

## RETHINKING A SUSTAINABLE TRUFFLE SECTOR UNDER GLOBAL CRISES

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With 1 figure

**Summary:** Global climate change is the main threat for the emerging truffle sector, which already extends across seven key regions in the Americas, Europe, South Africa and Australasia. At the same time, the potential effects of financial crises and global pandemics have not yet been considered in most risk assessments. Here we describe the direct and indirect impacts of the actual coronavirus pandemic on the rising truffle sector. We discuss how COVID-19 affects small family businesses and international enterprises, and if the current harvest decline will have ecological long-term benefits. Furthermore, we question extant cultivation practices, irrigation techniques and trade systems to prepare for a more equitable and sustainable future of the global truffle industry. Despite various foci on one of the most expensive gourmet foods and its associated agroforestry, we expect our reflections to be valuable for many other high-value crops, and a green agriculture in general.

**Zusammenfassung:** Der globale Klimawandel stellt die größte Herausforderung für den wachsenden Trüffelsektor dar, welcher sich innerhalb der letzten Jahre in sieben Regionen in Nord- und Süd Amerika, Europa, Süd Afrika, Australien und Neuseeland ausgebreitet und etabliert hat. Während negative Effekte von Hitzewellen und Dürreperioden für die Trüffelproduktion bekannt sind, wurden mögliche Folgen globaler Finanzkrisen und Pandemien bisher kaum bis gar nicht in bestehenden Risikoeinschätzungen berücksichtigt. In der vorliegenden Studie beschreiben wir die direkten und indirekten Konsequenzen der aktuellen Corona Pandemie auf den noch jungen Trüffelsektor. Wir diskutieren wie sich COVID-19 auf kleine Familienbetriebe und internationale Unternehmen auswirkt und ob reduzierte Trüffelernten einen ökologischen Langzeitnutzen haben. Außerdem hinterfragen wir bestehende Anbaumethoden, Bewässerungstechniken und Handelsbeziehungen im Hinblick auf eine gerechtere und nachhaltigere Trüffelindustrie. Wir hoffen das unsere kritische Auseinandersetzung mit der teuersten Delikatesse und deren Waldfeldbau nicht nur für andere Agrarprodukte, sondern ganz allgemein auch für eine Grüne Landwirtschaft hilfreich ist.

**Keywords:** biodiversity, COVID-19, economic crises, global pandemic, gourmet food, green-agriculture, irrigation systems, reforestation, rural economies

Farming of the Périgord black truffle (*Tuber melanosporum* Vitt.) has expanded rapidly during the past decades. With ~2.3 million km<sup>2</sup> of suitable truffle terrain across seven key regions in the Americas (Chile, California and Oregon), southern Europe (Spain, France and Italy), South Africa (the KwaZulu-Natal and Western Cape regions) and Australasia (southwest and eastern Australia and most of New Zealand), the emerging truffle sector – an important agroforestry practice – generates hundreds of millions of Euros annually (FISCHER et al. 2017; OLIACH et al. 2020). Enhanced cultivation techniques and an ever-growing number of plantations since the mid 2000s not only trigger economic benefits for rural areas (HALL et al. 2003; DONNINI et al. 2013; BÜNTGEN et al. 2017), but also increase landscape diversity and water-holding capacity (REYNA and GARCIA-BARREDA 2014). Comparable to mycotourism (BÜNTGEN et al. 2017), a thriving truffle sector can also support local and regional infrastructure, biodiversity and environmental awareness.

Similar to ecological and agricultural systems that are particularly prone to drought extremes and heat waves (TRNKA et al. 2020; BÜNTGEN et al. 2021b; OLESEN et al. 2021), anthropogenic climate change has been described as the main threat for the quality and quantity of truffle harvests (BÜNTGEN et al. 2012, 2019; THOMAS and BÜNTGEN 2019; GARCIA-BARREDA et al. 2020), which can exhibit an essential non-wood forest product for sustainable silviculture (DONNINI et al. 2013). However, risk assessments of the truffle sector do not consider the cascading effects of financial or other global crises. Reportedly, the current coronavirus pandemic (COVID-19) hits the sector at an unprecedented scale (<https://www.reuters.com/article/croatia-truffles-idINL8N2IC3D9>). While the direct and indirect impacts of the unfolding pandemic on agricultural production and trade have not yet been quantified (BECKMAN and COUNTRYMAN 2021), we argue that the devastating consequences for the truffle sector will affect small family businesses as well as global enterprises, with implications for the wider food industry (RIDLEY and DEVADOSS 2020; CHENARIDES et al. 2021).

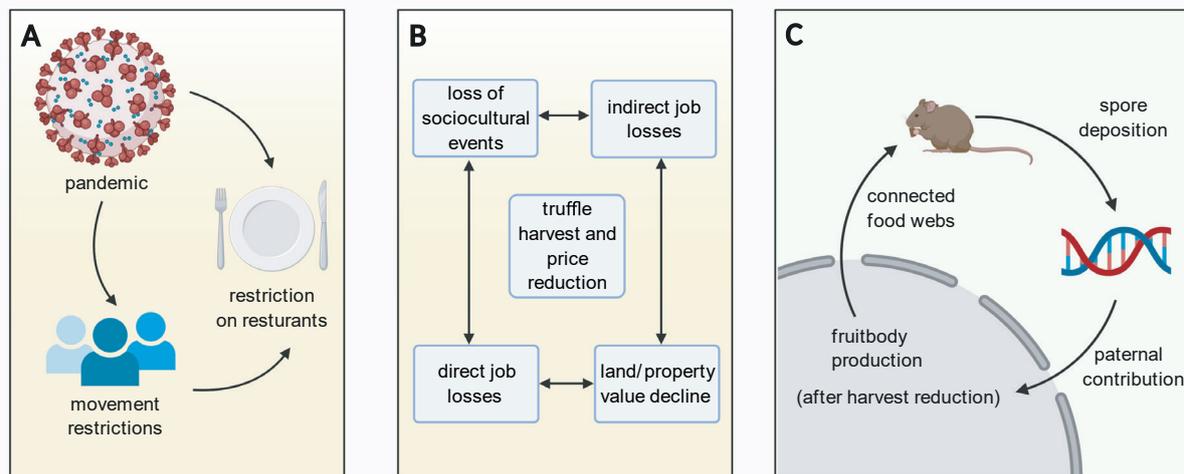


Like academia (BÜNTGEN et al. 2021a) and the wider mushroom agroindustry (HARVATI 2021), including mycotourism (BÜNTGEN et al. 2017), the influence of COVID-19 restrictions on truffle hunters, farmers, harvesters, sellers, and consumers has been inescapable (Fig. 1A). With pandemic-related enforced closures, demand from the most important market for truffles, the high-end restaurant sector, has suddenly declined. First grade fruitbodies of the Périgord black truffle are currently offered in the US for \$320USD/lb (January 2021), which is less than half of the regular in-season value. Moreover, truffle festivals, such as the annual Napa Truffle Festival in California (USA) or the Trufforum in Catalonia (Spain) have been cancelled for the 2020/2021/2022 harvest season, and many traditional markets and socio-cultural events are forced to close (Fig. 1B). Associated declines in employment levels may have a direct impact on household income, creating financial frictions and liquidity constraints. These impact property and housing markets directly and can lead to further declines in local employment levels (BRANCH et al. 2016). Therefore, the socio-economic consequences of declining truffle harvests can be complex and may exist at national and international scales (Fig. 1B).

Low truffle prices, combined with pandemic-related travel and trade disruptions have led some orchards to abandon harvesting for at least the 2020/21 season. Imposed movement restrictions in response to infection levels further impact large numbers of farm la-

bourers, and in Italy alone, this may affect over 100,000 seasonal workers and their truffle-search dogs. Indeed, the reduction in truffle prices and loss of peripheral truffle-related industries is particularly harmful for rural populations where such activities are centred (BÜNTGEN et al. 2017), and the direct loss of cultivators' income is not the only issue. In California (the largest truffle cultivation region in the Americas), for example, COVID-19 is likely to impact lower-wage agricultural workers disproportionately, and so staff shortages have been reported as being directly related to high rates of infections. Despite reduced labour availability, the maintenance of plantations has been largely continued under reduced capacity, although in the future the overall damage will likely depend on de-synchronisation of virus outbreaks and harvesting activities.

In contrast to the immediate economic constraints, there are potentially two long-term advantages of the current harvest decline (Fig. 1C). Firstly, the hypogeous nature of truffles leads to a dependence on mycophagy for spore dispersal. Consequently, there are many vertebrate and invertebrate species that predate them and in doing so, truffles may form an important component of animal food webs (Trappe, 2009). Although ecological networks are complex and multifactorial, the increase in unharvested fruiting bodies, especially in natural habitats, is likely to benefit populations of truffle specialists such as some flies of the genus *Suillia* (e.g., *S. tuberiperda*) and associated food chains (ROSA-GRUSZECKA et al. 2017). Secondly,



**Fig. 1:** Effects of the global coronavirus pandemic (COVID-19) on the emerging truffle sector. (A) Direct COVID-19 impacts on social movement patterns and the enforced closure of truffle markets and restaurants. (B) Socio-economic consequences of current COVID-19 restrictions on personal and monetary goods associated with declining truffle harvests and price reductions at local/national and global/international scales. (C) Long-term benefits of dampened truffle harvesting practices due to COVID-19 restrictions on natural and agricultural food webs and enhanced truffle fruitbody production. Reduced truffle harvests will likely result in greater spore availability, thus aiding to sexual reproduction and leading to greater fruitbody production.

a reduction in truffle harvesting may enhance future fruitbody production, because an increase in the truffle spore-bank of the soil from decomposing fruitbodies or faecal matter arising from truffle predation is beneficial to mycelial development (SCHNEIDER-MAUNOURY et al. 2019). Further, the most widely harvested Périgord black truffle is dependent on sexual reproduction for fruitbody formation, and it has been suggested that paternal contributions arise from the soil spore bank (TASCHEN et al. 2016; FISCHER et al. 2017). Thus, reduced harvesting pressure may in turn pay dividends by contributing to enhanced truffle yields in the future.

A purely market-oriented truffle industry, considered among many to be luxurious but dispensable, will always remain vulnerable to market changes and financial crises. The high-value nature of truffle production, combined with significant inter-orchard variation, has created a climate of envy and frustration among farmers and investors that threatens the ethical and professional standards of both green-agriculture and eco-tourism. If the marketing and promotion of truffles and their secondary products absorbs more time and receives more rewards than the effort to engage in sustainable hunting and farming, there will be little incentive to explore new pathways of ecological farming and fair trading. COVID-19 forces the vibrant sector to reflect on its goals and the ways to achieve them. The current restrictions present fresh opportunities to question extant cultivation practices, irrigation techniques and trade systems, and to prepare for a more equitable and sustainable future.

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