Succeeding from Nature:
The Non-Human Agency of Portuguese Cork

Accepted for publication in the Geographical Journal: 27.10.2019

Authors: Andrew Brooks & Robert A. Francis

Department of Geography, King's College London, London, UK

Email: Andrew.brooks@kcl.ac.uk

ORCID iD: https://orcid.org/0000-0001-6896-6635

Abstract:

Non-human life has economic agency. It acts on the cultural values of products. Naturalness is an important property in the market and imbues vibrant materials with organic, healthy, traditional and other contingent properties. However, "natural" products can be succeeded in form and function by "synthetic" alternatives. Their value is further affected by non-humans. Our signal case explores Portuguese cork-bark, an agroforestry product grown in the *montado*, a biodiverse managed mosaic landscape of forestry and farming. The natural value of cork bottle stoppers is based on their effect on wine flavour. Oxygen permeable cork enables beneficial ageing to enhance flavour, whereas cork contaminated with taint degrades wine. Synthetic stoppers recreate the form and function of corks without being a vector for contamination. A succession from natural cork stoppers to reliable artificial polyethylene corks led to a decline in demand for cork bark and negative impacts on *montado* biodiversity. Yet here we demonstrate that such successions can be reversed as the affective properties of cork bark products became revalued with improvements in manufacturing, increasing concern for environmental sustainability and rising consumer demand for natural products. This leads us to explore further the dynamics between natural goods and synthetic replacements. We argue that rather than being two discrete domains of reality, natural and artificial products are both co-produced through assemblages of human and non-human action. Understanding succession between "natural" and "artificial" products enables new insights in to the geographies of non-human agency.

1. Introduction: Nature and Natural Products

The idea of nature is socially constructed and contested (Smith, 2010). What is, and is not, a natural material is subjective. Nature persists as one of the most complex and flexible words in the English language (Williams, 1976). It is, as Noel Castree (2017, p.3) characterises, 'promiscuous', and the labelling of commodities as 'natural products' is among its most profligate applications. For consumer goods, naturalness is both an important biophysical property and an extrinsic quality that is difficult to define. This ambiguity makes the 'natural product' label commercially appealing, and its use is increasing (Google Ngram, 2019). Nature is effective in the market precisely because natural serves as a shorthand for conveying diverse messages about the material world (Castree, 2013). Naturalness stems from the agency of animals, bacteria, fungi, plants and physical geography in making materials and yet what is considered natural draws on culturally specific assumptions about the world and furthers particular social agendas, while concealing these motivations (Demeritt, 2002).

In this article we take an original approach to the function of nature in the market by foregrounding the role of non-human life in generating cultural and economic value. Our contribution extends to explore how non-human life affects the value of artificial (synthetic, or non-natural) products. Both living and inanimate non-humans have affective properties (Haraway, 2016). Assemblage theories have usefully explored the encounters between networks of objects and subjects in which non-human lives are entangled (Bennett, 2009; Callon, 1984; Latour, 1987). Open-ended assemblages of humans and non-human objects make both urban and rural landscapes (Gandy, 2003). Non-human life is an active agent rather than something only subject to human manipulation (Ingold, 2012). Geographical work has illuminated the agency of living non-humans, which impact societies through 'corporeal, geotechnical...pathological' and myriad other processes (Lorimer, 2007: 912). Non-human animals, such as urban monkeys, can be charismatic and animate social space (Barua and Sinha, 2019). Companion species, like dogs and cats, depend upon

and determine new social and economic regimes (Haraway. 2016). Plants too shape patterns of consumption. Paul Robbins' agenda-setting Lawn People (2007) showed how turfgrass has non-human agency. A living homogeneous lawn is considered a worthy aspirational component of a 'good' garden (Weigert, 1994). Good turfgrass lawns are lush, green, uniform and neat. Recent work has demonstrated how living lawns may be replaced by artificial grass, replicating the 'good' form and function of a living material, albeit with negative ecological effects (Brooks and Francis, 2019). Here we build on this analysis and examine how new types of synthetic consumption replicate and replace natural products. Artificial goods are succeeding the natural: fake fur coats are replacing animal hides, plastic flowers are displayed in place of real pansies, and synthetic lubricants substitute for mineral oils in motor engines. But these new artificial products are not divorced from nature; their values are affected by pre-existing non-humans.

In this paper we explore how non-human life acts on markets for natural and artificial products. We first consider what makes a 'natural product' to enable us to differentiate synthetic goods. Next, drawing on a worked example of Portuguese cork, we explore how natural cork bottle stoppers are valued. The cultural significance of cork is derived from its traditional production in Iberian agroforestry and its use in wine bottling, which includes the beneficial ageing or negative spoiling effects cork stoppers may have on wine (Costa et al., 2012). This industry has faced competition from plastic cork stoppers and screwtops, which to a greater and lesser extent replicate the form and function of natural corks (Sit, 2017). Cork trees and an entire ecological system have affects on natural and artificial products. We argue that the affective properties of non-human life establish value in natural products and enable replacement artificial products that would not exist without these non-humans. For instance, there would be no substitute synthetic fur without mammals with thick-growth hair coats. To reflect on such sequences of product replacement, we ultimately draw on the longstanding concept of ecological succession (as pioneered by Clements, 1916; Gleason, 1927; Tansley, 1935) to argue that non-human life extends into the socio-technical

to catalyse and facilitate new product niches, and illustrate how it can shape and produce cultural and economic outcomes.

This paper proceeds across five sections. In part 2 we establish what makes a natural product. Part 3 documents the Portuguese cork ecological system, drawing on fieldwork (May-August 2018) in the Alentejo, the Algarve, Lisbon and the Tagus Valley. This included observations and interviews in forests, information centres, museums, and cork factories in and around São Brás de Alportel. With this material foundation established, section 4 illustrates how cork agroforestry is interconnected with the wine industry, and discusses the material properties and cultural values of cork bark, drawing on visits to vineyards, wine warehouses and retailers. In section 5 the adoption of artificial corks in the wine industry is documented to illustrate how synthetic materials can rival the cultural and economic values of a natural product. In conclusion, we reflect upon how artificial products may succeed the natural in part 6, and the wider impacts of non-human life on both natural and artificial products.

2. What makes a natural product?

In response to a range of socio-ecological crises a growing basket of natural products, be they characterised by their authentic, eco-, green, heritage, organic, original, traditional or unprocessed attributes, are positioned as answers to the environmental impacts of unsustainable economies (Fletcher, 2012), as solutions that satisfy consumers' cultural needs (Bryant and Goodman, 2004), and/or as healthy alternatives to human-made goods (Herrick, 2011). But what makes such goods natural? A natural product has long been defined as something once living; a 'chemical substance produced by a living organism' (Webster's Dictionary, 1913) or 'small molecules produced naturally by any organism' (Nature, 2019). These organic categorisations can be expanded to

include materials made by physical environmental processes such as salts, metals and minerals, providing a simple and appealing definition: natural products derive from non-human life and physical geography. However, this pure biophysical mode of thinking is deeply problematic on three grounds.

First, it reproduces the fallacious modern concept of a separation between a natural and a cultural world (Caillon, et al., 2017; Haraway, 2016). This notion is false as human activity has extended to influence all biophysical entities. As Neil Smith (2010) argued, under capitalism the idea of nature is socially constructed to serve the demands of the market. Over the past five centuries, from the Colombian exchange (Turbelin et al., 2016), through climate change, to hi-tech material transformation of non-human life, such as gene manipulation (Sexton et al. 2019): '[n]ature has become a mere means to the end of profit realization, and in the process it has been physically reconstituted into an anthropogenic "second nature."' (Castree 2017, 16). The nature/culture binary can be further challenged by taking the counterpoint: there is no pure human-made world (Piccolo, 2017). For instance, the intensive agro-industrial polytunnel landscapes of southern Portugal and Spain are natural in the sense that seeds, pollinators and water have not been created by people from scratch. At the same time as no good could be divorced from humanity, no commodity can be produced outside the biophysical world (Castree, 2017). Secondly, chemically identical products can be produced both organically and through inorganic chemistry, which means there is no definitive way to materially differentiate products of non-human life (Reeser, 2013). Thirdly, the 'product' part of a natural product is important, as to be a product under capitalist social relations the thing must have exchange value (Fine, 1989), a prerequisite absent from biophysical and chemical classifications.

To define a natural product, we must turn from the material and the molecular to the market. The only definition that works is that a natural product is a commodity valued as a natural product. At first glance this rendering seems nothing more than tautologous. However, in the same way that

nothing has a precise economic value (or price) until it is sold and becomes a commodity (Fine, 1989), it is true that a product is only a natural product when it is *sold* (or otherwise exchanged) as a natural product. Naturalness can be implicit and draw upon the material culture that surrounds production, marketing and retail (Bryant and Goodman, 2004). Some goods are advertised as natural and in other cases the naturalness is assumed and not labelled. The natural values of a product are culturally contingent and whether something is natural is subjective (Ibert et al, 2019). No commodity is a pure biophysical product of nature and yet the market is full of products socially constructed as natural.

Social processes establish cultural value in natural products, but the things themselves also have affect. As Castree (2016, 187) argues 'what we call "nature" possesses a degree of agency and influence, but this is always defined relationally'. A natural product is defined relative to culturally specific assessments of what is suitably free of 'too much' human manipulation. The socially contingent, relational conditions that establish value in natural products lead to environmental disputes. Natural products can be made from living organisms, yet be unsustainable or perceived as traditional or unethical by cultural groups with different environmental values. Ivory, whale meat, and timber from old-growth forest are commercially and culturally valuable, and highly contested natural products (Braun, 2002). Criticisms of the use of these prized natural assets are couched in terms of the socially or environmentally undesirable effects of their harvest (Posnett, 2019) and as such, these examples reinforce how nature is a complex and flexible concept that contains culturally specific assumptions (Smith, 2010). In the cases of elephants, whales and ancient trees, the vibrancy of these charismatic biota has powerful affect, acting on human emotions (Lorimer, 2007, 2010).

3. Cork Ecology: The Portuguese *Montado* landscape

Cork (*Quercus suber*) is a charismatic species that captures the public imagination. The 235-year-old Whistler Cork Oak in the village of Águas de Moura, 43Km southeast of Lisbon amid the Setúbal wine region, is the oldest and largest cork tree in the world and was voted the 2018 European Tree of the Year (Município Pamela, 2017). Portuguese cork is valued for its association with wine making, landscape and heritage, and as a keystone species in a sustainable agroforestry system (Vessella *et al.* 2015). Cork trees typically live for up to 200 years and can be harvested after 20-25 years. A single harvest produces c.40-100+kg, depending on tree size and age (Costa et al. 2003). Cork forests are an integral part of the Portuguese rural landscape characterised in positivist ecology as "human-made systems with natural ecosystems embedded" (Bugalho et al. 2011, p.278). And yet culture and nature are not two distinct systems. Rather cork agroforestry is an assemblage of non-human and human agency, a second nature co-produced through millennia of human-environmental interactions. Cork trees are part of a multi-use forest, pasture and cereal landscape known as *montado* in Portuguese and *dehesa* in Spanish, that extends for between 3.5 and 4.0 million ha across the southwestern Iberian Peninsula (Pinto-Correia et al. 2011: p.82).

It is difficult to grasp the scale of the savanna-like mosaic of mixed density cork (*Quercus suber*) and holm oak (*Quercus ilex rotundifolia*) covering most of southern Portugal, until you drive through the landscape. *Montado* is a complex agroforestry system with variable soils, micro-climates and topographies (APCOR 2018). Agriculture thrives. Cereal crops are cultivated in long rotations. Trees provide fodder from acorns and offer shade in summer and shelter in winter for grazing cows, goats, sheep and Iberian pigs. Bee keeping, charcoal production and mushroom picking are all part of rural life (Surová and Pinto-Correia, 2009). The *montado* has high conservation value, great habitat heterogeneity and are rich in endemic species and biodiversity (Ellis and Ramankutty 2008). Many plants and fungi are valued as non-timber forest products with aromatic, culinary or medicinal properties. Plant diversity is facilitated by regular shrub clearing that creates a fine-scale

habitat mosaic to support a variety of floral communities. There are abundant small mammals, and communities of larger charismatic wild animals; red deer (*Cervus elaphus*), wild boar (*Sus scrofa*), black vulture (*Coragyps atratus*), Iberian imperial eagle (*Aquila adalberti*) and Iberian lynx (*Lynx pardinus*); these latter two are categorised as 'threatened' by the IUCN. The sustainable management of this agroforestry system requires local expert knowledge of the resilience of the mélange of diverse non-human life and environmental conditions (Costa et al. 2010). Landscape management is key, as without human intervention the heterogeneous mosaic deteriorates and ecological communities decline. The *montado* is a product of long-standing interactions between agricultural work and wildlife. Trees, fields and animal life come together in a geographically imagined 'natural' landscape, produced through the combined effects of non-human life and human agency (Plieninger et al. 2015; Watts 1999), and support sustainable agroforestry that gives rise to the production and consumption of natural products.

Cork trees are the most important part of the *montado* system, both ecologically and economically (interviews and observations). Cork oaks are seldom planted, and the harvesting of trees occurs only when a 1mm gap has developed between the cork cambium (phellogen) and the cork phellem. This bark is removed without felling the tree (interviews and observations). The cork sector is highly regulated, and cork is typically first harvested after 20 years and subsequently at 9-year intervals, prescribed in legislation since 1933 and 1935 respectively (interviews, cork growers). Cork is the phellem (outer) layer of bark tissue and is a compact, elastic, thermally insulating tissue of dead and impermeable cells. A new ring of growth is produced annually and not shed. The bark of the cork oak evolved to provide protection from forest fires; the outer phellogen cells die but another layer of active phellogen grows, maintaining the cork bark. The resilience of the *montado* system to forest fires is threatened by human action, as over-harvesting cork bark increases fire risk. Outbreaks have devastating impacts on humans and non-humans. Recent wildfires spread through central and southern Portugal resulting in the loss of 114 human lives in 2017 and

devastating 27,000 hectares of *montado* around Monchique in 2018 (Algarve Daily News, 2018). Cork trees that are fire damaged need to have their bark stripped after 3 or 4 years then farmers 'wait again ten years later till we have a good quality of cork' (interview, cork grower).

Portugal contains 34% of the world's cork production area and produces 49% of the global volume of 201,000 tons (APCOR 2018). Cork is an important economic sector and provides a €757 million contribution to the net balance of trade and 1% of all Portuguese exports. There is more demand for cork than Portugal can supply, with the main constraint being the availability of cork trees: 'the problems stay with our nature' (interview, cork grower). In addition to the economic contribution the landscape is valued for biodiversity (Bugalho et al. 2015), aesthetics (Surová and Pinto-Correia 2008), tourism and recreation (Pinto-Correia et al. 2011), and its relationship with wine-making (interviews, winemakers). It is considered High Nature Value (HNV) farmland by the European Environmental Agency (EEA 2016).

4. From Bark to Bottle

Harvesting cork is a highly skilled job. Workers cut carefully so as not to damage the living trees. Wages are '€120-150 a day', good pay for manual work in Portugal (interview, landowner). Once cut, cork bark planks are immersed in boiling water, in a process known as '*estabilização'* [stabilization], to clean the bark, expand the cells, and leave the planks pliable. Stabilized planks are graded for quality (factory observations, figure 1). The honeycomb-like structure of cells leaves a material that is light, compressible, resilient and impervious. Cork is valued for its low mass, water resistance and thermal properties and has many applications. Since antiquity it has been used in construction, floats and footwear. Pliny the Elder discuss holm oak and cork in *Naturalis Historia*, his contemporaries used bark for their sandals, and stoppers were found in amphorae [storage

vessels] at Pompei. More recently cork provided fuel tank insulation in NASA's space shuttles and dry, tan-coloured cork powder is the basis for mass-market natural beauty products. Cork bark is primarily used to make bottle stoppers, and 70% of Portugal's cork exports are for wine packaging (APCOR 2018). Exports to Western Europe date from at least the Middle Ages and grew with the increase in the trade of bottled wine in the 18th century. Cork forestry and industry expanded in response to this demand (Museu São Brás de Alportel).

Figure 1. Clockwise from top left: cork tree stripped of bark, cork bark sections, stabilized cork planks being trimmed, cork punching machine (Source, Authors' own photographs)

To make traditional wine corks, planks of bark are cut into narrow strips and stoppers are punched through the strips parallel to the outer layer of bark (factory observations, figure 1). Cylinders of inner cork bark are compressed to around 85% of their original size when pressed into glass bottles

to form water-tight seals. Lenticels (porous bark tissue) allow a minimal amount of air to pass through the stopper and reach the wine (interview, cork factory). Oxygen interacts and gradually causes the liquid to oxidize and develop mature, secondary qualities and expel unwanted aromas. Permeable cork bark stoppers allow around 1 milligram of oxygen to enter a bottle per year enabling age-worthy wines to develop their complexities (The Wine Cellar Insider, 2019). Cork has an effect on wine flavour specific to the liquid and the bark. Only certain wines will be beneficially aged (interviews, winemakers). Globally, estimates are as low as 1%, although higher for European wines (Vinepair, 2019). Despite the rarity of maturing wine, the presence of a natural cork is symbolic as an indicator of quality, even for wines not destined to be aged. In concert only good-quality cork bark stoppers (or synthetic alternatives) enable this process; these are the cork stoppers made from intact bark produced in the manufacturing process outlined above. These top-quality corks wholesale for '30-80 cents each' (interview, cork factory) and are used in more expensive wines. Cork stoppers are crucial components in the multi-billion-euro fine wine industry. By enabling the ageing process and facilitating the *natural* development of wines they amplify the value of reified, aged natural wine products (though it must be noted that the designation 'natural wines' is a label applied to wines made with minimal chemical and technological intervention, although it is not a regulated category like certified organic and biodynamic wines). The effect of cork is most apparent when a fine wine is opened, and the consumer takes a first taste of the matured product.

There is a further affect that cork-bark stoppers have on wine consumption. Around 3-8% of wines with cork-bark stoppers are 'corked' (The Wine Cellar Insider, 2019), although this figure is disputed (CIF, 2019). Corked wine is contaminated by TCA (2,4,6-trichloroanisole) a chemical compound that causes musty aromas and flavours. TCA forms through the interaction of plant phenols, chlorine and mould and may be transferred to wine when the liquid contacts contaminated cork, although it can occur elsewhere in wineries. Portuguese vineyards, like many

Old- and New-World wineries, use chlorine-based cleaning products and have damp spaces, old barrels, wooden pallets, doors and beams and cardboard cases (observations), all of which can be sources of phenols (Laube, 2007; Silva Pereira et al. 2000). Bleaching corks to give them a clean appearance can also cause taint. Portuguese corks are checked for taints. The Cork Industry Foundation (CIF) argues that its members adhere to a Code of Good Manufacturing Practice and are audited by an independent body, Bureau Veritas. Accredited CIF factories use 'microwaves, ozone, vacuum extraction systems and autoclaves… to guarantee that when the corks leave the manufacturers (in vacuum sealed packaging), there is no possibility that they are contaminated with TCA or any other substance that could taint the wine.' (CIF, 2019). Gas chromatography machines are used by producers such as Amorim to analysis thousands of cork samples a month to check for taint (Amorim, 2019). Despite these steps, wine industry sources still associate TCA contamination primarily with cork (Wine Folly, 2019).

Perception of TCA can vary between drinkers and a low-level taint may not ruin a wine or even be detectable. A check for TCA is the cork's much-parodied moment of theatre that occurs in restaurants when the waiter offers the customer a first sniff or sip of wine (Waterhouse 2015). This test is to immediately detect if the wine is contaminated, not to check the customer's approval of the wine's flavour (Berry Bros & Rudd, 2016). An experienced server can themselves detect TCA by a discrete sniff of the cork. But for many consumers trying the wine is a crucial ceremonial moment, it is part of the wider material culture that confirms the socio-economic value of both the wine and the cork as natural products; substances that are organic, vibrant, variable and vital (Bennett, 2009).

5. Synthetic cork alternatives

High quality cork bark stoppers are relatively expensive and are associated with a rate of spoilage unacceptable in most commercial supply chains. There is a 20-25-year lead time between planting and first harvest, and a nine-year interval thereafter. Supply is further constrained by the geographically specific growing conditions of Southern Europe and the Mediterranean fringe, which is distant from the new world wine regions of North America and the Southern hemisphere. Given these conditions it is unsurprising that wineries sought to find cheap and reliable alternatives. The cork industry itself responded to the cost issue by producing lower-quality cork-bark products that do not enable the ageing of wines. These 'technical corks' make up 39.7% of Portuguese cork stoppers (APCOR, 2018 p. 23) and are produced by compressing and gluing smaller cork parts together. Typically, these technical corks will not enable the wine to breathe as they lack intact lenticel, but like the whole cork-bark stoppers can be associated with TCA. Technical cork stoppers are still a natural product, as they do not have 'too-much' human-made material, are made from bark, recreate the appearance and form, and can play their role in the restaurant wine tasting ceremony.

Synthetic corks are an artificial alternative to the natural stoppers, but their form and function has been affected by the properties of the established cork bark stoppers. In their size and shape polyethylene bottle stoppers resemble a cork-bark stopper, require a corkscrew to be opened and can be cork coloured or any other hue, enabling product differentiation. They perform like lenticel cork-bark stoppers although they allow consistent transmission of oxygen at a rate determined by the wine-maker, enabling more predictable ageing. Cork-aged wine is subject to organic variability in oxygen transmission. Crucially synthetic stoppers are not a source of TCA (Waterhouse, 2015). In these respects, they are superior to natural cork. An alternative that does not directly succeed from cork agroforestry, but represents a shift in wine packaging design, is the metal screwtop. A screwtop is made up of an aluminium cap and an inner plastic liner that controls oxygen

transmission and can enable the ageing of a wine; but its form is fundamentally different, and it no longer represents a synthetic alternative. The screwtop's design, form and function has not been as markedly affected by the materiality of non-human life, although the characteristic of oxygen transmission is still a remnant of the lenticels vital to the life of cork trees, which fostered the culture of wine ageing.

The advantages of synthetic stoppers and screwtops and the rise of New-World wines as culturally distinct products presented a serious challenge to Portugal's cork industry in the 2000s (Unwin, 2005). Cork became less significant in establishing value in New-World bottles, thereby reducing the market. As Peter Weber, executive director of the California-based Cork Quality Council, explains: "Old world wineries typically honor traditional values of the wine being an extension of the land. Finished wines are expected to show depth, texture and complexity. These properties are more closely associated with cork-finished wines… [New-World wineries] often try to express the varietal component of the wine. Their finished products are often focused on displaying the fruit's varietal characteristics. These properties can be associated with screw-tops." (Plummer, 2018). Of even greater concern for cork producers was a spate of low-quality corks that entered supply chains in the early twenty-first century and a TCA 'pollution crisis' in the industry (Sit, 2017). Cork prices declined 30% between 2003 and 2009 due to tainting and competition (Bugalho et al. 2011, p.279). The cork sector responded with the CIF code of conduct and audits. There was a drastic improvement in quality and a revival in the cork industry (Sit, 2017). The CIF's anti-taint initiatives made cork stoppers less negatively affective, decreased wine spoilage and increased cork's socio-economic value. There were also regulatory measures undertaken to protect the cork industry in neighbouring Spain, the second largest cork producer. The Spanish government introduced a law in 2006 insisting that natural corks be used for wines to gain the important DO (*Denominacion de Origen*) origin status in 11 regions, including for all cava sparkling wines (Business Wire 2006). This measure further contributed to the cultural value codified in corks as natural products.

Since the emergence of a globalised wine industry, beyond Europe's Old-World region and the boom in affordable wines in the late twentieth century (Unwin, 2005), the value embedded in corks has shifted from utility to symbolism. The cork industry has nurtured the cork's image as a traditional and premium, as well as a natural, product (APCOR, 2016; 2018). The materiality of whole cork stoppers has had agency in this process. Artificial products are cheaper and reliable but only tested in the relatively short term. For vintage wines to be laid down for decades only cork-bark products have a proven track record at the pinnacle of the sector. Some vineyards use screwtops for early-drinking wines, but reserve corks for bottles intended for ageing. Premium brands have increased their use of corks demonstrating the high socio-economic value placed on the affect of non-human life (Mustacich, 2016; Sit 2017). Cork is also well positioned as a natural product because of its sustainable qualities, which the sector emphasises in contrast to the polyethylene stoppers (Schmitt, 2018). Consumers increasingly value cork's eco-credentials (Mestre and Vogtlander, 2013). In 2018, cork prices were high, and Portugal could not meet demand, especially as supply was reduced following the devastating forest fires in 2017 and 2018; but this has not always been the case (interview, cork factory). The decline in cork prices in the mid-2000s resulted in less intensive *montado* management, and even abandonment leading to shrub encroachment and a reduction in ecosystem services (Bugalho et al. 2011). The shifting socio-economic values of cork-bark and plastic stoppers has impacts upon non-human life, ecosystems and agricultural livelihoods.

6. Conclusion: Succession between "natural" and "artificial" products

Artificial goods can fill market niches originally formed by the provision of natural products (Fine, 2002). We use the idea of ecological succession in our theorisation to animate the affect of non-humans in enabling the market for certain artificial products. Artificial goods can imitate, out-

compete and replace natural products, in the same way that a more competitive species can out-compete an existing species in an ecological community. As such, they are simulacra (Baudrillard, 1994), fulfilling the socio-technical expectations and requirements of the product while removing their ecological foundation. But polyethene corks and other synthetic successors do not exist independently of non-human life. Their form and function are affected by the materiality of vibrant biophysical objects (Bennett, 2009). Cork bark's compressive, impermeable, and oxygen-transmitting properties are imitated by artificial corks. For wineries to change to synthetic materials these new stoppers must be superior products, whether through cost, reliability, aesthetics or some other cultural quality. Polyethylene stoppers out-competed corks when New-World wine producers sought more economical stoppers, and to establish divergent cultural values in their wines. In tandem, the value of natural corks was eroded by the affect of a TCA epidemic in the 2000s. There was a feedback from consumer to landscape ecology and a negative impact on the biodiversity of the *montado* (Bugalho et al. 2011). And yet because non-human life has agency in shaping socio-economic value (Ingold, 2012), the movement from natural to synthetic goods is not an inevitable, teleological process. Natural products can become more desirable, re-establish themselves, colonise other markets or form new product niches, just as excluded species can re-establish in an ecological community in response to changes in the biophysical environment or community interactions. A resurgence in cork values has been amplified by a greater concern for sustainable products. In the context of global crises of species extinction, habitat loss and climate change, the shifting cultural value of natural products opens opportunities and challenges with societal and environmental costs and benefits, and which deserves further exploration. Consideration of the ways in which the agency of naturalness can be effectively harnessed would mark an important progression in this area. Natural products can out-compete established artificial goods in market niches such as with the growing demand for compostable coffee cups or organic cottons (Sneyd, 2016). New 'eco-friendly', 'green', 'healthy', or 'sustainable' products offer much

needed solutions, or at least have affect through drawing attention to pressing social and environmental problems (Bryant and Goodman, 2004).

From natural landscapes, such as the *montado*, through to products like plastic wine stoppers, the world only consists of places and objects coproduced by humans and non-humans, be they living or inanimate (Smith, 2010). Disentangling nature and culture is impossible (Demerit, 2002). Cork trees, farmers, animals, fire and wine makers all have agency in the *montado* landscape. At the molecular level a polyethylene stopper is made up of a chain of carbon and hydrogen atoms, most commonly sourced from petrochemicals, obtained from fossil deposits of non-human life. A plastic cork would be natural if it was sold as a natural product. Natural products are only defined in the market; retailed with values that are directly or indirectly associated with a socially constructed naturalness. There is no material or molecular objectivity through which to define products as natural (Haraway, 2016). Rather, naturalness is culturally contingent and informed by invented tradition and geographical imagination (Hobsbawm and Ranger, 2012; Watts 1999). Natural products are not one side of a dichotomy existing in opposition to non-natural alternatives; rather than being two discrete domains of reality, "natural" and "artificial" products are two sides of the same coin (Caillon et al., 2017; Piccolo, 2017).

Understanding succession between "natural" and "artificial" products is a new way of thinking about the non-human agency that is all around us. By foregrounding a market-based definition of naturalness in our discussion and using a signal case to examine the agency of non-human life in producing value across natural and artificial products, we have demonstrated how reifying naturalness can form part of broader social and environmental politics. Stemming the successional replacement of cork stoppers by their artificial counterparts and promoting the cultural value of natural cork is desirable for the persistence of the prized montado landscape. Conversely, succession from natural to artificial products may provide answers to other challenges. For example, laboratory-grown beef burgers are synthetic replacements for animal flesh. They are

succeeding from an established natural product and may offer a more sustainable source of protein than traditionally farmed cattle (Sexton et al., 2019). There are countless other examples of natural to artificial successions with diverse social and environmental impacts, including acrylic fibres replacing wools, plastics in place of ivory and synthetic fertilizers replicating organic manures; and in each case these successions appear to diminish the influence of non-human life. Yet when an artificial product replicates the form and function of a natural product it is not made independent of non-humans, but rather these successors' very existence is due to the agency of what is termed 'nature'.

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