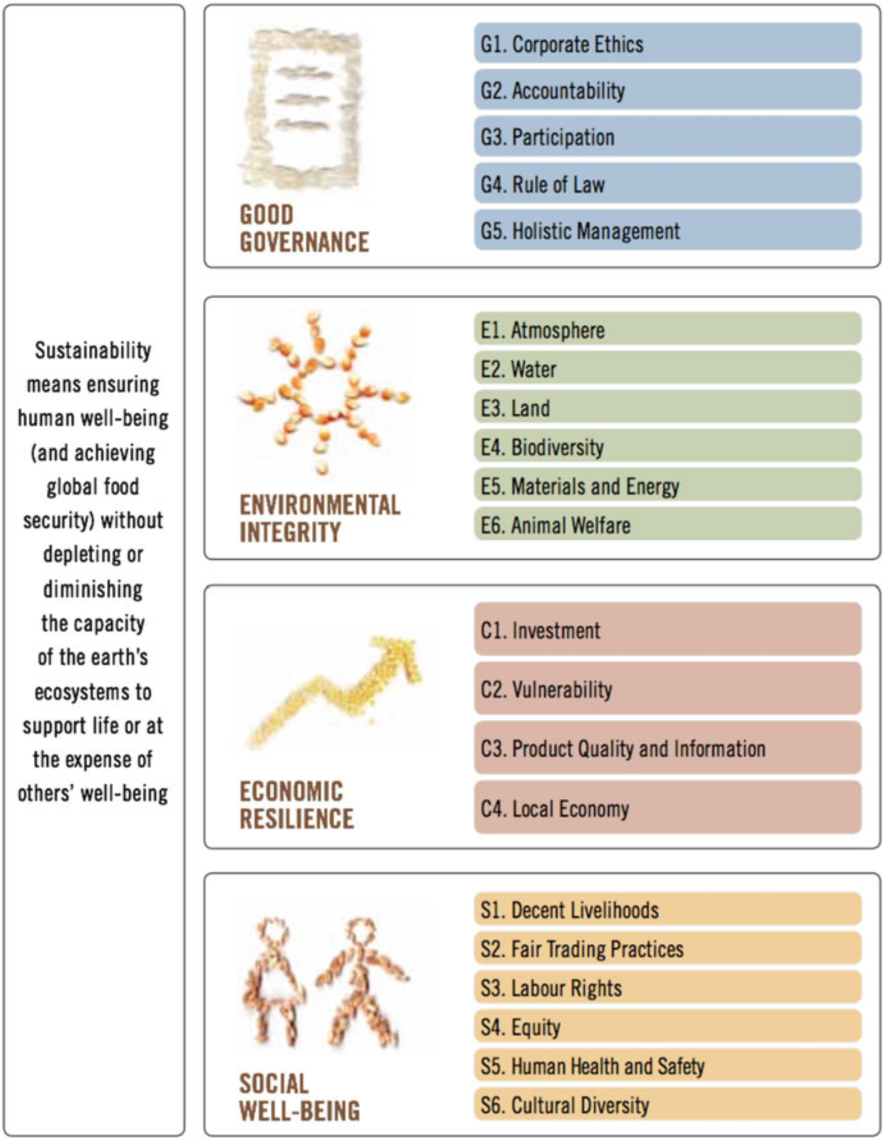

Fig. 1 SAFA sustainability pillars and themes (FAO 2013)

The different types of indicators within the SAFA system have varying weight in terms of their likelihood to fulfil the sub-theme objective. The SAFA system has a five-scale rating for the performance of indicators to which colours are attributed: red/orange/yellow/green/dark green are used, respectively, for unacceptable/limited/moderate/good/best levels of performance, corresponding to percentage scores from: 0–20/20–40/40–60/60–80/80–100. The SAFA sustainability performance ratings of a company are represented by the polygon (the thick black line) that connects theme performance following a traffic light colour code: best/good (green), needs improvement (yellow/orange) or unacceptable (red) as illustrated in Fig. 2.

The SAFA methodology is partly rooted in international metrics such as ISO 14040 (2006), the standard for Life Cycle Assessment (ISO 2009), and the ISEAL Code of Good Practice. The SAFA system provides a framework for improving the understanding of what a sustainability claim covers in practice and for comparing different production systems. It is also a useful quality assessment tool to identify performance of hotspots related to all aspects of sustainability within a company.

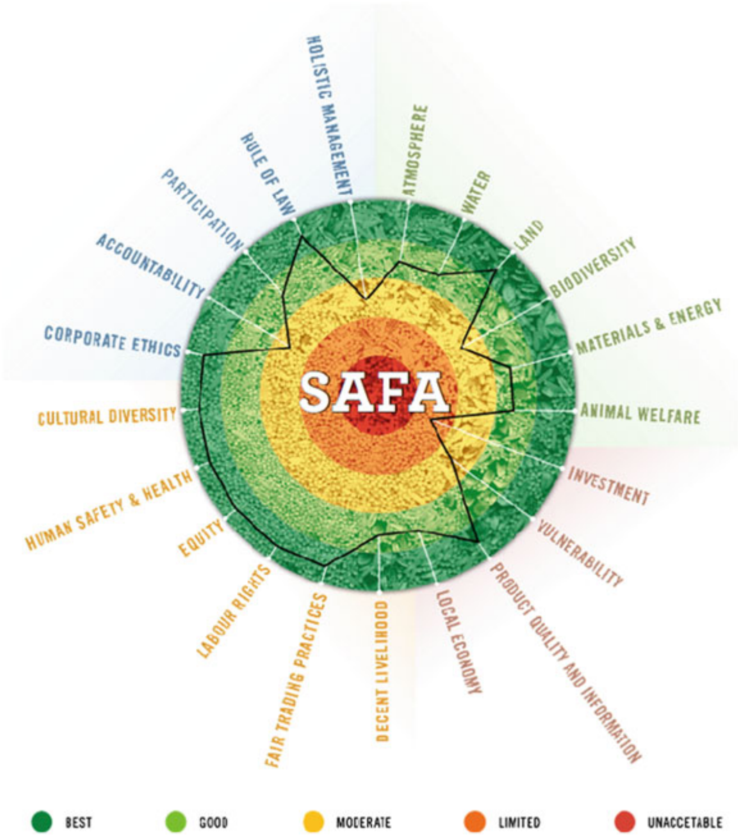

Fig. 2 SAFA sustainability polygon (FAO 2013)

Some final considerations have to be made on the cost of shifting to a more sustainable production model. As experienced in recent decades, the trade-offs between achieving a certain level of well-being, food security goal and environmental objectives often result in a negative-sum game, because of inappropriate policies and inadequate governance systems. On the production side, major costs are those including investments and operating expenses, but also opportunity costs related to income loss during the transition phase. The problem of delayed returns on investments is a significant barrier to achieving sustainability across all sectors. Risk and transaction costs are other significant elements during the transition to more sustainable systems. Transaction costs are those related to each stage of the business—e.g. transportation, communication and coordination activities. Various studies have reported that sustainable production systems require more coordination activities, for example in managing common-property natural resources, or in coordinating post-harvest, processing, storage and marketing activities. Natural market risks—e.g. volatility, the prices of raw materials, the supply of energy resources, sudden and catastrophic climate events—impact on most of the variables that affect the path towards sustainability.

The consumption system is facing a similar set of costs. The cost concerning the uncertainty of the quality of the goods purchased is of particular importance. Often the communication of sustainability features of the good is not effective and is made less efficient by the large number of claims that emphasise the "greening" of many products and which often deceive the consumer. A dietary model that considers the cradle-to-grave scenario has to be linked to the investment costs for the technology for disposal or re-use but also the cost of public action in terms of information. Finally, the effects of these behaviours are verifiable only in the medium-long run, which may cause a degree of disaffection of the consumer/citizen in continuing with equitable action.

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Part I
Agro-Food Systems

Biodiversity of Hypogeous Fungi in Basilicata

Gian Luigi Rana, Stefania Mirela Mang, and Ippolito Camele

Abstract During the last two decades, systematic studies were carried out on biodiversity of hypogeous fungi in forestry territories of the two Basilicata (southern Italy) provinces, Matera and Potenza. Identification of fungus taxa found in the region was commonly accomplished on the basis of macro- and microscopic features, and only in a few instances, molecular analyses were utilized. Thanks to these investigations, Basilicata now occupies, among Italian regions, the first and fourth positions for number of *Tuber* species, varieties or forms and total number of hypogeous fungi (*Ascomycota*, *Basidiomycota* and *Zygomycota*) naturally growing in its woodlands and Mediterranean maquis areas. In fact, the last up-to-date acquirements on the topic bring up to 29 and 53 the number of *Tuber* taxa and that of the other hypogeous and semi-hypogeous (only three entities) fungi present in the region, respectively. In this chapter, the essential information regarding these fungi is given, so updating to 2014 the relative available knowledge. Among the *Fungi*, object of this review, the *Ascomycota Pachyphloeus conglomeratus* and *Tuber malençonii*, the *Basidiomycota Hymenogaster decorus*, *H. hessey*, *H. rehsteineri*, *Schenella pityophilus* and *Myriostoma coliforme* as well as the *Zygomycota Youngiomyces multiplex* deserve a particular mention because of their rarity.

1 Introduction

In the last two decades, several researches have been carried out on biodiversity of hypogeous fungi of Basilicata, an Italian region characterized by a very heterogeneous territory for cenotic diversity deriving from its great geomorphologic complexity. The first studies accomplished on the topic by Cerone et al. (1994) and by the Potenza group of *Associazione Micologica G. Bresadola (Trento)* (Tagliavini 1999) showed that all the commercial species, varieties and forms of truffles were present in the region along with some unmarketable taxa, *i.e. Tuber excavatum* Vittad., *T. fulgens* Quél., *T. rufum Pico*: Fr. var. *rufum*, *T. rufum* var. *nitidum*

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A. Vastola (ed.), *The Sustainability of Agro-Food and Natural Resource Systems in the Mediterranean Basin*, DOI 10.1007/978-3-319-16357-4_20

(Vittad.) Montecchi & Lazzari, *T. gibbosum* Harkn., *T. maculatum* Vittad., *Choiromyces meandriformis* Vittad. and *Balsamia vulgaris* Vittad. The Institute of Plant and Forestry Pathology of the Agriculture Faculty of University of Basilicata [now School of Agricultural, Forestry, Food and Environmental Sciences (SAFE)] subsequently carried out systematic investigations on these fungi. Initially, with the graduation thesis entitled "Il tartufo in Basilicata" (Marino 1999), additional documented information was given on the above taxa, and presence of another hypogeous fungus, belonging to *Basidiomycota*, *Hymenogaster popouletorum* Tul. & C. Tul., was reported in Potenza province. Further studies (Cerone et al. 2000, 2002; Marino et al. 2003) allowed to bring up to 16 and six the numbers of Lucanian hypogeous fungi belonging to *Ascomycota Pezizales* and to *Basidiomycota*, respectively. Thanks to successive investigations (Marino et al. 2005; Rana et al. 2008, 2010, 2011, 2013a, and unpublished data), the number of hypogeous fungi naturally growing in Basilicata, including only three semi-hypogeous taxa, grew up to 82 entities as shown in Table 1. Although all fungi, object of the article, are well-known species, varieties or forms, *exsiccatae* of almost all specimens found in Basilicata were deposited in *Herbarium Lucanum* (*HLUC*) of SAFE. In this chapter, the essential information on these fungi is briefly reported. For those here mentioned for the first time, the main macro- and microscopic features along with the relative *exsiccata* number, date and site of finding are mentioned. For details about the great majority of Lucanian taxa, the available specific literature and truffle treatises by Montecchi and Sarasini (2000), Riousset et al. (2001), Gori (2005), and Granetti et al. (2005) should be consulted. The nomenclature and taxonomic classification adopted for fungi object of the article are those reported on the MycoBank website (Crous et al. 2004; Robert et al. 2005).

2 Lucanian Hypogeous and Semi-hypogeous Fungi

2.1 Ascomycota

2.1.1 ***Pezizomycotina*, *Eurotiomycetes*, *Eurotiomycetidae*, *Elaphomycetales*, *Elaphomycetaceae* (Tul. & C. Tul.) Paol.**

The following three species of *Elaphomyces* grow in nature in the region: *E. leveillei* Tul. & C. Tul., *E. asperulus* Vittad. and *E. muricatus* Fries. The first one was found in a mixed wood of Pignola (PZ) communal territory (Cerone et al. 2000); the second and the third ones were collected under oak and beech plants in Terranova di Pollino (PZ) area (Rana et al. 2008).

Table 1 Hypogeous and semi-hypogeous fungi found in Basilicata between 1994 and 2014, listed in the taxonomical order reported in the article

Division	Family	Species/Var/Form
Ascomycota		
	Elaphomycetceae	*Elaphomyces leveillei*, *E. asperulus* and *E. muricatus*
	Helvellaceae	*Balsamia vulgaris*, *Choiromyces meandriformis*, *Fisherula macrospora*, *Leucangium chartusianum* and *Picoa lefebvrei*
	Pezizaceae	*Pachyphloeus citrinus*, *P. ligericus*, *P. conglomeratus* and *Sarcosphaera coronaria* var. *coronaria*
	Pyronemataceae	*Genea fragrans*, *G. hispidula*, *G. lespiaultii*, *G. sphaerica*, *G. verrucosa*, *G. papillosa*, *Geopora clausa*, *G. sumneriana* and *Stephensia bombycina*
	Terfeziaceae	*Terfezia arenaria* and *T. olbiensis*
	Tuberaceae	*Reddellomyces donkii*, *T. aestivum*, *T. aestivum* var. *uncinatum*, *T. asa-foetida*, *T. bellonae*, *T. borchii*, *T. brumale*, *T. brumale* var. *moschatum*, *T. dryophilum*, *T. excavatum*, *T. foetidum*, *T. fulgens*, *T. gibbosum*, *T. hiemalbum*, *T. macrosporum*, *T. maculatum*, *T. malençonii*, *T. magnatum*, *T. magnatum* var. *Vittadinii*, *T. melanosporum*, *T. mesentericum*, *T. oligospermum*, *T. panniferum*, *T. puberulum*, *T. regianum*, *T. rufum* var. *apiculatum*, *T. rufum* fo. *ferrugineum*, *T. rufum* fo. *lucidum*, *T. rufum* fo. *nitidum* and *T. rufum* var. *rufum*
Basidiomycota		
	Strophariaceae	*H. aromaticus*, *H. bulliardii*, *H. decorus*, *H. hessei*, *H. luteus* var. *luteus*, *H. luteus* var. *subfuscus*, *H. lycoperdineus*, *H. olivaceus*, *H. populetorum*, *H. rehsteineri* and *H. vulgaris*
	Melanogastraceae	*Melanogaster ambiguus* var. *ambiguus*, *M. broomeanus*, *M. tuberiformis*, *M. umbrinigleba* and *M. variegatus*
	Octavianiaceae	*Octavianina asterosperma*
	Rhizopogonaceae	*Rhizopogon vulgaris*
	Geastraceae	*Geastrum fimbriatum*, *G. triplex*, *Myriostoma coliforme* and *Schenella pityophilus*
	Gomphaceae	*Gautieria graveolens* var. *graveolens*, *G. graveolens* var. *otthii* and *G. morchellaeformis*
	Hysterangiaceae	*Hysterangium inflatum*, *H. nephriticum* and *H. stoloniferum*
Zygomycota		
	Endogonaceae	*Youngiomyces multiplex*

2.1.2 *Pezizomycotina*, *Pezizomycetes*, *Pezizomycetidae*, *Pezizales*, *Helvellaceae* Fries

Balsamia vulgaris seems able to grow quite commonly in the region under *Quercus* spp. or in mixed woods (Cerone et al. 1994; Marino et al. 2005; Rana et al. 2011). It has been refound in "Mantenera-Malcanale" mixed wood (Tricarico, MT) in 2014

(Rana et al. unpublished data). *B. polysperma* Vittad. was so far never found in Basilicata and appears limited to northern Italian regions (Montecchi and Sarasini 2000). *C. meandriformis* is enough distributed in Basilicata. It was at first found by Cerone et al. under *Quercus pubescens* Willd. (*s.l.*) and *Fagus sylvatica* L. (1994 and 2000) and repeatedly discovered in mixed woods of Tricarico (MT), Abriola and Brindisi di montagna (PZ) in successive years (Rana unpublished data). Findings of *Fischerula macrospora* Mattirolo, a taxon apparently limited to Italy (Montecchi and Sarasini 2000), occurred in territories of Tricarico (MT) in 2006 and Abriola (PZ) in 2011 (Rana et al. 2008, 2011) under *Q. pubescens* (*s.l.*) and *F. sylvatica*, respectively. *Picoa carthusiana* Tul. & C. Tul. [= *Leucangium carthusianum* (Tul. & C. Tul.) Paol.] and *P. lefebvrei* (Pat.) Maire were both only once reported in the communal mixed wood of Tricarico (PZ) (Rana et al. 2008, 2010).

2.1.3 *Pezizomycotina*, *Pezizomycetes*, *Pezizomycetidae*, *Pezizales*, *Pezizaceae* Dumortier

The hypogeous fungus genera naturally growing in Basilicata and belonging to this family are *Pachyphloeus* Tul. & C. Tul. and *Sarcosphaera* Auersw.

Two species of *Pachyphloeus* were discovered under oaks in Basilicata in 2002 and 2003, *P. citrinus* Berk. & Br. and *P. ligericus* Tul. & C. Tul., respectively (Marino et al. 2005) Another species, *Pachyphloeus conglomeratus* (Berk. & Br.) Doweld (*exsicc*. n. 88), has been recently discovered in the region. More in detail, five ascomata were complexively found: two of them under *Salix elaeagnos* Scop. and *Populus alba* L. in Roccanova territory (PZ) in October 2013 and the remaining three in the “Montecaruso” mixed wood of Filiano (PZ) in November of the same year. The macro- and microscopic features (see Fig. 1a, b, c) of the fungus were very like if not identical to those already described for the *Pezizacea* (Montecchi and Sarasini 2000). The poisonous *Sarcosphaera coronaria* var. *coronaria* (Jacq.) J. *Schröt* [= *S. crassa* (Santi: Strudel) Pouzar] is quite common under pine woods in Basilicata (Tagliavini and Tagliavini 2011) at the end of winter or in spring. Its last documented finding occurred under *Pinus halepensis* Mill. in “Mantenera-Malcanale” wood (Tricarico, MT) 4 years ago. DNA extracted from a Lucanian ascoma of the fungus, subjected to PCR with primers ITS4 and ITS5 (White et al. 1990), gave an amplification product of about 562 bp. The same sequence was deposited in EMBL database under accession code FR827862 and matched at 89 % ($E = 0$) two sequences, DQ200843 and DQ200844, of the same *Pezizacea* (Rana et al. 2011).

2.1.4 *Pezizomycotina*, *Pezizomycetes*, *Pezizomycetidae*, *Pezizales*, *Pyronemataceae* Schröter

The hypogeous fungi of this family found in Basilicata belong to genera *Genea* Vittad., *Geopora* Harkn., *Hydnocystis* Tul. & C. Tul. and *Stephensia* Tul. & C. Tul.

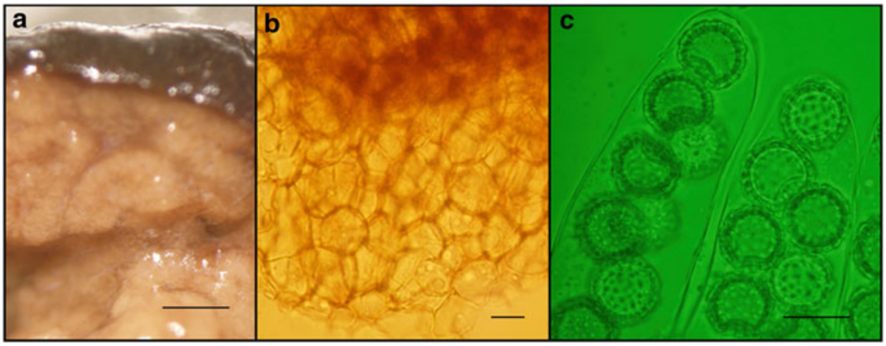

Fig. 1 Gleba cross section (**a**), pseudoparenchymatic structure of peridium (**b**), asci and spores (**c**) of a Lucanian ascoma of *Pachyphloeus conglomeratus*. Bars: (**a**) 15 mm, (**b**) 10 μm and (**c**) 20 μm

Findings of *Genea* species present in Basilicata are reported by Cerone et al. (2000) and Marino et al. (2002) for *G. verrucosa* Vittad. and *G. lespiaultii* Corda, Marino et al. (2005) for *G. fragrans* (Wallroth) Paol. and *G. hispidula* Berk. & Br. and, finally, Rana et al. (2011, unpublished data) for *G. sphaerica* Tul. & C. Tul. and *G. papillosa* Vittad., the last of which is thought to be a bay-brown form of *G. verrucosa* (Montecchi and Sarasini 2000).

Two species of *Geopora*, *G. sumneriana* (Cooke) Kers and *G. clausa* (Tul. & C. Tul.) Burds., and one of *Stephensia* (Tul. & C. Tul.), *S. bombycina* (Vittad.) Tul., result in inhabitation of some areas of the region. Tagliavini and Tagliavini (2011), about the first species of *Geopora*, wrote that "it is rare but abundant in the sites where it grows". *G. clausa* (Tul. & C. Tul.) Burds. [= *Hydnocystis clausa* (Tul. & C. Tul.) Ceruti] is present in Bernalda (MT) area and exactly in the "Biogenetic Natural Reserve of Metapontum and Marinella—Stornara" (BNR) (Rana et al. 2011). *Hydnocystis piligera* Tul. & C. Tul., that has been reported in the extended Apulian portion (1,456 ha) of BNR, was so far never encountered in Basilicata.

Finally, *S. bombycina* (Vittad.) Tul. & C. Tul. was firstly reported under *Quercus cerris* L. in Corleto Perticara (PZ) territory in 2006 (Rana et al. 2010) and subsequently refound for two–three times in Filiano (Rana et al. 2011) and Rionero in Vulture (PZ) territories (Rana et al. unpublished data).

2.1.5 *Pezizomycotina*, *Pezizomycetes*, *Pezizomycetidae*, *Pezizales*, *Terfeziaceae* Fischer

The species of *Terfezia* Tul. & C. Tul. so far found in Basilicata are *T. arenaria* (Moris) Trappe (= *T. leonis* Tul. & C. Tul), sniffed by a well-trained Lagotto dog under *Quercus* spp. in the inland Lucan territory of Brindisi di montagna town (PZ) in June 2013 (Rana et al. unpublished data), and *T. olbiensis* Tul & C. Tul.

which grew close to *P. halepensis* and *Cistus salvifolius* L. in the before mentioned "Mantenera-Malcanale" wood.

It is conceivable to hypothesize that two other *Terfezia* species, i.e. *T. leptoderma* Tul. and *T. boudieri* Chatin, present in the close region Apulia, the first, between Torre dell' Orso and Melendugno towns (LE) and, the second, in the Apulian BNR surface (Rana et al. 2010), could also grow in the Lucanian part (45 ha) of the same reserve.

2.1.6 *Pezizomycotina*, *Pezizomycetes*, *Pezizomycetidae*, *Pezizales*, *Tuber*aceae Dumortier

Tuber aestivum and *T. aestivum* fo. *uncinatum* are the most common black truffles of Basilicata; their natural beds are located in broad-leaved and coniferous woods of 93 and 37 Lucanian communes, respectively (*Bollettino Ufficiale Regione Basilicata-BURBas* 2004). Prudential estimates indicate that a single professional truffle hunter can pick up two–three q/year of their ascomata. Both truffles can be successfully cultivated in the region and ascomata weighting 400–700 g are not rarely produced. In nature, an exceptional Lucanian ascoma weighting 1,006 g was collected under oaks in Rieti (PZ) area during October 2006 (Rana and Marino 2007).

The other truffles, which are marketable according to the national and regional laws n. 752 of June 20th 1985 and n. 35 of March 27th 1995, are, in decreasing order for quantity and economical importance, *T. borchii* Vittad. (including all truffles of *T. puberulum* Berk. et Br. group as well as *T. gibbosum* Harkness), *T. magnatum* Pico, *T. brumale* Vittad. and its fo. *moschatum* (Ferry) Montecchi & Lazzari, *T. macrosporum* Vittad., *T. bellonae* Quél., *T. hiemalbum* Chatin, *T. melanosporum* Vittad. and *T. mesentericum* Vittad. (complex species which probably comprehends more than three taxa) (Leonardi et al., manuscript sent to Fungal Biology). The last *Tuber* species and, more specifically *T. mesentericum* (*s. s.*), although abundant in beech wood of Basilicata at 1,000–1,300 m a.s.l. and appreciated in Campania, is scarcely used in kitchen in the Lucanian region. *T. borchi* grows either in coastal pine woods or under oaks on the Basilicata mountains in more than 20 natural sites (*BURBas* 2004).

The tasty *T. melanosporum* was found growing in small natural beds of Fardella, Marsicovetere, Muro Lucano, Teana and Rotonda (PZ) (*BUR-Bas* 2004).

The precious *T. magnatum* grows in loamy-sandy, calcareous soil along the banks of more or less large torrents and streams located between Agri and Sinni rivers as well as along Basentum in territories of about 20 Lucanian towns (*BURBas* 2004). Cerone et al. (2002) described the ecological characteristics of a natural bed of this *Tuber* species existing in Chiaromonte (PZ) territory where *Populus canescens* (Aiton.) Sm. predominantly grows. A realized niche of the species, located in upper Sinni river area, was recently studied using GIS, direct in situ survey and genetic diversity at DNA marker loci (Figliuolo et al. 2013).

Furthermore, 89 ascomata of *T. aestivum*, *T. borchii*, *T. brumale*, *T. magnatum* and *T. mesentericum* from 41 different Basilicata sites were object of a biodiversity study (Pomarico et al. 2007) employing molecular tools.

T. macrosporum grows in limited areas of oak and beech woods in a few communal territories of the region (Marino et al. 2002; *BURBas* 2004; Rana unpublished data).

Among the numerous unmarketable Lucanian truffles, *T. excavatum* Vittad. and *T. rufum* var. *rufum* are very abundant; *T. malençonii* Donadini, Riousset et Chevalier is, on the contrary, very rare (Rana et al. 2013a) whereas *T. regianum* Montecchi and Lazzari, *T. maculatum* Vittad., *T. foetidum* Vittad., and *T. dryophylum* Tul. et C. Tul. can be rarely encountered (Rana et al. 2011, 2013a, unpublished data).

Tuber gibbosum Harkness was only found under *Pseudotsuga menziesii* (Mirbel.) Franco in territories of Abriola, Campomaggiore and Teana (PZ), *T. oligospermum* (Tul. & C. Tul.) Trappe and *T. asa-foetida* Tul. & C. Tul. in pine woods of the Lucanian Jonian coast (Marino et al. 2003) and *T. panniferum* under *Q. ilex* L. in Tursi and Marsicovetere areas (Cerone et al. 2000) and, on July 9th, 2012 and June 22th, 2014, in Calciano (MT) area and in the "Mantenera-Malcanale" mixed wood, respectively (Rana et al. unpublished data).

Finally, *Reddellomyces donkii* (Malençon) Trappe was found in the BNR surface of Basilicata under *P. halepensis* in 2007 and 2008 (Rana et al. 2010).

2.2 Basidiomycota

2.2.1 *Agaricomycotina*, *Agaricomycetes*, *Agaricomycetidae*, *Agaricales Strophariaceae* Singer & A. H. Sm.

The species of *Hymenogaster* Vittad. so far reported in Lucanian territories are listed hereafter: *H. populetorum* Tul. & C. Tul., *H. luteus* Vittad. var. *luteus* and *H. vulgaris* Tul. & C. Tul. that were found in territories of Trivigno, Marsicovetere, Pignola, Vaglio di Basilicata, Campomaggiore, Corleto Perticara and Anzi (PZ) in the first years of research (Cerone et al. 2000); *H. aromaticus* Velenovski. [= *Protoglosum aromaticum* (Velen.) J.M. Vidal.] presence of which in the region (Cerone et al. 2002) needs to be confirmed, because some of the original *exsiccata* resulted to be *H. populetorum*; *H. lycoperdineus* Vittad., collected under *Quercus* spp., *F. sylvatica* L. and *Ilex aquifolium* L. in Gorgoglione (PZ) and Tricarico (MT) territories from 2002 to 2004 (Marino et al. 2005); *H. bulliardii* Vittad. and *H. luteus* var *subfuscus* Soehner, found in the "Mantenera-Malcanale" wood and Pignola area (PZ) (Rana et al. 2008); *H. olivaceus* Vittad. collected in a cultivated truffle ground planted in Ruoti (PZ) territory (Rana et al. 2011).

Furtherly, presence of the following other *Hymenogaster* species is here reported for the first time: *H. decorus* Tul. & C. Tul. (*exsicc*. n. 89), collected under oaks at about 1,000 m a.s.l. in Rionero in Vulture (PZ) area on February 2013 and identified thanks to the spore morphology and average dimensions (20–25 × 12–15 μm), the loose and markedly knotted perisporium and the typical two-spored basidia (Montecchi and Sarasini 2000) (see Fig. 2a), *H. hessey* Soehner (*exsicc*. n. 90),

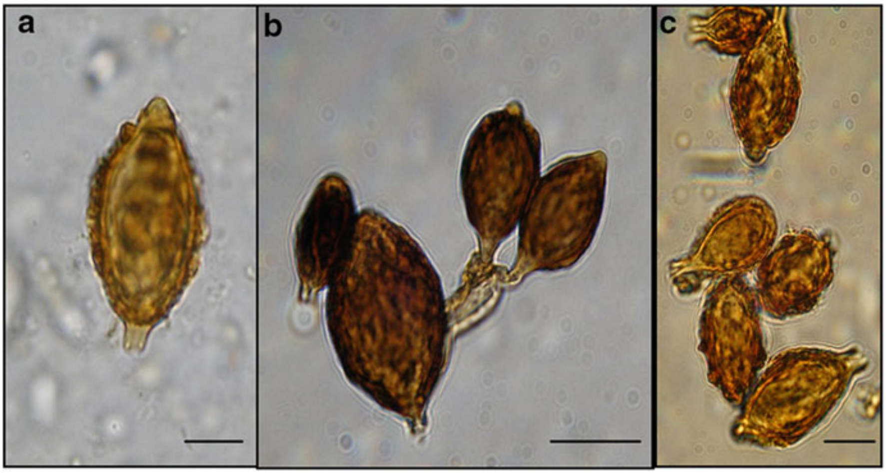

Fig. 2 Basidiospores of *Hymenogaster decorus* (**a**), *H. hessei* (**b**) and *H. rehsteineri* (**c**). *Bars:* (**a**) and (**c**) 10 μm, (**b**) 15 μm

found in the same regional zone and date and recognized on the base of sour and pungent scent of its basidiomata, gold-yellow colour of its unripe spores and average dimensions of the mature ones (21–24 × 15–16 μm) which were morphologically much variable (see Fig. 2b) and, finally, *H. rehsteineri* Bucholtz (*exsicc*. n. 91) (see Fig. 2c), found under *P. canescens* in Chiaromonte (PZ) territory at about 300 m a.s.l. at the end of October 2014. Useful for identification of the last species were the variable scent of its basidiomata and spore morphology that matched almost perfectly that described by Montecchi and Sarasini (2000).

Some recent findings of *H. albus* (Klotzsch) Berk. & Br. and *H. niveus* Vittad. under *Eucalyptus camaldulensis* Dehnh. and oaks, respectively (Rana unpublished data), still request to be confirmed.

2.2.2 *Agaricomycotina*, *Agaricomycetes*, *Agaricomycetidae*, *Boletales*, *Melanogastraceae* Fischer

Five out of the ten known *Melanogaster* Corda species result present in Basilicata:

M. ambiguus var. *ambiguus* (Vittad.) Tul. & C. Tul. and *M. umbrinigleba* Trappe & Guzmàn found under *Q. cerris* in Filiano (PZ) territory and under *P. halepensis* in the above-mentioned “Mantenera-Malcanale” wood in 2011 and 2009, respectively (Rana et al. 2011); *M. tuberiformis* Corda under *Q. cerris* in Corleto Perticara (PZ) area in 2006 (Rana et al. 2008); *M. variegatus* (Vittad.) Tul. & C. Tul., that is the most common *Melanogaster* species in the region, and *M. broomeanus* Berk. apud Tul. & C. Tul. in Brienza and Pietragalla (PZ) mixed woods (Cerone et al. 2000; D’Auria et al. 2014; Rana et al. unpublished data).

2.2.3 *Agaricomycotina*, *Agaricomycetes*, *Agaricomycetidae*, *Boletales*, *Octavianiaceae* Loquin ex Pegler & Young

The genus *Octavianina* Kuntze is known in Europe for the presence of a single species, *O. asterosperma* (Vittad.) Kuntze that has been found in Basilicata under *Q. cerris*. and *F. sylvatica*. on Volturino mountain in Marsicovetere (PZ) territory in spring–summer 2001 (Marino et al. 2003). Basidiomata of the same fungus were often refound in region [*e.g.* in a mixed wood of Tricarico territory on July 2011 and June 2012 as well as under oak in a zone between Satriano di Lucania and Brienza (PZ) during June 2013] (Rana et al. 2011 and unpublished results).

2.2.4 *Agaricomycotina*, *Agaricomycetes*, *Agaricomycetidae*, *Boletale*, *Rhizopogonaceae* Gäumann & Dodge

Rhizopogon vulgaris (Vittad.) M. Lange is the only species of the genus *Rhizopogon* Fries so far discovered in Basilicata. After its first finding in the region under *Pinus pinaster* Ait. in Policoro (MT) territory in 2001, it was again encountered under *E. camaldulensis* and *P. halepensis* in BNR (Bernalda, MT) in April 2011 (Rana et al. 2011).

2.2.5 *Agaricomycotina*, *Agaricomycetes*, *Phallomycetidae*, *Geastrales*, *Geastraceae* Corda

Geastrum fimbriatum Fries and *G. triplex* fo. *triplex* Jungh. have been often found in Basilicata (Tagliavini and Tagliavini 2011; Rana et al. 2013b, unpublished data). The last findings are referred to the "Mantenera-Malcanale" wood and, for the close Apulia, to BNR and Corigliano d'Otranto (LE) territories. Another hypogeous fungus, belonging to this family and found under *P. halepensis* in the region (Rana et al. 2011), is *Schenella pityophilus* (Malençon and Riousset) Estrada & Lado. It was previously considered rare in Europe, but it seems common enough along the Adriatic and Jonic coasts of Apulia and Basilicata, respectively (Signore et al. 2008). It was again encountered in "Mantenera-Malcanale" mixed wood in the region in February 2014 (Rana unpublished data). Molecular analysis, accomplished as before summarized on one of its basidiomata, gave an ITS gene amplicon of 625 bp. Its sequence resulted very like (similarity coefficient = 91 %) that present in GenBank under accession number GU184106 for *S. pityophilus*. The sequence obtained from the Lucanian sample of *S. pityophilus* was deposited into the EMBL database under FR821766 accession number (Rana et al. 2011). *Myriostoma coliforme* (Dicks.) Corda, a rare, semi-hypogeous *Geastracea*, was found in two localities of the region, "Villa Caivano" (Picerno, PZ) and "Manferrara" (Pomarico, MT), at 700 and 400 m a.s.l. in autumn of 2008 and 2009, respectively (Rana et al. 2013b).

2.2.6 *Agaricomycotina*, *Agaricomycetes*, *Phallomycetidae*, *Gomphales*, *Gomphaceae* Donk

Three varieties of *Gautieria graveolens* Vittad. were so far found in Basilicata:

G. graveolens var *graveolens* Vittad., *G. graveolens morchellaeformis* var. *morchellaeformis* Vittad. and *G. graveolens* var. *otthii* (Trog) Zeller & Dodge. A single basidioma of the second variety was firstly found in Brienza (PZ) territory during February 2006. Presence of the third and the first varieties was reported under *Q. pubescens* (*s.l.*) in Corleto Perticara (PZ) area (Rana et al. 2010) and in a mixed wood of *Q. cerris* and *Carpinus betulus* L. in Gorgoglione (PZ) territory in 2009 (Rana et al. 2011). Although molecular analyses were carried out, identification of the first variety was based mainly on basidiospore morphology and dimensions. A 775 bp ITS gene DNA sequence of a Lucanian specimen of the same *G. graveolens* variety was deposited in NCBI database under accession code FN666413 (Rana et al. 2011).

2.2.7 *Agaricomycotina*, *Agaricomycetes*, *Phallomycetidae*, *Hysterangiales*, *Hysterangiaceae* Fischer

Three species of *Hysterangium* Vittad. were so far found in Basilicata: *H. stoloniferum* Tul. & C. Tul. under *Q. cerris* in Corleto Perticara (PZ) area (Rana et al. 2008), *H. inflatum* Rod. under *Eucalyptus* spp. in BNR in 2007 (Rana et al. 2010) and *H. nephriticum* Berk. under oak in "Mantenera-Malcanale" forest (Tricarico, PZ) in 2012 (Rana et al. 2013a).

2.3 Zygomycota

2.3.1 *Mucoromycotina*, *Endogonales*, *Endogonaceae* Paoletti

Only one species of *Youngiomyces*, *Y. multiplex* (Taxter) Yao (= *Endogone multiplex* Taxt.), has been reported in the region under *P. pinaster* in winter 2000. Its identification was mainly achieved considering spore morphology and dimensions (Marino et al. 2003).

3 Concluding Remarks

On the basis of the up-to-date information available for hypogeous and semi-hypogeous fungi naturally growing in Basilicata, a reckoning of 82 taxa comes out as shown in Table 1. The fungal entities so far found belong to 14, nine and one genera of *Ascomycota*, *Basidiomycota* and *Zygomycota*, respectively. Among

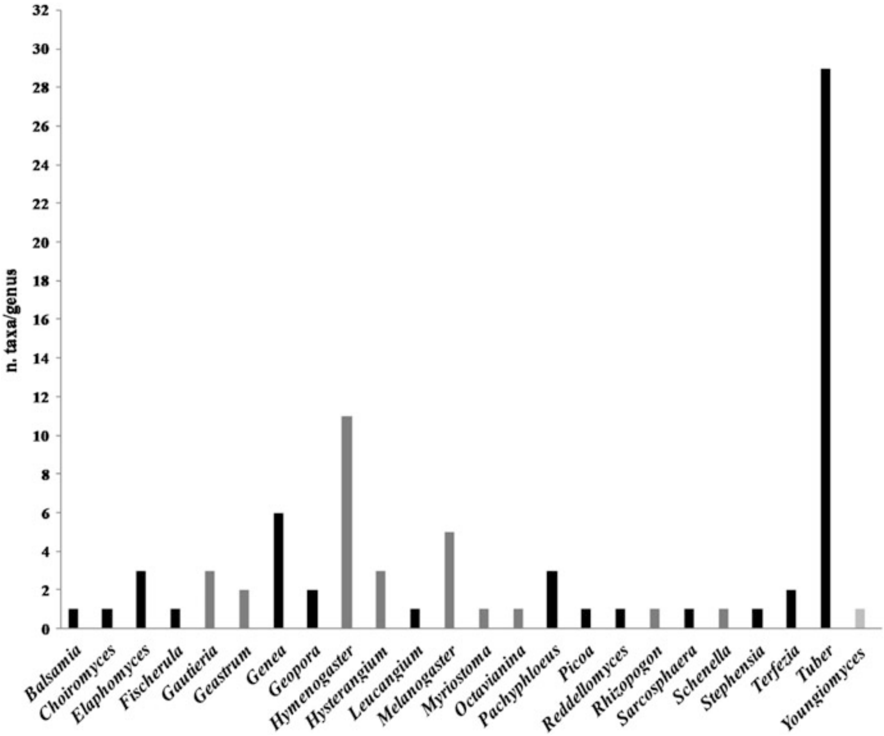

Fig. 3 Number of taxa/genus of hypo- and semi-hypogeous *Ascomycota* (*black*), *Basidiomycota* (*grey*) and *Zygomycota* (*light grey*) growing in nature in Basilicata

Ascomycetes, the most numerous genus is *Tuber* Micheli: Wiggers which includes, except for *T. gennadii* (Chatin) Patouillard (= *Terfezia gennadii* Chatin), all the taxa described by Montecchi and Sarasini (2000) and Riousset et al. (2001) as well as the hypothetical variety *vittadinii* of *T. magnatum* (Daprati 2007) for a total of 29 taxa.

A more restrictive estimate, considering that *T. aestivum* is identical to *T. aestivum* var *uncinatum*, i.e. *T. uncinatum* Chatin, either morphologically (Tanfulli and Di Massimo 2002) or molecularly (Wedén et al. 2005), *T. brumale* to its var. *moschatum* (Gandeboeuf et al. 1997) and *T. hiemalbum* to *T. melanosporum* (Dupré et al. unpublished data, as reported by Riousset et al. 2001), would reduce the above number to 25 (see Fig. 3). Anyway, Basilicata, 4 years after a previous review (Venturella et al. 2011), for the number of *Tuber* taxa which can grow in its territory, confirms its first position among Italian regions.

Other genera enough represented in the region are *Hymenogaster* (11 taxa), *Genea* (6), *Melanogaster* (5), *Gautieria*, *Elaphomyces*, *Pachyphloeus* and *Hysterangium* (3).

The region has an enviable biodiversity of hypogeous and semi-hypogeous fungi. Some of them, as the marketable *Tuber* species, play an important economical role for human beings. The other *Tuber* species and *taxa* belonging to the various *Ascomycota* and *Basidiomycota* mentioned certainly are precious for some components of wild fauna as squirrels (Venturella et al. 2011), field-mouse, mole, fox, etc.

Despite of the high number of hypogeous fungus *taxa* already identified in the region, some zones (*e.g.* Italian State's and Basilicata Region's properties and protected areas) still remain unexplored in this respect and numerous semi-hypogeous and hypogeous fungi are waiting to be discovered.

The drawback is that the natural *Tuber* production showed a progressive marked decrease in Italy and other main truffle producing European countries (France, Spain) in the last 20 years (Hall et al. 2007). This negative trend occurred also in Basilicata due to the massive presence of wild boars on its woody areas and the excessive and the often illegal exploiting of its natural truffières.

This situation renders necessary and pressing the widespread diffusion of the available know-how to extend truffle cultivation in the region and to preserve, through *in situ* conservation programmes, the survival of some hypogeous fungi which risk extinction before being known. In this mode, the future generations will inherit this fascinating and incommensurable patrimony of the Nature.

Acknowledgements The authors are grateful to Dr. Mariano Annarita (Basilicata Region, PZ) who provided basidiomata of *Hymenogaster decorus*, *H. hessey* and *H. rehsteineri* and to Cerroni Andrea and Cerroni Nazzareno (Pignola, PZ) who found sporophores of *Pachyphloeus conglomeratus*, *Terfezia arenaria* and *Melanogaster broomeanus*.

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