Natural cork bottle stoppers: a stopper on CO_2 emissions?

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Committed to the Environment

CE Delft is an independent research and consultancy organisation specialised in developing structural and innovative solutions to environmental problems.
CE Delft's solutions are characterised in being politically feasible, technologically sound, economically prudent and socially equitable.

Contents

Terms and definitions

Allocation
Partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems (source: ILCD Handbook, ISO 14044:2006).

Carbon sequestration (C-sequestration)
The process of capture and long-term storage of CO_2. In this report: the storage of CO_2 in standing biomass (cork oaks) and soil.

CO_2 fixation
Synonym to carbon sequestration.

Co-product
Any of two or more products coming from the same unit process or system (source: ILCD Handbook, ISO 14044:2006).

Functional unit
The subject of the study: the specified quantity of the product under study. For instance: 1 kg of finished natural cork stoppers, at production facility.

Greenhouse gas (GHG)
Concerns a gas in the Earth's atmosphere that absorbs infra red radiation and sends it back to the Earth's surface, thereby contributing to the heating up of it's surface.

ILCD Handbook
Provides technical guidance for detailed LCA studies, it builds on the ISO specifications for LCA.

ISO 14000
Series of standardization documents, issued by the International Organization for Standardization. The ISO 14000 family addresses various aspects of environmental management, among which:

ISO 14040	Environmental management - Life cycle assessment - Principles and framework
ISO 14044	Environmental management - Life cycle assessment - Requirements and guidelines
ISO 14064	Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removal

Land use, land use change, and forestry (LULUCF)
A greenhouse gas inventory sector that covers emissions and removals of greenhouse gases resulting from direct human-induced land use, land use change and forestry activities (source: unfccc.int).

Life cycle assessment (LCA)
Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle (source: ISO 14040: 2006).

Life cycle inventory (LCI)
Life cycle inventory, LCI in short, is the data collection portion of LCA. LCI is the straight-forward accounting of everything involved in the 'system' of interest. It consists of detailed tracking of all the flows in and out of the product system, including raw resources or materials, energy by type, water, and emissions to air, water and land by specific substance.

PAS 2050
Documents in the PAS 2050 series (Publically Available Specifications), issued by the British BSI, contain specifications for quantifying greenhouse gas emissions throughout the life cycle of goods and services. It builds on the ISO specifications on Life Cycle Assessment and is focussed solely on GHG assessments.

Summary Natural cork bottle stoppers: a stopper on CO_2 emissions?

1 Introduction and purpose of this report

This report is a discussion paper about the carbon footprint of natural cork stoppers for wine bottles.

More specifically, it discusses one particular aspect of the carbon footprint of cork: the CO_2 that is sequestered in the cork oak forest. Should this CO_2 be taken into account in the carbon footprint analysis, and if yes: how?

Figure 1 Cork oak landscapes are most often partly open landscapes or savannah's

Picture courtesy of azenhadoramalho.com, cork oak forest landscape.

Let's explain.

Carbon footprint and carbon sequestration

The carbon footprint of a product is the total amount of CO_2 and other greenhouse gases (= climate changing) that are released into the air or by the production, use and disposal of the product:

1. Production of raw materials.
2. The production of the product.
3. Transportations.
4. Use of the product.
5. Disposal after use.

The production of wood represents a temporal CO_2 sink, a temporary decrease of CO_2 in the air. Trees take up CO_2 from the air and fixate or sequestrate it as carbon in the wood (stem, bark, branches, roots) and soil. When the tree is cut down, the sequestered CO_2 is released again as the wood decays.

Carbon sequestration: a negative carbon footprint for cork products?

The well known natural cork bottle stopper often applied as a seal in wine bottles is produced from the bark of the cork oak, a species of oak tree growing in the region around the Mediterranean Sea. After the cork oak has grown big enough and the bark has become thick enough (after 25–40 years) the bark is peeled of every 9-12 years and grows back again in the intermediate period. As the cork oak tree is not cut down for cork harvesting, the CO_2 fixated in the wood of the cork oak remains sequestered.

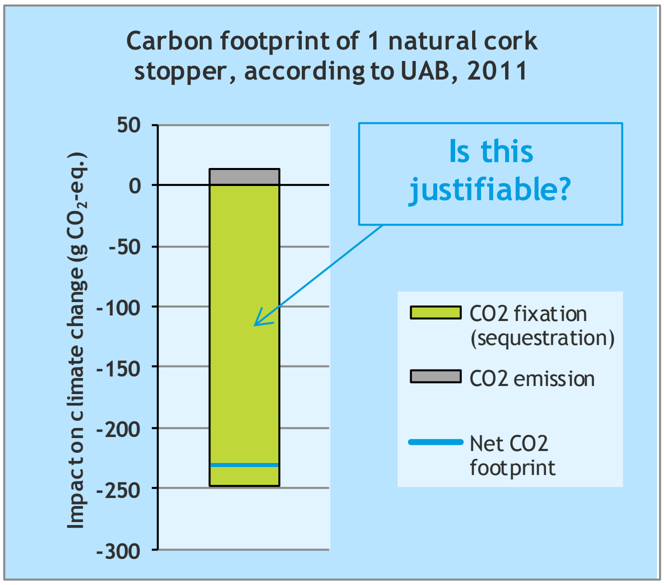
According to two recent studies (UAB, 2011 and PWC, 2008) the CO_2 fixated in the wood of the cork oak can be attributed to the natural cork bottle stoppers (and other cork products) produced from its bark. According to both studies, the amount of CO_2 that can be attributed per bottle stopper is very large:

- The amount of CO_2 sequestered in the cork oak, as calculated in (UAB, 2011) (see Figure 2) is 30-40 times larger than the amount of CO_2 emitted during harvesting of cork, processing the peeled cork in the cork factory and the disposal of the stopper.
- The amount of CO_2 fixated in the cork oak per individual bottle stopper comparable to as much as 20-40% of all CO_2-emissions related to the bottle of wine it closes. This would mean that the use of a natural cork on a wine bottle decreases the carbon footprint of the bottle of wine by 20-40% (according to UAB, 2011).

This conclusion has been used as marketing instrument by the cork products industry to promote cork products.

But to what extent may the CO_2 that is sequestered in the forest become part of the carbon footprint of natural cork products? Is it justified to attribute this CO_2 to the natural cork?

Figure 2 Carbon footprint of one natural cork stopper, according to UAB, 2011



Approach

Nomacorc has asked CE Delft to check the UAB (2011) and in particular investigate the claim of the negative carbon footprint.

The purpose of this discussion paper is to address several aspects of how to assign CO_2 sequestered in cork oak forests to natural cork products, cork stoppers in particular:

1. **The amount of CO_2 that is sequestered in cork oak forests**
   - Is the amount of CO_2 fixated in cork oaks calculated correctly?
   - When considering the big picture of forest growth and use, over decades and ages, is there carbon sequestration at all?

2. **The methodology: how to assign sequestered CO_2 to cork products.**
   - If there is carbon sequestration in natural cork, how should it be divided among all the different natural cork products (stoppers, flooring, shoe soles, etc.)?
   - Methods for standardization of CO_2 foot print calculation exist, such as the PAS 2050 and ISO standards. What do they say about carbon sequestration and how to take it into account in a carbon footprint?
   - There are protocols for CO_2 that surpass CO_2 standardization on LCA level. On country level, the emission trading system (ETS) also has rules for accounting for CO_2 sequestered in forests. Are the 'CO_2 rights' still free to claim for LCA?

Finally, CE Delft shortly reflects on LCA aspects other than CO_2 sequestration in cork oak forests.

2 Subject 1: sequestered carbon in cork oak forests: amounts and characteristics

1a. The amount of sequestered carbon

> The amount of CO_2 fixated in cork oaks according to UAB (2011) is an overestimation. Scientific studies on cork oak growth suggest that the total carbon that is fixated in cork oaks is 4 to 5 times lower than mentioned in UAB (2011).

Based on a plurality of scientific studies on cork oak growth, we conclude that on average 0.95–1.25 tonne C/tonne cork is sequestered in cork oaks. This is 4 to 5 times less than reported by UAB (2011).

1b. Change in sequestered carbon: net value

> In UAB (2011), the gross fixed amount of carbon is calculated. No indication is given of the actual net fixed amount of CO_2.

In the UAB (2011) study - but also in the PWC (2008) study - only the productive life of the cork oak as supplier of bark and the amount of CO_2 fixated in that period are considered. By taking this scope, both studies implicate that there was no vegetation - and no CO_2 fixation - before the cork oak germinated and that the cork oak remains in place for ever after, keeping the CO_2 it fixated during its productive life sequestered for all eternity.

In fact, cork oak savannah landscapes seem to have been partly developed by removing other trees.
Also, part of the cork oaks, which reached the end of their economic life are removed and not replaced by new trees. Sometimes the cork oak area is replaced by intensively cultivated arable land. In this case the CO_2 fixated in the cork oak is released again.

So overall both studies give a gross and not a net value for CO_2 sequestration. The net value is very likely smaller than the gross value.

3 Subject 2: Methodology: how to assign sequestered carbon to cork products.

2a. Allocation: dividing the CO_2 over various cork products

The allocation as applied in UAB (2011) is not complete and not according to standardized methods. The chose allocation in UAB (2011) is not complete and not according to standardized methods. The chose allocation in UAB (2011) is arbitrary and assigns more impact (or CO_2 benefit, in the case of carbon sequestration) to the cork stoppers compared to other cork products.

'Allocation' means: to assign the environmental impact over multiple products. An example: a cow has an impact, because of raising and feeding the cow. The cow provides multiple products: milk, meat, gelatin and more.
The impact of these products is a part of the impact of the cow. All products are allocated part of the impact of the cow.

This allocation is necessary at two points in the lifecycle of natural cork stoppers:
- First, cork oak landscapes - and especially cork oak savannahs - represent an integral system that produces other products next to natural cork, like firewood, pork, wool and mushrooms. The incomes of these products help to keep these landscapes economically viable and may represent 20-60% of total economic returns of the area. Subsidies for specific services and private payments for ecological services are also ignored.
- Next, at the factory, the bark of the cork oak is used to create a number of (half)products, like cylinders (which are practically stoppers), cork discs and cork granulates in various qualities.

In UAB (2011), the first allocation is ignored: the cork bark gets assigned 100% of the emissions for maintenance and CO_2 credits. The second allocation is done in an arbitrary way, which assigns disproportionally more impact to the cork stoppers compared to other cork products. This means that natural cork also gets too much credit for the carbon sequestration benefit in UAB (2011).

CE Delft suggests applying economic allocation for the multiple output system. This is the preferred method by the standardization methods ISO and PAS. Also, CE Delft offers a suggestion for how to deal with the various intermediate products at the cork factory. The suggested approach by CE Delft yields clear environmental impact values for all intermediate products. It has as a benefit that the results can readily be used by any cork using company, such as wineries or shoe makers, to construct the (impact of) their specific own cork product.

2b. Preferred procedure by standardization methods

At this moment, standardization methods for carbon footprinting declare that **sequestered carbon should not be taken into account in carbon footprint assessments.**

Carbon footprint standardization is a developing field. At the moment there are no specific rules for cork, but there are rules for forestry products.

Standardized methods such as ISO 14000, the ILCD Handbook and PAS 2050 and its supplement for horticultural products all seem to exclude carbon stocks (carbon sequestered in wood and soil).

The standardized methods all include changes in carbon stocks due to land use change. However, managed cork oak landscapes and other forms of managed forest do not fit within that definition. The PAS 2050 standardization gives a clear advice: “While forest management activities might result in additional carbon storage in managed forests through the retention of forest biomass, this potential source of storage is not included in the scope of this PAS.”

Exclusion in standardized methods means that sequestration cannot even be claimed as an environmental benefit for natural cork bottle stoppers.

2c. Restrictions by other CO_2 emission protocols?

The EU emission trading system (ETS) also deals in carbon credits, but this system turns out not to be a limiting factor.

On a national level, countries determine their carbon footprint. Under the Kyoto Protocol, countries report on their CO_2 emissions and sinks. Changes in carbon fixated in forests play an important role in climate policy. CE Delft explored whether this has any consequences for the right to include carbon uptake in carbon footprints of forestry products. This is done because it is important to check that no double counting of CO_2 credits occurs.

CE Delft concludes that the Kyoto Protocol and ETS in themselves only limitedly allow for discounting CO_2 sequestration. Double counting of carbon credits by land owners and national states is unlikely to occur.

4 Other LCA issues

So far, we have discussed two specific aspects of UAB (2011):
- the carbon sequestration result;
- the allocation method.

CE Delft wishes to emphasize that we don’t criticize the entire study of UAB (2011). The study offers a thorough assessment of both cork oak forest management, the harvesting of raw cork and of the production processes by the cork industry in Catalonia. The study offers a good overview of the cork production chain and as far as we can tell from reading the report, there is no reason to question inventory of these life cycle phases.

There are, however, some aspects in the life cycle of natural cork stoppers that are not or marginally taken into account:
– End of life of natural cork bottle stoppers: only landfilling of stoppers is included, not waste incineration, the dominant treatment process for domestic waste in Northern and Western EU member states.
– Wrappers enveloping the natural cork bottle stoppers are not taken into account.
– The use phase of the cork product is not taken into account. Natural cork is known to cause more loss of wine (due to cork taint), compared with other stoppers.

Taking these aspects into account could significantly influence the total carbon footprint of the bottle stoppers.

> To be able to compare the LCA results of natural cork stoppers with other stopper types, the use phase should be included as well as additional materials that are needed for closing the wine bottle.

5 Overall conclusions

CE Delft concludes:
– The negative carbon footprint as calculated by UAB (2011) is not correct. It is much too high, because:
  - the calculation is not correct;
  - reference land use is not taken into account;
  - the method of assigning the result to the natural cork is not correct.
– Standardization methods for carbon footprints indicate that sequestered carbon in forests should not be taken into account in carbon footprints of forestry products (such as cork). This goes for all carbon footprint studies of cork.

This means that claims concerning carbon footprint benefits for natural cork bottle stoppers cannot be maintained.

Cork oak landscapes are very valuable from the perspective of biodiversity, hydrology and maintaining soil quality. Our suggestion would be that efforts to quantify the value of these landscapes would be related more to these aspects and less to carbon footprints of products generated by these landscapes.

1 Introduction

In 2011, the Universitat Autonoma de Barcelona published a doctoral thesis - UAB (2011) 'Environmental evaluation of the cork sector in Southern Europe (Catalonia)'. This study assesses the impact of raw cork extraction in Catalonia and cork product manufacturing in Catalonia by means of life cycle assessment (LCA).

An important part of the LCA is the carbon footprint analysis. The results of which are largely determined by the way in which temporary sequestration of CO_2 in cork oak trees is taken into account. Carbon sequestration, or CO_2 fixation, is the uptake CO_2 by trees during growth. The UAB thesis (UAB, 2011) reports a net sequestration of 18 kg CO_2 per kg raw cork or 234 g CO_2 per natural cork stopper. This uptake of CO_2 leads to a negative carbon footprint of cork products. Based on this outcome the report suggests that using a natural cork stopper in wine bottles is a practical means to green the packed product and to reduce the greenhouse gas footprint of a bottle of wine with as much as 20-40%.

As is understandable, the International Organisation of Vine and Wine and wine producing companies (Rotllan Torra) have adopted the figures and report in the media that the use of a cork stopper reduces the carbon footprint of wine and use the negative carbon footprint for comparison with other stopper types.

It has been observed that companies that sell cork products other than cork stoppers also claim a CO_2 benefit of for their products (websites by Wicanders and Amorin).

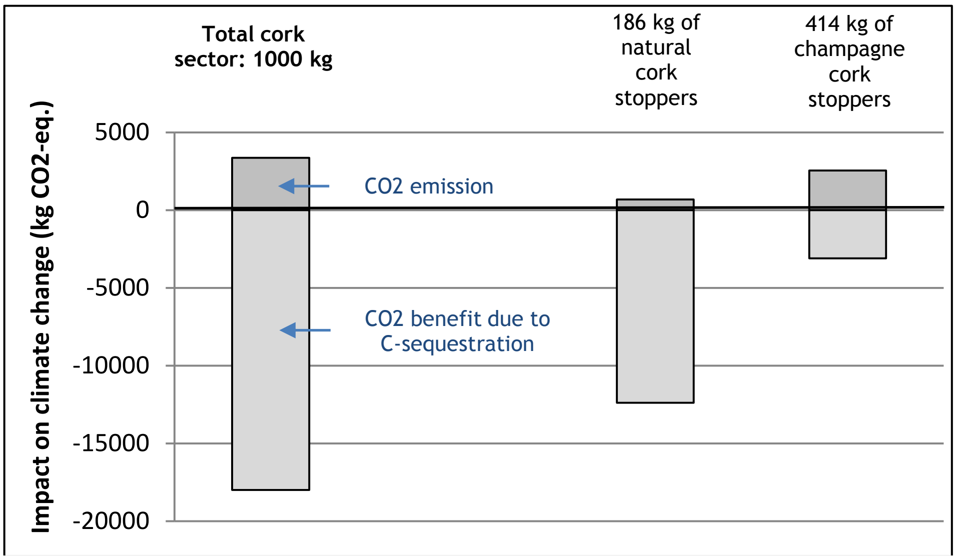
1.1 Purpose of this discussion paper

The highly negative carbon footprint of the UAB thesis (UAB, 2011) and the resulting public CO_2 claims for cork products caught the attention of Nomacorc. Nomacorc wished to know whether the carbon sequestration of 18 ton CO_2 per ton of raw cork published in the UAB thesis (UAB, 2011) is correct and whether it is legitimate to use this figure for cork products.

This report attends to all these questions. We mean to provide insight and present our view. The purpose of the paper is to stimulate discussion about the carbon footprint of cork products, including the carbon credits due to carbon sequestration in cork oak forests. We hope that this discussion will lead to consensus throughout the involved sectors: the cork production sector, the wine sector and producers of stopper out of other materials.

Nomacorc explicitly has asked to deal with this question in a more general way so that the discussion exceeds cork products and is relevant to other agricultural and horticultural products or forestry in general.

Figure 3 Impact on climate change as reported in UAB (2011)



1.2 Approach

CE Delft has looked into the matter and has explored the subject of carbon sequestration in LCA, specific for cork products, which is a broad subject. We have sought answers to the following questions:

- How Is the sequestration of 18 ton CO_2 per ton raw cork calculated?
- To what extend is this value representative for all cork, from all cork production regions?
- Should a carbon sequestration figure be taken into account in LCA according to standardization carbon footprinting methods (e.g. PAS 2050), and if yes: how?
- How should the environmental impact or benefit for raw cork be distributed over the various cork products?
- Are the results for cork stoppers as calculated by the UAB thesis (UAB, 2011) suited for comparison with other stopper types?

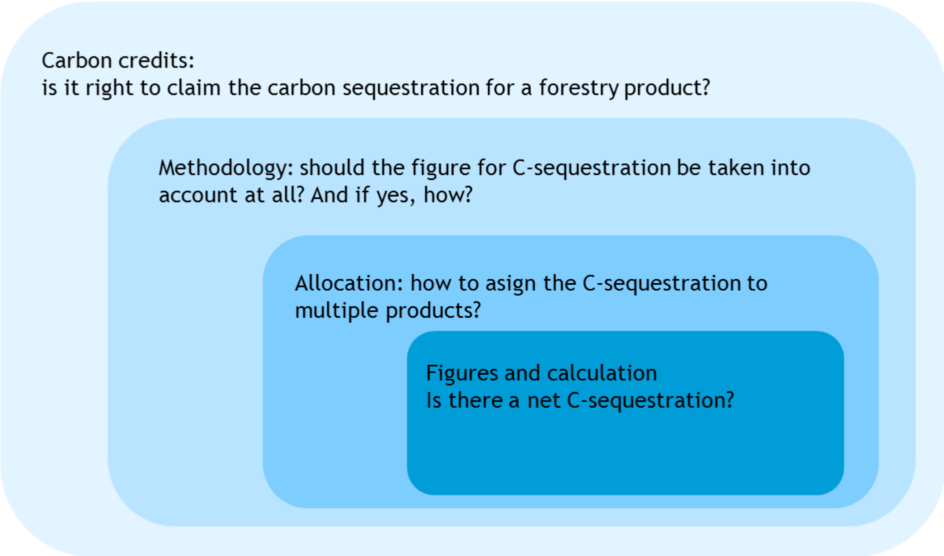
Apart from the questions asked on the calculation of the footprint of the product we see a tension between claims made by national governments on CO_2 reduction and individual producers. This is not only the case with cork. Nevertheless, if a discussion is held on the way in which should be dealt with products like cork, we also might look at this on a macro-level. The question we have at the macro level is:

- How should LCA practitioners deal with carbon rights trading by governments? Are the carbon credits from cork oak forests available for cork products, or are they already used by the national government?

1.3 Hierarchy and structure of the report

The topics mentioned in the previous paragraph - those which relate to carbon sequestration - can be structured hierarchically, as shown in Figure 4.
The report is structured according to these topics, from ‘inside’ to ‘outside’; each has its own chapter. The final chapter treats topics that are not related to carbon sequestration, but to LCA for cork stoppers in general.

Figure 4 Hierarchy of the topics



The chapters contain several sub-questions or issues - paragraphs - that together give insight into the main topic. The paragraphs have a similar structure:
1. Posing the question/dilemma: what issue do we observe?
2. Discussion: the issue is explored and illustrated by examples.
3. Conclusion: CE Delft’s suggestion on how to deal with the issue.

This shows the nature of the paper: a discussion paper. We provide information and our conclusion, which is open for debate.

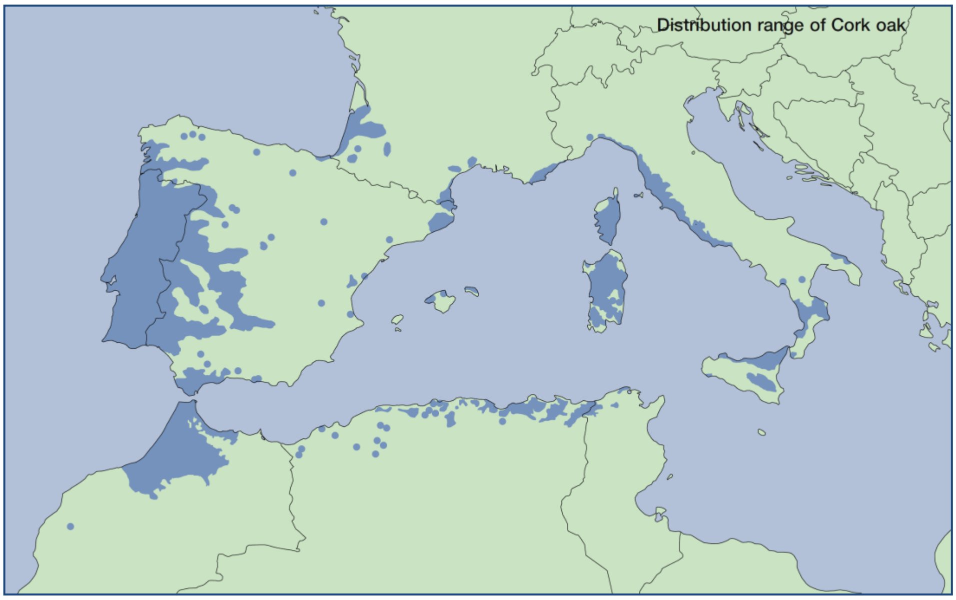
2 Key figures on cork oak cultivation

2.1 Cork oak areas

The cork oak is an evergreen broad-leaved tree, the natural range of which includes the coastal regions of the western Mediterranean Basin (see Figure 5 and Table 1). Cork oak grows mainly on poor sandy and lightly structured soils and is found under a wide range of annual rainfall, ranging from 500 mm in Mamora (Morocco) to 2,400 mm in some north-western areas of Portugal and southern Spain. The species is long lived (200–250 years), commonly growing to a height of 15–20 m but it can reach 25 m under ideal conditions.

Portugal and Spain produce over 80% of the raw cork, while representing 54% of the total cork oak area. In other countries, primarily Morocco, Algeria and Tunisia (Table 1), the cork oak is less intensively cultivated.

Figure 5 Distribution of cork oak



Source: EUFORGEN, 2008.

Cork oak is mostly grown in agroforestry systems, known as Montado in Portugal and Dehesa in Spain, open managed savannahs with low tree density 20–100 trees per hectare (Landscape Europe/KNNV) in the south-western part of the Iberian Peninsula. These landscapes possess a very high biodiversity.

Table 1 **Cork forest area in cork production data**

Country	Area (hectares)	Percentage	Annual production of cork (tons)	Percentage
Portugal	715,992	33.8%	100,000	49.6%
Spain	574,248	27.1%	61,504	30.5%
Morocco	383,120	18.1%	11,686	5.8%
Algeria	230,000	10.9%	9,915	4.9%
Tunisia	85,771	4.0%	6,962	3.5%
France	65,228	3.1%	6,161	3.1%
Italy	64,800	3.1%	5,200	2.6%
Total	2,119,089	100.0%	**201,428**	100.0%

Source: Apcor, 2008.

In traditional Montado's and Dehesa's forage crops (grasses, to a lesser extent cereals) are commonly grown under the trees and extensively grazed by cattle, sheep or goats, providing meat, wool, skin and milk. Acorns are used for pig rearing for production of pata negra. Other outputs are honey, wild, and mushrooms.

Figure 6 **Cattle grazing under cork oaks**

Source: Wikipedia – Dehesas: http://en.wikipedia.org/wiki/Dehesa_%28pastoral_management%29.

Trees are pruned for optimum crown development and old trees are removed being replaced by replanted species. Wood from pruning and removed trees is utilized as fire wood or charcoal.
The whole system is aimed at optimization of the economic value of the mixture of different products, of which cork is in general the highest contributor.

According to the UAB thesis in Catalonia and France a different exploitation system, the forest system, is applied. In this system cork oaks are grown in managed forests with several hundreds of trees per hectare of which approximately 400 trees per hectare produce cork; the other trees are intended for natural regeneration (UAB, 2011). The cork oak forests need intensive care in order to be productive, and it is necessary to remove competing vegetation. Unproductive oaks, oaks yielding cork of insufficient quality and trees in stands with a too high density are also felled. The wood is sold as fire wood.

As quoted in the UAB thesis (UAB, 2011) half of Catalan cork oak forests are no longer managed. This probably is the result of a shift of cultivation from traditional cultivation areas in Catalonia and France to more productive cork oak woodlands in the south-west of the Iberian Peninsula or the north of Africa[1].

2.2 Raw cork to cork products

The cork of the oak is the primary economic income from cork oak landscapes, forming e.g. 80% of total revenues from Dehesa's (WWF, 2006)[2]. Cork is obtained by peeling the bark away from the trunk as slabs. Depending on the management system and region the first harvest (virgin cork) is made when the tree is approximately 25–40 years old. Subsequent harvests can be made every 8-14 years. Third and subsequent harvests can be used for high quality products (natural stoppers, champagne stoppers), the first two harvests only for lower quality products.

The harvested cork is pre-treated by a process of subsequent slabs boiling, cutting slabs into strips, strips boiling, punching out the cylindrical natural cork stoppers and finally applying a surface layer of paraffins and/or silicons. Natural cork stopper production uses about 20% of the cork while generating more than 80% of the added value (EUFORGEN, 2008).
The remainder is processed into champagne cork stoppers, agglomerated stoppers, and other agglomerated products[3].

2.3 Life cycle assessment of cork stoppers

Life cycle assessment (LCA) is an environmental impact study of a product. The results of an LCA are impact scores for environmental effects, such as impact on climate change. It is called life cycle assessment because it examines all phases of the life cycle of a product: from material use, production processes, transportation, use and disposal. In an LCA all aspects that lead to emissions are inventoried, for instance the use of energy for production processes, the use of fuel for transport and use of materials (such as glue for making agglomerated cork products).

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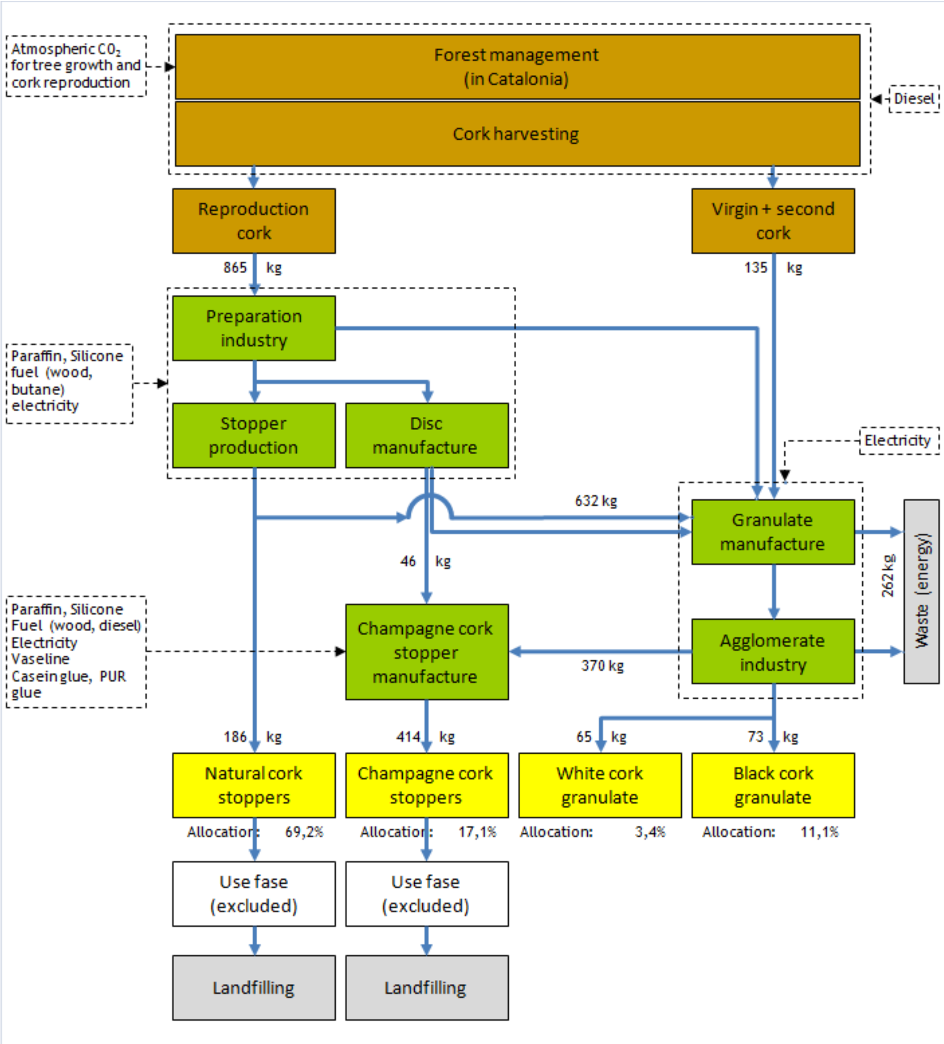
1 See: www20.gencat.cat/portal/site/culturacatalana/menuitem.be2bc4cc4c5aec88f94a9710b0c0e1a0/?vgnextoid=b9825c43da896210VgnVCM1000000b0c1e0aRCRD&vgnextchannel=b9825c43da896210VgnVCM1000000b0c1e0aRCRD&vgnextfmt=detall2&contentid=2ba1352101fd7210VgnVCM1000008d0c1e0aRCRD&newLang=en_GB.

2 This percentage is based on 2006 prices. Cork prices have since then dropped.

3 These include: including insulation panels, floor and wall tiles and sound-proofing in the car industry, as well as for handicrafts and artistic uses.

Figure 7 shows the production chain as defined in UAB (2011), it shows the various steps that lead to the production of cork stoppers. It shows which phases are included and excluded: the system boundary of the study. The dotted lined textboxes show the aspects that affect emissions.

Figure 7 **System boundaries as applied in UAB (2011)**



Source: CE Delft.

The UAB thesis (UAB, 2011) first calculates the environmental impacts associated with 1 ton of raw cork material, next the ton raw cork is converted into the most representative products. On the left corner, it can be seen that one of these inputs is 'atmospheric CO_2': this is the carbon sequestered in the cork oak and soil.

As can be seen the raw cork is processed, via various half-products into end-products. There are many links between the various production processes and products. The cork from the first and second harvest, which is of lesser quality is used as granulates instead of discs or natural stoppers. Reproduction cork also generates granulates, called white granulate, after production of discs and natural cork stoppers.

Some products are partly made of natural cork from reproduction cork and partly out of granulates. This figure does not show other cork end-products than natural cork stoppers and champagne cork stoppers, the UAB thesis (UAB, 2011) does not take them into account, but there are many.

Figure 8 Other cork products: various agglomerated products; technical cork stopper 1+1; agglomerated cork stopper

Sources: corklink.com; advancecork.com.

3 Calculating carbon sequestration

As indicated in the previous chapter, natural cork bottle stoppers are claimed in several LCA studies to have a very favorable carbon footprint as a result of the carbon sequestered in the cork oak.

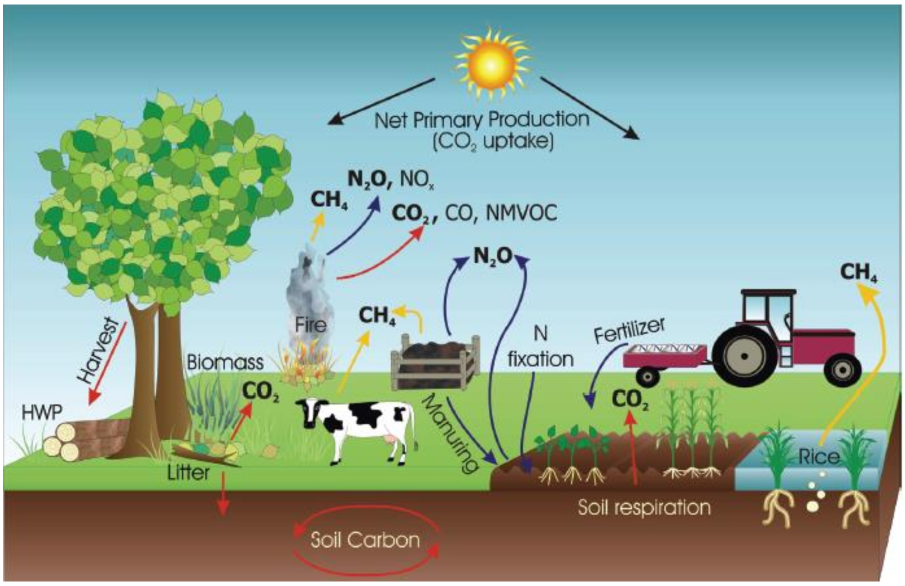
After introducing and explanation of the phenomena 'sequestration' in relation to vegetation in general in Paragraph 3.1, this chapter focuses on cork oak vegetation and the issue of how much CO_2 is actually 'stored' in cork oaks.

3.1 What is meant with sequestration?

The sequestration of carbon in cork oaks as taken into account in LCA's of natural cork bottle stoppers refers to the general principle of tree growth and growth of plants in general.

Trees and other kinds of plants take up CO_2 from the atmosphere and water from soils and – with the help of sunlight as energy source - convert these into biomass for their growth, thus fixating atmospheric carbon. That is, as long as the tree lives:
- Already during its live the tree will produce several parts or products – such as leafs, twigs, fruits, fine roots – that have a shorter live than the tree itself. When these components fall of and die off as litter, the carbon sequestered in them is partly released again as CO_2 and is partly converted into soil organic carbon – such as humus and microbiological biomass in the soil.
- Eventually the tree itself will die off and the wood of stem and branches will undergo the same fate as the shorter living fractions of the tree.
- The soil organic carbon is also degradable (soil respiration) and will slowly disappear if there is no continuous supply of litter or dead trees.

Figure 9 The main greenhouse gas emission sources/removals and processes in managed ecosystems

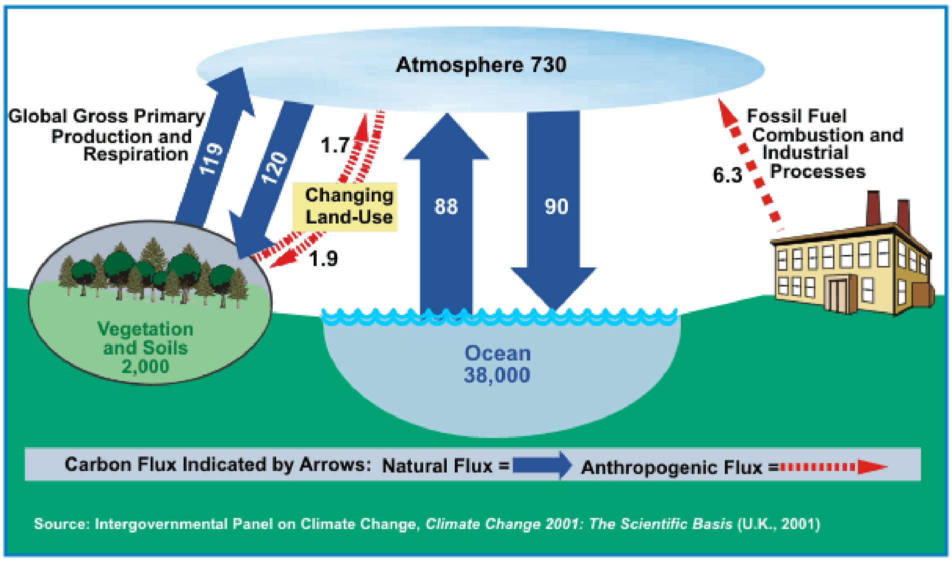


Source: IPCC, 2006.

There is only net additional sequestration if following preconditions are met:
1. There is a net increase in biomass and/or soil organic carbon per hectare compared with the reference land use situation.
2. The increased amount of biomass and/or soil organic carbon remains constant hereafter.

In a natural system such as a pristine natural forest the flows and carbon stocks are balanced (see Figure 10) and no net increase or decline occurs. Human activities such as:
– afforestation, reforestation or deforestation;
– changes in forestry management resulting in higher average biomass stocks (see Figure 11).
may influence these flows and stocks and the carbon balance of the system or the considered area may change.

Figure 10 Carbon cycle: emissions and uptake



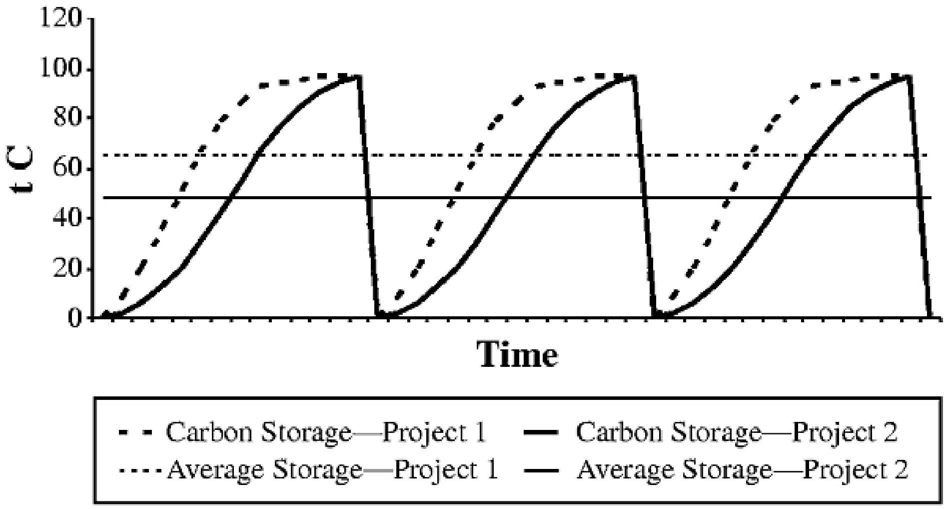
Source: http://www.eia.doe.gov/oiaf/1605/ggccebro/chapter1.html.

In the case of cork production this would mean that there is a net incremental increase in the amount of sequestered carbon if:
– a new cork oak savannah or forest is realized on a previously barren area or area with less carbon in vegetation and soil as in a cork oak savannah or forest;
– changes in management of a cork oak savannah or forest result in an increase in the amount of carbon sequestered in vegetation and/or soil.

For practical reasons often only a period of 20 years for changes in carbon stocks is considered, but longer periods may be considered in more detailed analyses[4].

[4] www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_02_Ch2_Generic.pdf.

Figure 11 Example of two forest plantation projects with different average biomass stocks



Source: IPCC, 2000[5].

Elucidation: Both horizontal lines indicate the time averaged amount of carbon stored in the plantation trees. In Project 2 the time-averaged biomass stock is higher as the tree grows faster as indicated by the steeper shape of the first part of the saw-tooth.

3.2 Carbon sequestration calculation in (UAB, 2011)

In the UAB thesis (UAB, 2011) a constant annual sequestration rate of 0.78 ton C/ha/year or 2.9 metric ton of CO_2 mentioned in Gràcia (2012) for cork oak forests in Catalonia is used as the basis for the GHG footprint calculation.
The sequestration rate is assumed to be constant throughout the life of the tree, average life of Catalonian cork oak assumed to be 200 years.
As the sequestered CO_2 is partly used for producing cork, the annual average cork yield over the life of the tree – assumed to be 0.15 ton/ha/year - is subtracted from the sequestered amount of CO_2. No relation with the chemical composition of the cork and its carbon content is taken into account.

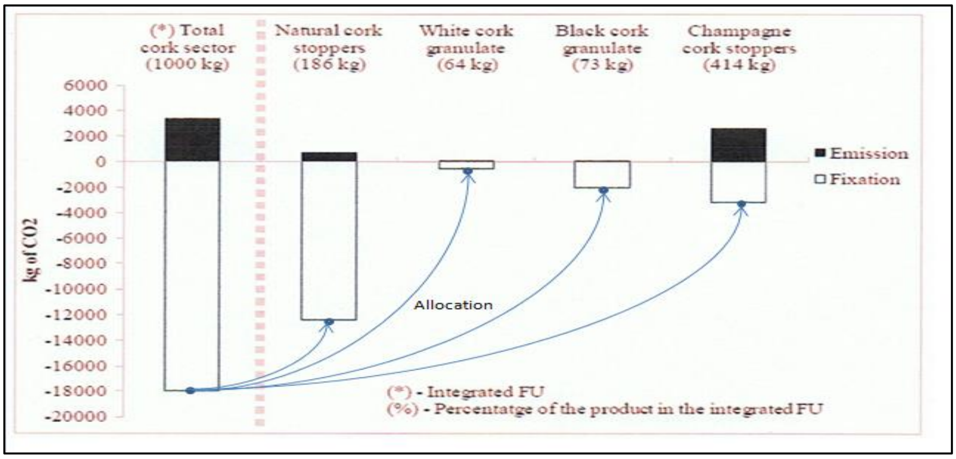
Assuming these constant annual fixation rate for CO_2 and cork yield, the amount of CO_2 effectively sequestered per unit of cork is calculated in the thesis as being (2.9 – 0.15) ÷ 0.15 = 18.3 ton of CO_2/ton of cork.
The footprint calculation ignores reference land use and possible removal of cork oak after they reached the end of their economic useful life.

It is this value of 18 ton CO_2/ton cork, as well as the allocated values as shown in Figure 12, that are presented in the media[6] by the natural cork industry for promoting cork for bottle closure and as a way of reducing the greenhouse gas footprint of wine, according to the UAB thesis (UAB, 2011) with as much as 20-40%.

5 See: http://www.ipcc.ch/ipccreports/sres/land_use/index.php?idp=274.

6 See e.g.: Rotllan Torra: www.rotllantorra.com/pages/pdf/N%C2%BA41-2012/RT%20NEWS%20Publ%20No%2041%202012.pdf.
OIV: www.corkfacts.com/publications/2011dec29pge03.htm.

Figure 12 CO_2 balance for the cork sector in Catalonia, as calculated in UAB (2011), figures per 1,000 kg harvested cork



Source: UAB, 2011.

Elucidation: The left bar gives the total emission (black part) of greenhouse gases and the total amount of CO_2 sequestered in cork oaks. The four bars at the right side of the graph give the division over the four products.

It is noted that this footprint calculation ignores reference land use and possible removal of cork oak after they reached the end of their economic useful life.

In following paragraphs we explore the different aspects related to gross and net carbon sequestration in cork oak landscapes.

3.3 Land use and cork oak systems throughout the ages, is there actually a net-sequestration?

As indicated in Paragraph 3.1 there is only a claimable carbon sequestration in vegetation and/or soil organic matter when:

1. There is a net increase in biomass and/or soil organic carbon per hectare compared with the reference land use situation.
2. The increased amount of biomass and/or soil organic carbon remains constant hereafter.

Both aspects are discussed in this paragraph.

Reference land use

It is for certain that the land area on which a cork oak agro-forestry system is applied has had a prior 'use' - either economic or natural - and that there was vegetation before the cork oak system was realized.

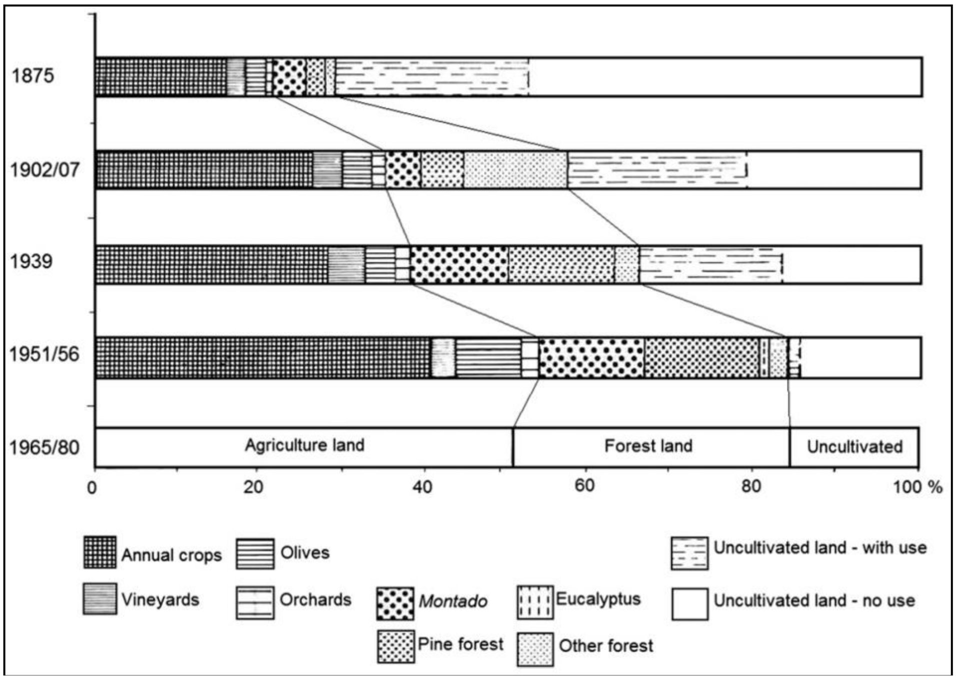
- A study by Plieninger (2007) for example shows on the basis of cartographic, written and oral historical evidence that Dehesas in Andalusia – the main cork region in Spain - have been established primarily by thinning of more dense woodlands and shrub lands.
- A study by Jones et al. (2011) also clearly indicates that in Portugal too most Montado cork oak systems have been realized by conversion of 'uncultivated land', mainly referring to 'macchia' and the 'garrigue' shrub lands.

This means that cork oak agro-forestry systems supplying cork for still wine closures have probably been established by removal of vegetation. The amount of carbon additionally sequestered in cork oak landscapes (including soils and undergrowth) will be lower than the total amount of carbon present in vegetation and soil and may even be negative, if the original vegetation contained more carbon than the managed cork oaks.

End of life of cork oak and cork oak regeneration

There is only a net carbon sequestration if the cork oak agro-forestry system is maintained. However socio-economic drivers such as pressure due to factors as the exodus of rural populations and the unprofitability of the 'traditional' Montado and Dehesa systems have resulted on one hand in the abandonment of these systems or of understory mismanagement in these systems.
But on the other hand these drivers also resulted in conversion of these systems into intensively used arable land (Regato-Pajares et al., 2004).
In other words in the removal of the cork oaks. This is in contrast with the UAB thesis (UAB, 2011) and similar LCA's, in which the assumption is made that the tree will remain in place forever.

Figure 13 Land use change in Portugal (1875-1980)



Source: Jones, 2011.

Subsidies have also proven to be a threat to traditional cork oak woodlands. As stated by WWF: 'Subsidies have Plantations of exotic forest species have replaced the traditional cork oak forest landscape in many areas, whilst in others, valuable scrub areas have been converted to cork oak plantations. These plantations typically have low biodiversity values. Often driven by agricultural and forestry subsidies, this combination of conversion, intensification, and changed land use has contributed to an increase in the incidence of fires and a reduction in the health of the cork woodlands[7]'.

7 http://awsassets.panda.org/downloads/beyond_cork_publication.pdf.

Conclusion
There is a probability that preconditions under which carbon sequestration in cork oaks could be claimed are not met as cork oak landscapes have at least partially been created by removing original vegetation and as part of the cork oak landscapes has been converted into arable land.

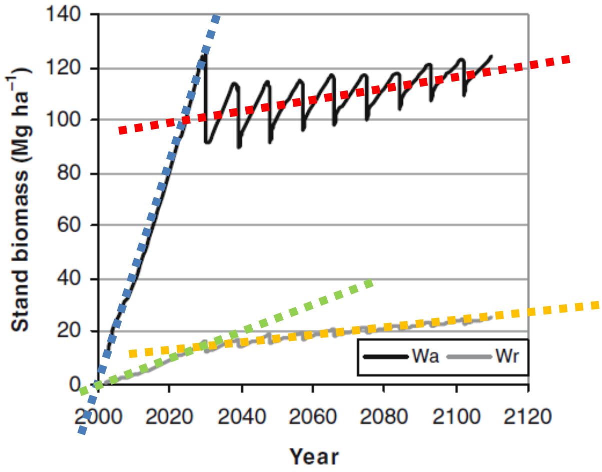
3.4 Carbon sequestration during tree growth: different age - different regions - different seasons - different amounts - different averse conditions

But even if both preconditions mentioned in Paragraph 3.1 are met and 1) there is a net increase in biomass per hectare compared with the reference land use that; 2) next remains constant in time, the question remains how much carbon cork oak agro-forestry systems can actually sequester.

Growth and carbon sequestration in managed cork oaks
How much a cork oak will eventually grow and how much wood and cork it will contain and produce depends on the natural conditions (climate, soil) and on tree management.

A managed cork oak has different growth rates during its life time. Carbon stock build up is rapid in the beginning and slows down to practically zero when the tree is getting older en cork oak is being harvested and pruned regularly. In combination with tree thinning practices, this has a detrimental effect on the amount of biomass accumulation per ha. According to (Canellas 2008), this biomass is rapidly increasing until the tree age of 30 years and then remains pretty constant through the remainder of its life span (see Figure 14).

Figure 14 **Cork oak forest biomass growth rates per ha as function of time for above ground (Wa) and below ground (Wr) carbon mass**



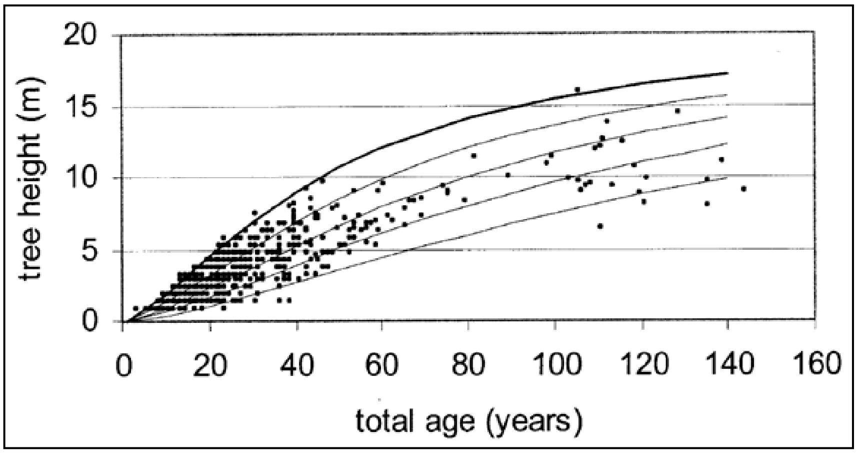
Source: Canellas, 2008.

Regional differences in growth and cork yield

Since natural conditions in the different regions in Spain, Portugal and northern Africa vary, the growth rate as indicated by the increase of height, also differs between the different regions:

- Cork oaks in Spain – both south Spain and Catalonia - and in Tunisia general reach a height of 8-12 metres after 80 years (see Figure 15).
- Cork oaks in Portugal on average reach a height of 10-14 metres after 80 years. At optimum locations a height of 16-18 metres may be reached, see Figure 16.

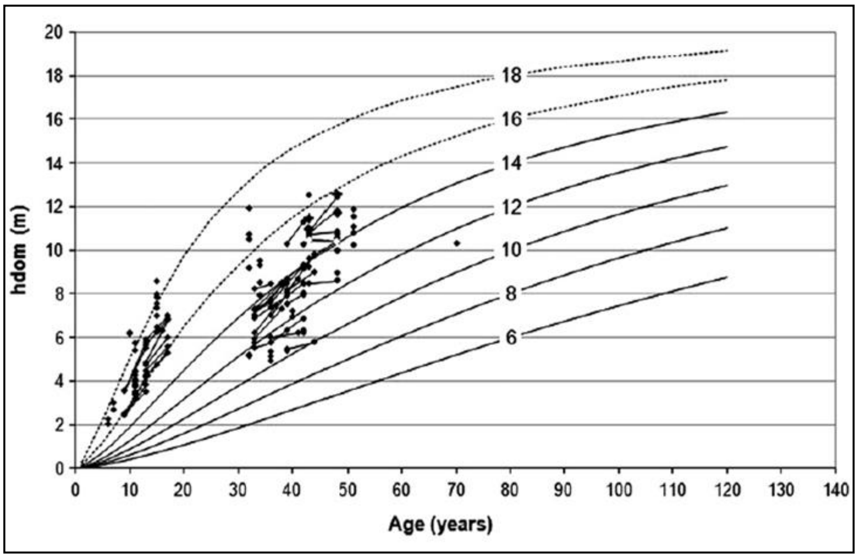
Figure 15 Height growth curves for cork oaks in Spain (Catalonia and Andalusia)



Source: Sánchez-González et al. (2005); Sánchez-González et al. (2010).

In the same region, the growth rate can vary due to year-to-year climatological differences. A nice example was reported by Pereira (2007) which shows that carbon stock growth in four consecutive years can be very different and can range from 0.28 ton C/ha/yr to 1.40 ton C/ha/yr. In this case, the amount and timing of the rainfall was very important to regulate the growth potential of the oak tree.

Figure 16 Height growth curves for cork oaks in Portugal



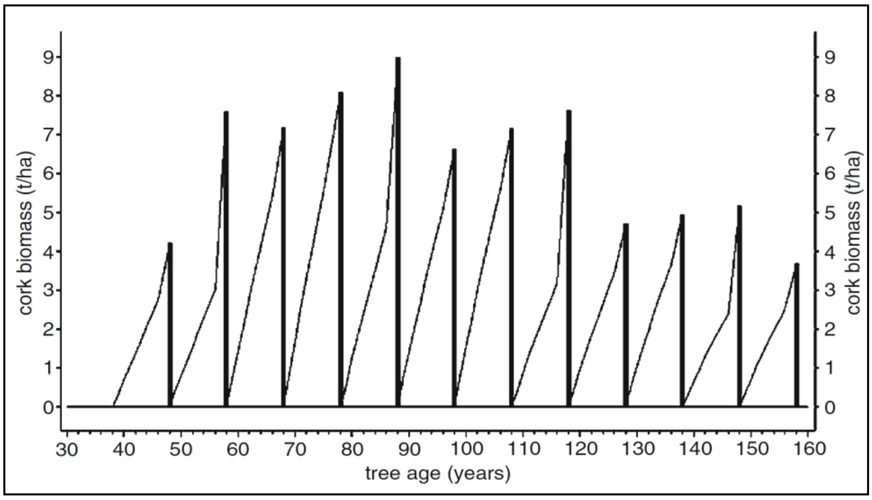
Source: Coelho, 2012.

The effect of the different management systems in which frequent thinning of the standing stock to optimize production of cork (and acorns – Paragraph 2.1) results in flattening of the increase of biomass in standing stock to:

– approximately 150 metric tons dry wood/hectare or 70 metric tons of C[8] per hectare (rounded, including roots) on average for cork oaks in southern Spain and Portugal (Canellas, 2008) and produce approximately 73 metric ton of raw cork (dry matter) during their productive life (see Canellas, 2008);
– approximately 250 metric tons dry wood/hectare or 120 metric tons of C[6] per hectare (rounded, including roots) for stands in Portugal on favorable locations (dominant height after 80 years of 15 meters) (see Coelho,2012).

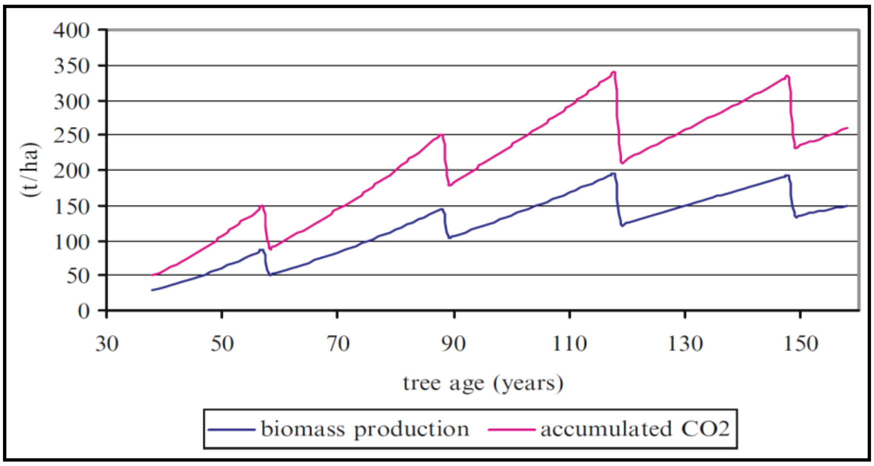
An indication of the development of the amount of cork in time is illustrated in Figure 17.

Figure 17 Cork biomass production during average cork oak life in Spain



Source: Canellas, 2008.

Figure 18 Biomass production and accumulated CO_2 for wood in cork oak forests in Spain



Source: Canellas, 2008.

8 The amount of carbon sequestered in this biomass can be estimated assuming a carbon content in cork oak wood of 47% (Canellas, 2008).

Table 2 Some specifications of cork oaks on the Iberian Peninsula

	Region	Yield				Cycle duration (years)	Tree life (years)	No. of Trees (no/ha)	Dominant height after 80 years (meters)	Climax carbon sequestered in tree (ton)	Simulation or field measurement
		(kg/tree/ cycle)	ton d.m./ ha/cycle	ton d.m./ ha/year	ton d.m. during total tree life						
WWF, 2006											
– Young tree		25									
– Mature tree		60									
Canellas, 2008	Spain, average										sim.
– Maximum	(Quality II location)	60	9.0	0.90		10		150			
– Minimum, first harvest		8	4.2	0.42		10		500			
– Average			6.1	**0.61**	**73**	10	160		12	**70**	
Costa, 2004	South-western Portugal			0.90		9		67			field
Caparros, 2010	Los Alcornocales, Spain			0.49	70	20	144				sim./field
Coelho, 2012	Portugal			**0.69**	**96**	9	140	270-40	15	**120**	sim.
Canellas, 2002	Extremadura					10					field
– Maximum		75									
– Minimum		35									

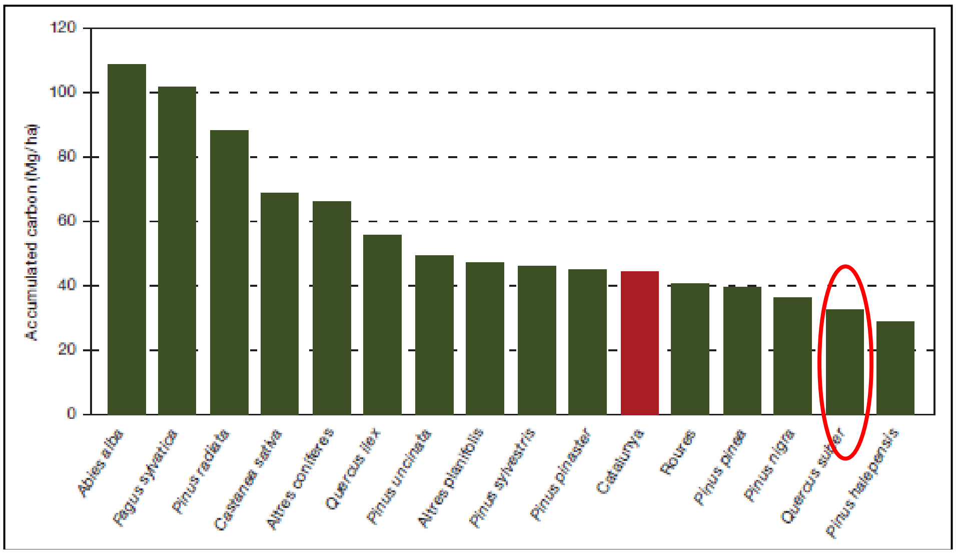
More information is summarized in Table 2. The data in the table is compared with practical yields as reported in literature for verification.

In practice carbon stocks in vegetation may be smaller as indicted in the table, due to loss of trees or parts of trees due in wild fires.
On the Iberian Peninsula, wild fires are commonly occurring. The cork oak tree has a large chance of surviving these fires but still during the blast CO_2 is emitted and lead to a lowering of the carbon stand.

Catalonian cork oak forests
Studies by Sánchez-González et al. indicate that cork oaks in Catalonia and Southern Spain reach comparable heights after 80 years. Based on this information, we assume that the amount of carbon sequestered in cork oak on average in Spain is also representative for cork oaks in Catalonia.

According to the Catalonian 2012 greenhouse gas emission inventory (see Llebot, 2012; Gràcia, 2012)[9] current standing stock of cork oaks amounts to approximately 32 metric tons of carbon per hectare (Figure 19) and annual sequestration amounts to 0.78 ton C/ha/year.
These figures indicate that Catalonian cork oak forests are probably relatively young as the accumulated amount of carbon is rather low and as annual sequestration is rather high.

Figure 19 **Accumulated carbon per forest area unit in Catalonia of different tree species**



Source: see Llebot, 2012[10].

3.5 A more appropriate sequestration figure?

As can be seen from Table 2, there are many different reports and values for carbon stock growth rates of cork oak forests. Looking at the number used by UAB (2011) it is on the high side of the spectrum, which would mean that the total amount of CO_2 sequestered per ton raw cork extracted is on the high side too.

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9 See: www15.gencat.cat/cads/AppPHP/images/stories/publicacions/informesespecials/2010/sicccat/informe_per_captols/05_embornals.pdf.

10 www15.gencat.cat/cads/AppPHP/images/stories/geccc/sicc_resum.pdf.

Since there are so many variables which come into play for determining the carbon stand growth rate, it will be difficult to have one representative number which can be used to calculate the amount of CO_2 sequestered per ton raw cork extracted from the forest. It would be better to provide a range (min, max) per region of origin which would describe the situation and takes forest age, climate change, soil conditions, etc. into account.

Another thing to consider is that cork oak forest are not always pure and are in many cases mixed forests. Since many other trees have higher carbon stock growth rates than cork oak (see Llebot, 2012) it will create a higher per ha carbon growth rate than when this would be a pure cork oak forest.

For the time being, CE Delft would recommend to use modeling data to come to an accepted and representative carbon stock growth rate. Based on literature we would suggest using a range from 0.95 to 1.25 C/ton cork (see Table 2 and Paragraph 3.4):

- On average Spanish locations:
  - a cork tree sequesters 145 tons of biomass or 70 tons of carbon per ha during its life span;
  - likewise, during its life span it delivers 73 tons of raw cork per ha;
  - so the amount of carbon sequestered per ton of raw cork is 70 ÷ 73 = 0.95 ton C/ton cork;
  - this would correspond to 3.5 ton CO_2 per ton of raw cork which is 5 times less than reported by UAB (2011).
- On favorable locations in Portugal:
  - a cork tree sequesters 250 metric tons dry wood/hectare or 120 metric tons of C per hectare during its life span;
  - likewise, during its life span it delivers 96 tons of raw cork per ha;
  - so the amount of carbon sequestered per ton of raw cork is 120 ÷ 9,673 = 1.25 ton C/ton cork;
  - This would correspond to 4.5 ton CO_2 per ton of raw cork which is 4 times less than reported by UAB (2011).

3.6 Overall conclusions

There is a probability that preconditions under which carbon sequestration in cork oaks could be claimed are not met as cork oak landscapes have at least partially been created by removing original vegetation and as part of the cork oak landscapes has been converted into arable land.

Next to this the carbon sequestration rate assumed in UAB (2011) is in itself at the high end of the range found for cork oaks and is more representative for the early development of the tree in its first decades of growth – before cork of sufficient quality for wine bottle stoppers can be harvested. For the time being, CE Delft would suggest using a range from 0.95 to 1.25 C/ton cork.

A more representative and region or location specific sequestration rate may be determined via modeling studies with models such as CORKFIT and SUBER.

4 Carbon sequestration and LCA

4.1 Introduction

In previous chapter we discussed the value of carbon sequestration. Or more exact: the change in carbon sequestration over the years. It is investigated how much carbon is extra sequestered in cork oak forests, in respect with the reference land use situation. In Chapter 3, we also showed the variability of carbon sequestered in biomass and soil per region.

The next questions are: may we actually take this change in carbon into account in LCA? And if yes: how?

In this chapter we look into this matter. Is there a standardized method? Does it apply to cork as well? Secondly, the issue of dealing with different regions is discussed.

4.2 Standardization methods on carbon sequestration

4.2.1 Carbon credits in LCA

Question should the carbon sequestration be taken into account in LCA?

A number of documents offer guidelines for performing life cycle assessment:

- ISO standards within the 14,000 range[11] offer directions for good LCA practice and greenhouse gas inventories on a macro level.
- The ILCD[12] Handbook, elaborates on the ISO standards on LCA. It is developed by the joint research centre (JRC) for providing more detailed guidance. Both a general guide for LCA and a specific guide for LCI[13] exist.
- The British PAS 2050 specification (PAS 2050:2011) builds on the ISO standards on LCA and provides hands on approach for CO_2 footprint studies of goods and services. In 2012, a supplementary PAS 2050 document was issued (PAS 2050-1:2012), specific for GHG emissions of horticultural products.

There is consensus that effects due to land use change should be taken into account: both the ISO standard, the ILCD Handbook by JRC and PAS 2050 mention this. This means that when cultivation leads to either a carbon uptake or to a carbon loss, the net results should be incorporated in the LCA study. The time horizon for GHG accounting due to land use change is 20 years: only GHG emissions or uptake that occurred during the previous 20 years should be taken into account in carbon footprint studies.

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[11] ISO 14040 Environmental management - LCA - principles and framework.
ISO 14044 Environmental management, Life cycle assessment, Requirements and guidelines.
ISO 14064 Greenhouse gases (Part 1, 2 and 3).

[12] International Reference Life Cycle Data System.

[13] LCI is short for Life Cycle Inventory (see terms and definitions).

ISO and ILCD don't supply specific guidelines; the PAS documents do. But, we will see that it depends on how we define the cork oak cultivation system, whether or not we should take carbon sequestration into account. This is illustrated by a number of statements of the PAS documents.

On the issue of carbon sequestration in forests, PAS 2050:2011 states:
'While forest management activities might result in additional carbon storage in managed forests through the retention of forest biomass, this potential source of storage is not included in the scope of this PAS.'
So (Statement 1): **NO.**

But on soil carbon:
'When not arising from land use change, changes in the carbon content of soils, including both emissions and removals, shall be excluded from the assessment of GHG emissions (…)'.
So (Statement 2): **NO, unless it is due to land use change.**

And on products from trees:
'Carbon incorporated in plants or trees with a life of 20 years or more (e.g. fruit trees) that are not products themselves but are part of a product system should be treated in the same way as soil carbon, unless plants and trees are resulting from a direct land use change occurring within the previous 20 years'.
So (Statement 3): **NO, unless it is due to land use change that occurred within the previous 20 years.**

But then, the most recent supplement for horticultural products, PAS 2050-1:2012, states:
'Cradle-to-gate assessment of horticultural products shall include GHG emissions and removals arising from all processes, inputs and outputs (…) including: emissions and removals of biogenic carbon (…) where that biogenic carbon does not become part of the horticultural product.'
So (Statement 4): **YES.**

Conclusion: whether or not to take net carbon sequestration into account in LCA depends how raw cork is defined and whether the carbon sequestration is due to land use change. At least: when PAS 2050 is followed. This issue will be discussed in the next paragraph.

4.3 Interpretation of the cork cultivation system within PAS 2050

So how should the cork cultivation system be interpreted, to know whether or not the net carbon sequestration should be taken into account in LCA?
And what are the consequences?

The carbons sequestration in cork oak forests is, however, not specifically due to land use change, it occurs naturally while the forest matures.

Cork is not a horticultural product, it is a product from agroforestry, but it is similar to horticultural products - such as apples, berries and grapes - in the sense that a part of the tree or plant is harvested. A forest area by definition is at least 30% covered by the crowns of the trees and is at least 5 meters in height (see e.g. REDD). The Dehesas and Montados comply with this definition and are called forests. Products from horticulture do not match the criteria - most orchards are less than 5 meters high.

We conclude: cork is not a horticultural product and does not have to follow PAS 2050 for horticultural products (see Paragraph 4.2, Statement 4).

If we follow PAS 2050, it should be checked whether or not the carbon sequestration is due to land use change (by human actions). We would reason that is not. People started to cultivate the land many years ago and nowadays the forests are managed, but this leads to no structural change to the ecosystem. So based on the current PAS standardization, CE Delft would conclude that the net GHG effect due to carbon sequestration should **NOT** be taken into account in the case of cork products from existing cork oak forests.

However, this does not settle the case. At this moment, no clear rules for cork products exist, but the field is in development and it might well be that for non-wood forestry products such as cork, rules will be established in the near future.

Next, an exception can be thought of: when a new cork oak forest or plantation is started, new land use change effects occur. In this case it would be prudent to follow Statement 2 (see Paragraph 4.2) and include sequestration of carbon in the soil.

Also, whether the sequestered carbon may be claimed for cork products depends on whether this is allowed, when the carbon credits of the cork oak forest are used by the country as part of their national target for CO_2 reductions (see also the hierarchy in Figure 4). This is elaborated upon in Chapter 6.

Conclusion

CE Delft concludes that although there would be merit in considering forest carbon sequestration into forestry products, that at the moment there is no standardization method which would capture how to do it. Therefore, the rules have to be defined and any value reported in the literature cannot be used in LCA yet.

5 Allocation

5.1 Introduction

5.1.1 Explanation of allocation within the cork production chain

In LCA, allocation means the need to attribute the environmental impact of a process (or benefit) to multiple products. When looking into the cork production chain, this occurs at two points; this is depicted in Figure 20.

First at the forestry level, it is necessary to allocate the carbon sequestration figure (and impacts of forestry) among the various outputs of the cork oak woodland. The cork oaks produce raw cork, both the high quality reproduction cork as well as cork of lesser quality - called by-products - like first and second generation cork, winter cork and cork with defects. As also mentioned in Paragraph 2.1, a forest delivers other products next to raw cork, like honey, firewood, mushrooms and various animal products (milk, meat, wool). Tourism also can be considered an outcome of the cork production area. Which outputs are generated in the cork oak cultivation area varies per region. For LCA studies of cork products, it is necessary to divide the environmental impact or benefit, like carbon sequestration, from the forest management phase to the multiple products that the forest produces. This allocation issue is the subject of Paragraph 5.3.

Secondly, allocation is necessary at the level of cork product manufacturing. As explained in Paragraph 2.3, the raw cork delivers various intermediate products (half-products) out of which a large number of cork end-products are made. Often, the end-products are a combination of natural cork and granulates.
The end-products that UAB (2011) focusses on are cork stoppers for wine and champagne. Other well known examples are flooring, panels and table mats; furthermore cork is used in footwear, in musical instruments, baseball bats and in many other products. The question is how to make a fair division of the environmental impact of raw cork into the various half-products or final products. This allocation issue is the subject of Paragraph 5.4.

5.2 Which allocation method?

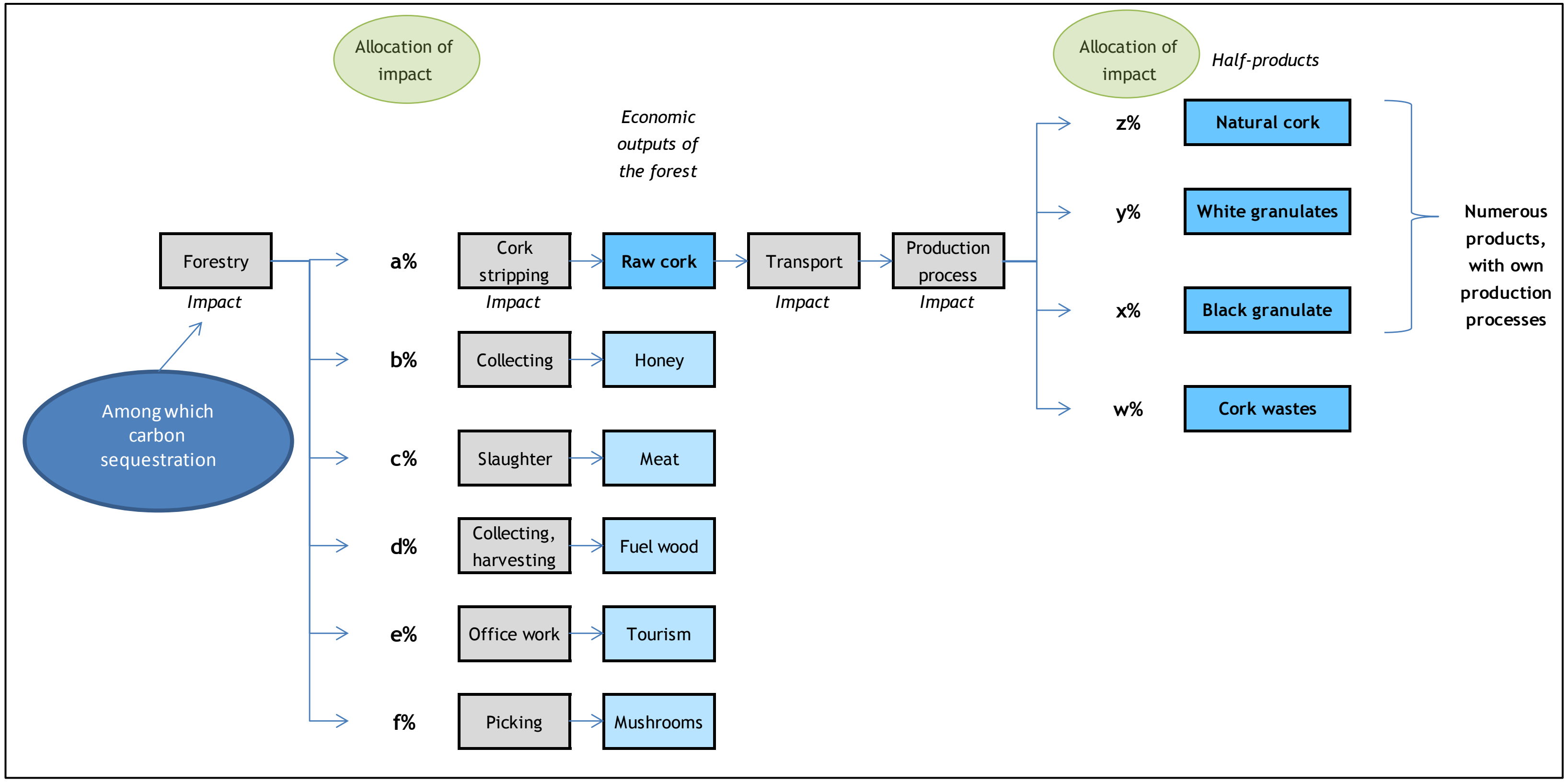
There are different methods to perform allocation and in LCA, the selection of the right allocation method is known to be a subject of discussion.
In (UAB, 2011) it is rightly stated that allocation is a controversial issue, because different allocation methods cause different results.

The various ways to deal with multiple co-products within a system are:

- Allocation:
  - by subdivision of processes, system expansion, substitution.
- Allocation:
  - mass allocation;
  - economic allocation.

ISO 14040 suggests to avoid allocation whenever possible. In the case of cork products, this is not feasible: we want to obtain environmental results for individual cork products.

Figure 20 **Allocation spots within the cork production chain (basic schematic representation)**



Source: CE Delft.

PAS 2050, the British guideline for CO_2 footprint studies by means of LCA, states that system expansion or substitution is preferred, but when not possible, economic allocation is preferred over mass allocation (page 22).

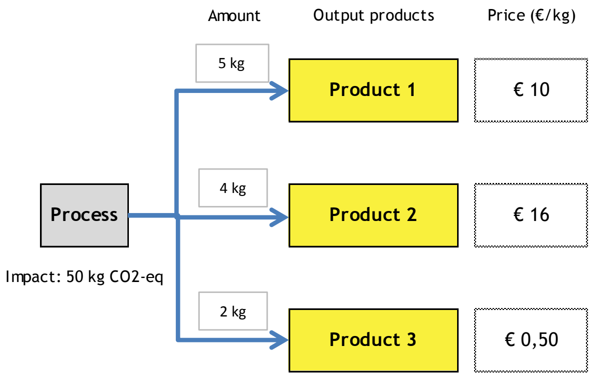
The mass allocation factors are determined by the weight of the multiple outputs.
The economic allocation factors are determined by the total revenue (€/ha/yr).

In a recent exchange of opinion on the LCA mailing list by Pré (November/December 2012)[14], it is discussed whether to prefer mass or economic allocation. As one of the contributors observes: 'It seems that the balance of opinion has tilted towards economic allocation'. A strong argument for economic allocation is that it reflects the thinking of businesses. As a proponent states: 'Processes exists at all because someone invests in them. The investors motivation is to gain economic return on that investment from the stream of products or services that the process produces'.
This statement fits the cork production industry well.

Example

Figure 21 shows by means of an example how economic allocation works, how an impact is divided over multiple outputs of one production process. In this (fictive) case a production process has a climate change impact of 50 kg CO_2 eq. and delivers three output products in the ratio 5:4:2 kg. Each product has a certain market value (€/kg). With this information, allocation can be performed, as shown in the table at the right of Figure 21.

Figure 21 Calculation example of economic allocation



	Value x amount	Allocation factor	CO2-impact per amount	
	50	50/115 = 43,5%	22	per 5 kg
	64	64/115 = 55,7%	28	per 4 kg
	1	1/115 = 0,9%	0,4	per 2 kg
TOTAL	115	100%	50	

Once this the allocation of the process over the various product is done, the impact per kg of product is known as well:
Product 1 has an impact of (22/5=) 4,3 kg CO_2/kg.
Product 2 has an impact of (28/4=) 7,0 kg CO_2/kg.
Product 3 has an impact of (0,4/2=) 0,2 kg CO_2/kg.

14 http://lists.pre-sustainability.com.

5.3 One hectare, many outputs

Question: what is the best allocation method for the multiple outputs from the cork oak cultivation area and how does it influence the results?

Review and discussion

In UAB (2011) it is chosen to assign all the environmental burdens and benefits of the cork production area to the cork itself. Three reasons are stated:
1) it reduces the complexity of the study; 2) cork would be the product that represents the highest revenue and 3) the cork production allows for all other economic activities.
This 100% allocation to cork is not what is meant by avoiding allocation. Neither is it mass or economic allocation, despite the economic argumentation. It is a sort of simplified rounded economic allocation.

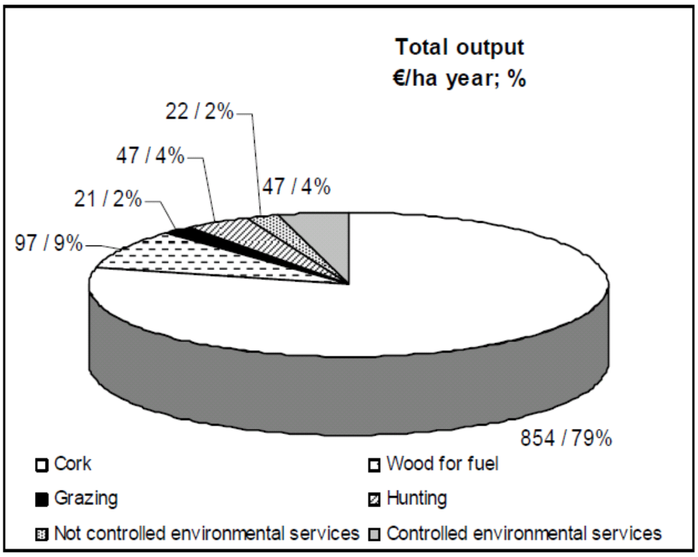
When considering mass or economic allocation for the multiple outputs of the forest, mass allocations seems not suitable, since all the products are very different in nature and function. Economic allocation is preferred by many LCA practitioners and definitely also in this case (see the statements in Paragraph 7.2).

Examples

In WWF (2006) the other valuable goods and services from cork oak landscapes are taken into account. It does not show the situation in Catalonia, but it does provide the revenue of two cork oak areas in Spain and Tunisia. For the Spanish woodland, the largest revenue is generated by raw cork: 79% (in 2003; distribution may differ nowadays). This means that 21% of the environmental impacts related to the forest itself, including carbon sequestration, should *not* be accounted to the cork.
In this example, the carbon sequestration figure is lowered by 21% when allocation over the different cork oak forest outputs is applied.

Figure 22 Outputs of a Spanish cork oak woodland (as published in WWF, 2006)

Figure 3. Total outputs of a well-managed Spanish cork oak woodland (hypothetic mature cork oak woodland which naturally regenerates 0,7% of its area every year). Average yearly values.

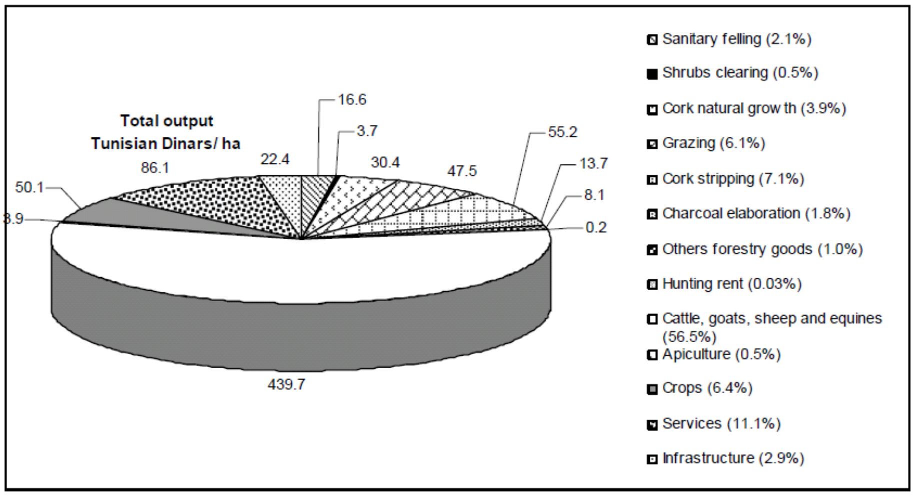


Prepared by Torres (2006), based on Campos *et al.*, 2003.

The other example in WWF (2006) is a cork woodland in Tunisia (dated 2005). Despite the fact that the values are probably outdated, the Tunisian case shows that cork is not necessarily the main output of a forest in terms of revenue. In this case, cattle raising is (56,5%); cork comes second (7,1% + 3,9%). So in Tunisia, according to this distribution, only 11% of the sequestration value can be assigned to raw cork.

Figure 23 **Outputs of a Tunisian cork oak woodland (as published in WWF, 2006)**

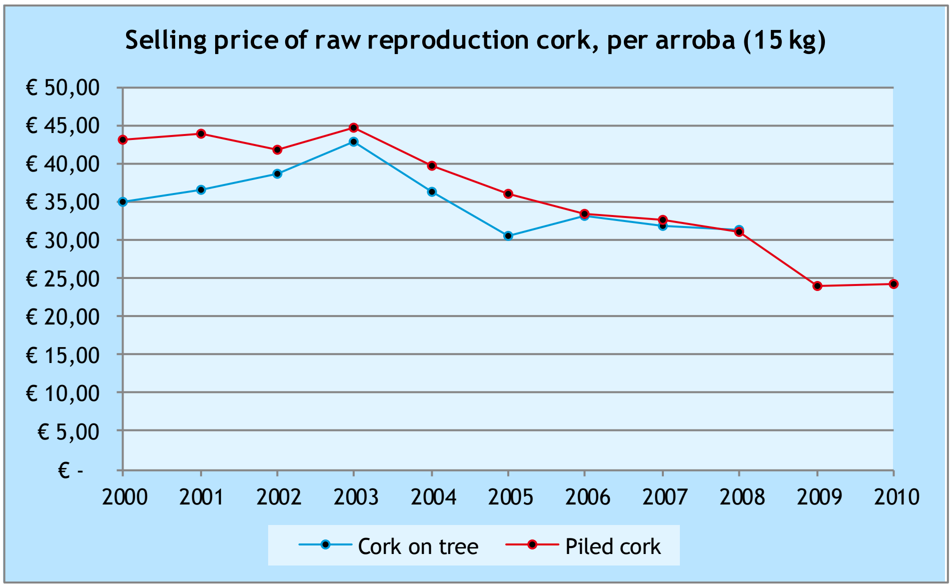
Figure 4. Total outputs of a Tunisian cork oak woodland.



Prepared by Torres , 2006, based on Chebil *et al.* (2005). Tunisian Dinar TND .(1 Tunisian Dinar = 0,60 euros)

It has to be said that the cork revenue fluctuates over time. Statistics of the raw cork price, by Portuguese cork association Apcor (2012) and Autoridade da Concorrência (2012) show that the price of cork has declined over the years, especially since 2008. Compared with 2006, which is the benchmark in Figure 22, the value of Portuguese raw reproduction cork has declined by about 25%. If this is also the case for Spanish cork, and if the prices of other products from the cork oak forest did not decline, the revenue of cork represents now only (79% - 79%*25% =) 58% of the cork oak forest.

Figure 24 Selling price per Portuguese arroba (1 arroba equals 15 kg)



Conclusion

Large differences exist between cork cultivation areas as far as land management and yields of various outputs. To allocate 100% of the environmental impacts/benefits (carbon sequestration) of the forest to the raw cork is not completely according to reality, as is also mentioned in UAB (2011). Not for the woodland in Spain, but certainly not for the situation in Tunisia. Therefore, it is not legit to apply the 100% assumption for all cork, from all regions. Figure 22 and Figure 23 indicate that the carbon sequestration value may be considerably (21%) to much (89%) lower when allocation to output products of a cork production area is applied.

5.4 Support schemes: an additional aspect to consider in allocation?

Cork oak forests and landscapes are ecologically important landscapes with a unique biodiversity and as such are worthwhile to be conserved. They also have an important role in water management in these dry regions and are important in preventing erosion and desertification. And yes, they store a significant amount of carbon in the shape of cork oaks.

However, as indicated in previous paragraphs, the claim that the storage of carbon in cork oaks can be allocated completely to natural cork bottle stoppers (and similar cork products) is difficult to uphold as these landscapes produce more than only cork.

Next to this, there is a second argument for finding this claim by the cork industry on all carbon sequestered in cork oaks disputable: national and international support schemes and Payment for Ecosystem Services (PES) programs.

For example, a significant part of Spain's cork oak forests is part of the 'Los Alcornocales' (literally 'the cork oak groves') national park in southern Andalusia. Landscape management in the national park is partly paid for by public funds, which are aimed at reducing the risk of forest fire and destruction of the typical cork oak landscape[15].
Parts of Dehesa and Montado landscape are also included in other national parks, such as the Donana and Cabaneros national parks in Spain or the south-west Alentejo and Vicentine Coast Natural Park in Portugal.

Another example is WWF's campaign in the Mediterranean to preserve cork oak forests. As part of this initiative WWF has realized a voluntary PES[16] project in Portugal between Coca Cola Portugal and local land-owners in which Coca Cola pays the land-owners for applying best environmental practices aimed at preservation of an aquifer vital to Coca Cola's water supply[17] (WWF, 2006).

A further example is given by the positive results of the EU CAP policies. Between 1975 and 1995, the area occupied by cork oak in Portugal increased by approximately 10% (from 657,000 ha to 713,000 ha) because new plantations were subsidized by Common Agriculture Policy (CAP) (Sauro, 2006). The presumed sequestration of carbon in cork oaks is claimed by European cork products producers such as Rotllan Torra.

To summarize, subsidies and PES incomes also contribute to keeping cork oak landscapes economically viable and conserving them.
It would seem logical that when applying economic allocation, these incomes are also taken into account and part of the fixated carbon under consideration in the allocation is allocated to the provider of these subsidies or payments. As stated in (Guinnee, 2001)[18], page 24:

> *"If subsidies are given for a specific performance, this performance may be defined as a product. An example is that of subsidies for nature conservation measures in agriculture, where, for instance, farmers in the Netherlands may be paid for each successful nest of meadow birds. "Meadow birds" is the a co-product sold to the government, with its own clear share in the total proceeds of the farm."*

In the case of cork oak landscapes such products related to financial support and PES may be 'm^3 of water that can be extracted', 'xx individuals of yy species of birds, mammals, plants, ...' or 'zz hectares of cork oak landscape and products thereof, not consumed by fire'.

Subsidies have by the way also proven to be a threat to traditional cork oak woodlands. As stated by WWF: "Subsidies have Plantations of exotic forest species have replaced the traditional cork oak forest landscape in many areas, whilst in others, valuable scrub areas have been converted to cork oak plantations. These plantations typically have low biodiversity values. Often driven by agricultural and forestry subsidies, this combination of conversion,

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15 See: www.fs.fed.us/psw/publications/documents/psw_gtr208en/psw_gtr208en_535-544_campos-palacin.pdf.

16 PES = pay for environmental services.

17 See: www.efi.int/files/attachments/events/2012/pes_event_bugalhomnthink forestseminar27thnov.pdf.

18 See: http://media.leidenuniv.nl/legacy/new-dutch-lca-guide-part-2b.pdf.

intensification, and changed land use has contributed to an increase in the incidence of fires and a reduction in the health of the cork woodlands[19]".

5.5 Raw cork converted into many cork products

What is the best allocation method for the multiple outputs of the cork products manufacturing phase and how does this influence the results?

In UAB (2011) p.126, a clear overview of the link between raw cork, cork intermediate products and cork end-products is provided.

From 1 kg of raw cork, which delivers various intermediate products, a large number of end-products are manufactured. As can be seen in the figure, natural cork stoppers are directly produced out of reproduction cork (no intermediate product).

Raw cork comes in various qualities: the first and second generation cork does not have the quality to produce the natural cork stoppers, but granulated it can be used in many agglomerated products. The reproduction cork has the highest quality, but besides making cork stoppers smaller pieces are used for discs and the remaining pieces are granulated and end up in agglomerated products. Small bits can be pulverized and also used in agglomerated products.

The variety of and all the links between intermediate products and end-products make allocation difficult.

Figure 25 Raw cork, intermediate products and end-products

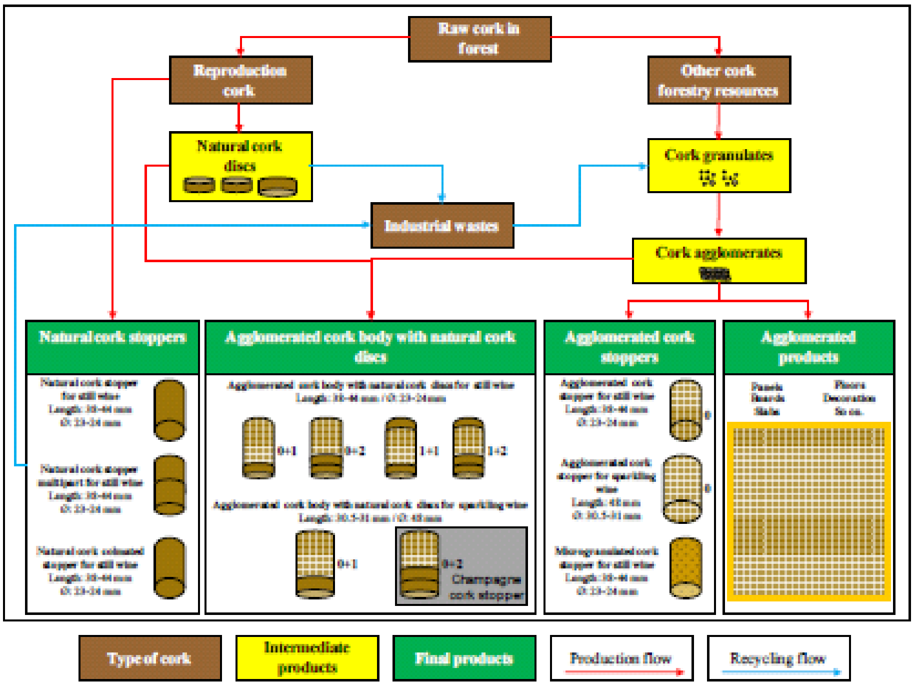


Figure 6.1. Cork products: variety of cork stoppers depending on the type of cork used and the combination of intermediate products.

Source: UAB (2011).

19 http://awsassets.panda.org/downloads/beyond_cork_publication.pdf.

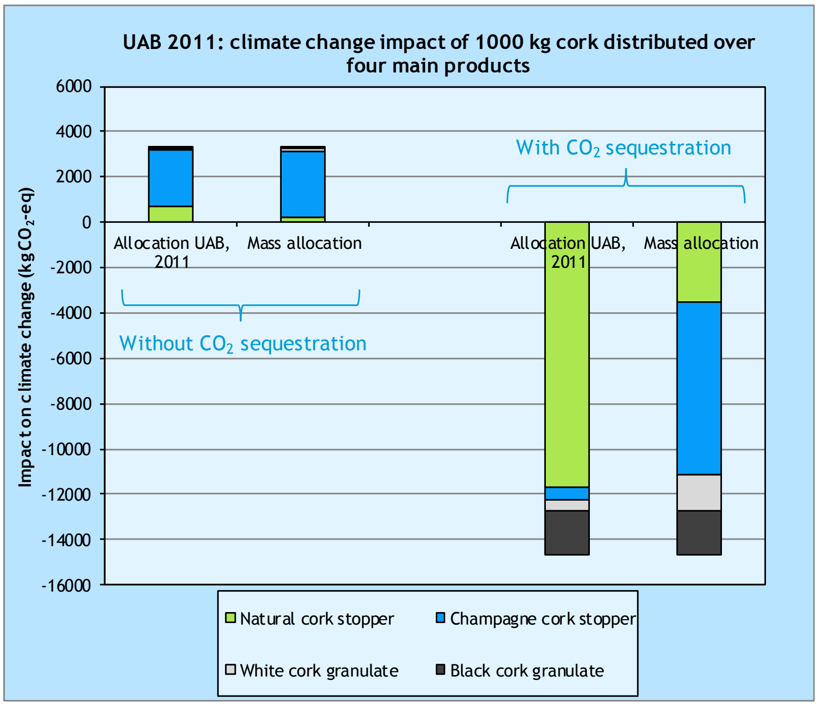
See Figure 7 in paragraph 2.3 for illustration of the following text.

In UAB (2011) both the environmental impact of 1,000 kg raw cork is divided, based on mass, between reproduction cork (865 kg) and 1st and 2nd generation cork (135 kg). The latter consists of white and black granulate. Then UAB (2011) chooses to assign 100% of the impact of the reproduction cork to the natural ('intact') cork products, being cork stoppers and discs. In the study the white granulates from reproduction cork are considered waste products, so the impact of the natural cork becomes the impact of all the reproduction cork.

In Chapter 7, UAB (2011) calculates the environmental results for 1,000 kg of raw cork, divided over four types of products: the natural cork stopper, champagne cork stoppers, white granulate and black granulate (the granulates are not processed into products). When carbon sequestration is taken into account, this leads to the following results (see also Figure 26):
– products out of natural cork get a very high share of the environmental impact of 1,000 kg raw cork: their 'own' impact plus the impact for the 'industrial waste' white granulates that are used in other products;
– white granulate get a very low share since most of the white granulate is considered as 'industrial waste';
– black granulate get a higher share of the environmental impact than products out of the white granulate, since all of the black granulate originates from the forest;
– products which are part natural cork and part white granulate, such as champagne stoppers, have a share which depends on the amount of natural cork.

Figure 26 also shows the results in case of mass allocation, as calculated by UAB (2011). The results according to mass allocation lead to a completely different outcome, as is also observed in (UAB, 2011). Economic allocation, which is the most preferred allocation method, is not considered. CE Delft would have expected at least some discussion of applying economic allocation.

Figure 26 **Distribution of CO_2 scores due to allocation**



Generated based on table 7.6 and 7.9, UAB, 2011.

CE Delft has two critical remarks to the approach of UAB (2011):
1. The allocation method is arbitrary and leads to an arbitrary distribution between cork products. There is no good reason not to apply economic allocation for various co-products out of reproduction cork.
2. This approach is a mix of end-products (the two stopper types) and half-products (the granulates). It does not take into consideration those other wine stopper types that are widely available on the market, like colmated stoppers and technical stoppers (1+1; 2+0; 2+2). The end results are also not well suited to determine the environmental impact of other cork products.

Our suggestion
CE Delft would suggest to apply economic allocation for the multiple output system and place the system boundary at the level of various half-products[20].

This has two large advantages:
1. This is conform the ISO and PAS standards.
2. It leads to clear environmental impact values for all half-products, which any company can easily use to construct the (impact of) its own cork product.

The drawback is that more aspects need to be inventoried and the calculation is more complex.

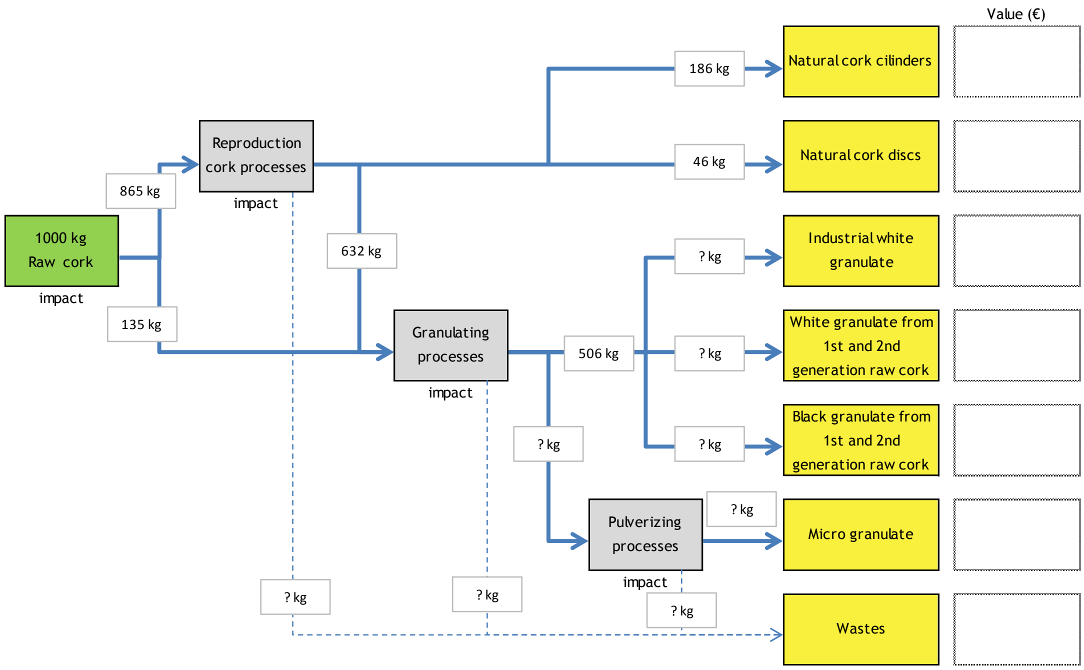
Elaboration
The allocation factors determine how the environmental impact is distributed over multiple output products, see for the general approach the example in Paragraph 5.2.
For cork, the environmental impact of 1,000 kg of raw cork, plus additional production processes, has to be divided over many different cork half-products. To perform this allocation according to CE Delft's suggestion, the chart becomes more complicated. Not all production processes are applicable to all output products. Figure 27 shows the information needed to obtain the allocation factors. This flow diagram shows a wide range of cork half-products[21]. For each half-product, it is necessary to know the price (€/kg) and output amount (kg) per ton of raw cork. It might be that even more half-products can be distinguished, like various qualities of natural cork. The diagram may be adjusted to optimally represent the cork product's production chain.

The information is partly filled out in the flow diagram, as far as available in UAB (2011). The currently available sources to CE Delft are not sufficient to perform the economic allocation. In collaboration with the cork manufacturing industry, this could be achieved.

[20] The natural cork cylinders are considered to be almost the natural cork stoppers, except for the optional print on the cork.

[21] This is an example diagram: the list of half-products can probably be optimised and the amounts in the diagram are based on UAB (2011) and partly unknown.

Figure 27 Information needed to obtain allocation factors for different cork end-products



Once the information is complete, the allocation factors can be determined per half-product, following the method as outlined in Figure 21 in Paragraph 5.2:

$$\text{Allocation factor} = \frac{\text{Value x amount}}{\sum \text{Values x amounts}}$$

With the allocation factors, the impact of 1,000 kg raw cork and the impact of the various production processes can be divided over the half-products.

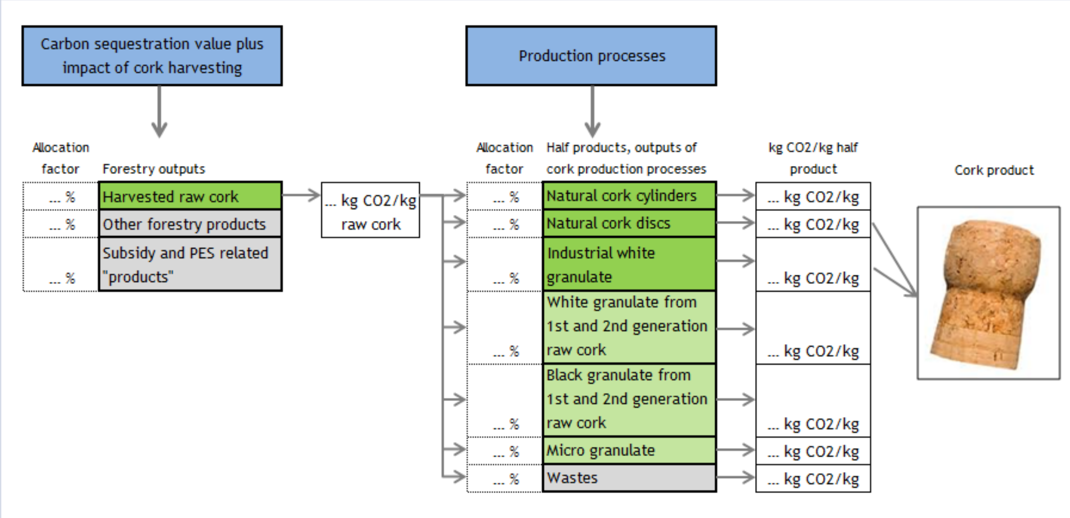
5.6 Summary

At two points in the cork production chain allocation is necessary.

- Allocation 1: the carbon sequestration figure needs to be divided over the various products produced from cork oak landscapes and over financial support schemes and PES payments. The environmental impacts for harvesting the cork are added to obtain the climate change impact of one kg raw cork (kg CO_2 eq.).
- Allocation 2: the obtained value for raw cork has to be divided over the various outputs of the production processes.

The end result is a value for each half-product: kg CO_2 eq. per kg half-product. With these end values, the environmental impact of any cork product can be constructed.

Figure 28 Allocation flowsheet



Source: CE Delft.

The allocation factors for forestry outputs (‘Allocation 1’) differ per region and the allocation factors for the production process (‘Allocation 2’) are to be determined with help of the cork production industry.

6 Carbon credits and forestry, claim of sequestered CO_2

Changes in carbon stock in forests, either new or existing, play an important role in climate policy and voluntary offsets. Under the Kyoto Protocol, countries report on so-called LULUCF emissions and sinks.

In this chapter, we will explore whether these regulatory and voluntary frameworks have any consequences for the right to count carbon uptake in forests toward carbon foot printing of forestry products. The focus is on forest management in existing forests. Although there is some expansion of cork oak forests and this certainly involves significant extra carbon sequestration[22], this would count as land use change. Dictated by most carbon foot printing protocols, the effect would be amortized over 20 years following the transformation. Hence, the harvest of wine-stopper quality cork currently supplied to the market would fall outside that period.

6.1 National carbon accounting under Kyoto Protocol

It is important to distinguish between the Convention (UNFCCC) and the Kyoto Protocol (KP) The Kyoto Protocol is an international agreement linked to the UNFCCC and commits its Parties by setting internationally binding emission reduction targets. Parties to the Convention must submit national reports on implementation to the Conference of the Parties (COP). The required contents of national communications are different for 'Annex I and 'non-Annex I' Parties. Most of the Annex I Parties of the Convention are Annex B Parties of the Kyoto Protocol (i.e. they have committed to a national target, for the first and/or the second commitment period of the KP, see below).

Under the UNFCCC, countries in principle report all national emission sources and sinks for greenhouse gases. Under the Kyoto Protocol, only some of these sources and sinks are counted toward the national target. More specifically, the situation for LULUCF sources and sinks is of concern here.

In the **first commitment period (CP1, 2008-2012)** of KP, emission sources and sinks due to afforestation, reforestation and deforestation after 1990 have to be included in the national accounts (KP, Article 3.3). Accounting for emission sources and sinks due to forest management of forests existing in/before 1990 is voluntary (KP, Article 3.4). Forest management is about carbon sequestration on existing forest area, not about changes in that area (changes in area are covered by Article 3.3). Carbon storage in wood products (in the economy) is not taken into account.

The quantity of greenhouse gas credits (removal units, RMUs) to be produced from forest management under Article 3.4 or acquired under Article 6 (Joint Implementation) is limited[23]. So while full removals via forest management may be reported in the UNFCCC national inventory report, the amount that may be toward reduction within the context of the KP is capped. Parties (annex I) may also acquire a maximum of 1% in CER credits from

22 And an important pillar of e.g. Portugal's strategy to fulfil its Kyoto target.

23 In a rather complex fashion, see http://unfccc.int/methods_and_science/lulucf/items/3063.php.

afforestation and reforestation under CDM (KP Article 12) but in practice such credits have only been issued once so far (Brazil, see World Bank 2012). Parties can also acquire removal credits via Joint Implementation or via trading (IET), but again this has occurred only once so far (Hungary to New Zealand, see text box). RMUs cannot be carried over to the second commitment period.

In the **second commitment period (CP2, 2013-2020)** of KP, forest management is a compulsory item in the national accounting, along with any activities already reported under Article 3.4 in first commitment period. Also, accounting for harvested wood products as an additional carbon pool, is a requirement. Forest management credits – in own country (RMU) or via Joint Implementation (ERUs, KP Article 6) – are capped at 3.5% of the base year GHG emissions excluding LULUCF.

Overview and terminology

UNFCCC	United Nations Framework Convention on Climate Change
KP	Kyoto Protocol
CP1, CP2	First commitment period (2008-2012), second commitment period (2013-2020)
LULUCF	Land use, land use change and forestry
RMU	Removal unit, 1 ton CO_2 eq., KP (via LULUCF activities in own country) (both Article 3.3 and 3.4). RMU generated from forest management are capped
ERU	Emission reduction unit,1 ton CO_2 eq., KP (via JI) (before sale, an RMU of country 1 is converted into an international ERU and appears as such in registry of country 2)
CER	Certified Emissions Reduction, 1 ton CO_2 eq., KP (via CDM)(afforestation and reforestation only)
JI	Joint Implementation (KP article 6) (reduction in other Annex I countries)(may include forest management)
CDM	Clean Development Mechanism (KP article 12) (reduction in non-Annex I countries)
IET	International Emissions Trading (KP article 17) between countries (not to be confused with EU ETS)
Article 3.3	Kyoto Protocol, re afforestation, reforestation and deforestation after 1990. This is an obligatory category and 1990 net emissions are included in the calculation of 'initial assigned amount'
Article 3.4	Kyoto Protocol, re forest management, cropland management, grazing land management and revegetation. Voluntary category in the first commitment period. Net emissions are **not** included in the 'initial assigned amount'. In the second commitment period, forest management is a compulsory category

6.1.1 Value of removal units

The effect of including forest management in the accounting for Kyoto at the national level will typically[24] be that a country with significant existing forest area will reach its reduction targets more easily (cheaply) as fewer reduction measures in other sectors will need to be taken. In other words, there is a potential implicit financial benefit to other sectors, via the system of national accounting. This benefit is very indirect, as there is no clear redistribution mechanism for the credits and moreover the number of credits is capped.

24 This is a simplification, but adopted here for the sake of the argument.

Only in one case so far have RMUs actually been traded between two Parties (see text box). This sale, from Hungary to New Zealand[25], represented less than 0.01% of the total global carbon market (World Bank, 2012). Those RMUs were most likely generated under Article 3.3 (reforestation, hence not capped) but the value per RMU can be considered indicative of all RMU. In the absence of more sales, however, the true market value remains unclear.

4.2.4 Removal Units (World Bank, 2012)
These units can be issues by parties on the basis of land use, land-use change and forestry (LULUCF) activities such as reforestation. RMUs represent the same compliance value as other Kyoto flexibility mechanisms and can be traded among parties. The first RMUs were issued in 2011, in the National Registries of France, Australia, Russia and Hungary. At the end of 2011, both France and Australia held 23 million RMUs in their National Registries. Russia held 4 million RMUs at the end of 2011, and was issued 462 million in February 2012. 2011 witnessed the fist sale of Removal Units (RMUs), coming form Hungary. Hungary's forests cover around a fifth of the country after its forested area grew 13% to 19.217 square kilometres between 1990 and 2011, referring to data from the Hungarian Statistic office. As a result, Hungary issued itself the first RMUs in 2011 after the UN finalized the county's 2008 greenhouse gas emissions data in the previous years. The country, along with Denmark, France and Switzerland, has opted to print RMUs annually, while other Kyoto signatories will receive RMUs in 2014, two years after emissions data for the entire 2008-2012 Kyoto period is finalized.
In October 2011, the National Development Ministry of Hungary announced it had issued 3.9 million RMUs. The country also announced that the revenue from the sale of the units would be used to support environmentally friendly investments. The sale of a certain volume was announced in December 2011. Neither the volume nor its value were confirmed; however, in a press briefing, the Hungarian government confirmed that Kyoto permit revenues in 2011 totalled HUF 2.7 billion ($ 11.5 million) and that it expects further HUF 1.6 billion in 2012. Since no AAU deal was announced by Hungary in 2011, it is likely that revenues came from the RMU sale. Finally, the New Zealand registry showed the transfer of 3.9 million RMUs from overseas in 2011. Although not confirmed, if the volume shown in the New Zealand registry corresponds to the purchase of the Hungary RMUs, average prices for the transaction were US$ 2.95 per RMU (US$ 11.5 million for 3.9 million RMUs).

6.1.2 Who gets the money?

As stated above, the revenue of the credits goes toward the national budget and Hungary plans to use it to support certain green investments. This is a very indirect way of distributing funds. The situation of forest management under the Kyoto Protocol is not desirable from the perspective of economically efficient incentives, as well as other reasons (Kägi and Schmidtke, 2005). Land owners are the ones who make decisions regarding forest management - possibly influenced by subsidies - and if they don't get the benefits of forest management those decisions may not be the ones that are optimal from a full societal point of view. Unfortunately, there are some major complications that have prevented direct distribution of carbon 'credits' to land owners:

- extremely detailed accounting would be needed at level of individual land holdings;
- if the land owners gets the benefit, they have to carry the risk as well (natural disasters);
- the amount of credits that can actually be issued is limited (see above) so it isn't simply a credit unit per ton of CO_2 sequestered.

[25] NZ has an emission trading scheme that does allow trading of RMU.

For these reasons, there are no carbon policies that allow for all carbon sequestration to generate direct revenue. The example of Hungary shows a kind of 'top down' distribution of revenue generated at national level. In some existing carbon policy schemes, there is a more 'bottom up' approach to allow landowners to make money directly via (well defined and monitored) carbon offset *projects*:

- Australia carbon farming initiative (project based, proponent proposed and nationally approved methodologies) to generate compliance offsets for national carbon tax/trading scheme (as well as voluntary offsets).
  The category 'improved forest management' has been available for non-Kyoto-compliance market (internal fund, voluntary offsets) as Australia chose not to report forest management during the first commitment period (CP1). For CP2, this category will potentially yield compliance offsets, but no methodologies have been proposed or approved to date.
- California has a cap-and-trade program that allows entities to meet up to 8% of their obligation via compliance credits[26]. Possible offset projects are in forestry (including urban forest projects), livestock and ozone-depleting substances. The category 'improved forest management' is one of the options. Credits will come primarily from new project developments, but there is the possibility to transfer existing credits developed under certain approved voluntary quantification methodologies.

6.1.3 Portugal and Spain

Both Portugal and Spain have opted to account for forest management in their NIR, but as stated in the World Bank report (2012), credits will not be received by those countries until 2014. According to Portugal's 2010 national inventory report, the net carbon stock increase (living biomass) in cork oak forests is of the order of 0.9 Mton CO_2 eq. or which could provide an offset of 1.5% of the base year emissions for Portugal. However, the counting of credits due to forest management is capped, as mentioned earlier.

The forest management cap[27] is 0.22 Mton C per year for Portugal (KP decision 5/CP.6). This means that Portugal can claim a maximum of 4 Mton CO_2 eq. from forest management over CP1 (i.e. 5 years, 2008-2012). Against an approximate 10 Mton CO_2 eq. sequestration per year, this means that only 8% of the forest management sink will generate 'value' under Kyoto.

For Spain, this cap is 0.67 Mton C per year or a maximum of 12.3 Mton CO_2 eq. from forest management over CP1. With an annual 19 Mton CO_2 eq. sequestration per year, this means that about 13% of the forest management sink will generate 'value' under Kyoto for Spain.

The cap applies to the total number of RMUs generated under Article 3.4 from forest management, whether or not they are subsequently traded with another Party (after conversion to ERU) Conversely, when a Party acquires forest management RMUs via Joint Implementation, the cap applies to those in addition to the domestic removals. Hence, any carbon removal generated through forest management outside the FM cap cannot generate value within the UNFCCC/Kyoto framework.

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26 http://www.arb.ca.gov/cc/capandtrade/offsets/offsets.htm.

27 Essentially the maximum to RMUs generated under Article 3.4 when net emissions in Article 3.3. are negative, as is the case for both Portugal and Spain.

6.2 EU ETS

Under the entity emission trading scheme in the EU, removal units (RMUs) are not accepted (we assume this will continue in phase III of the ETS, from 2013-2020). This means that the direct benefit for ETS entities of a country including forest management in the national accounts is zero. The RMU price is (probably) much lower than the ETS trading price, as demonstrated by the Hungary case, but this provides only one sampling point.

6.3 Voluntary markets

The value of voluntary land-use carbon markets is larger than the compliance market. It is unlikely that old (cork oak) forests would be able to generate any such credits, however, especially those in European countries but also in Northern Africa. Most offset forestry projects involve new plantations of fast-growing species. New cork oak forests could potentially be established, triggered by the market for voluntary carbon offsets, but no examples are known.

The REDD mechanism is designed to generate a flow of money from developed to developing countries to reduce deforestation and degradation; again it seems unlikely that this is relevant to cork oak forests.

6.4 Implications for carbon foot printing

The question now is how (legal) ownership of carbon credits for forestry management influences the carbon foot print of the forestry products. In principle, CFP standards follow physical cause-effect relations rather than regulatory frameworks. Current standards typically prefer to count only the carbon uptake into the cork itself (i.e. its actual carbon content) in CFP.

However, if there is a real, net increase in the total carbon stock of the (cork oak) forest under consideration, one may well argue this should be attributed to the (all) forest products in one way or another. The four 'thought experiments' below consider several arguments that are relevant to the discussion. They should be considered as attempts to establish whether regulation or policy may provide guidance on attribution of forest management benefits to product carbon foot prints.

1. Indirect effects

Cork oak forests in Portugal/Spain generate credits (RMU, see 6.1) for a part of the increased carbon stock due to forest management. They can be traded between countries or used to offset national emissions. If this happens, it means that elsewhere in the economy, the sink is negated by an emission that would otherwise have been avoided. One can thus argue that there is in fact no net carbon removal and the uptake cannot be attributed to any of the forest products. However, the same argument could be made regarding emission reductions at e.g. a steel furnace. Some of the credits for that will, after all, be sold to another trading entity who will then need to reduce less of its own emissions. Only if allowances are not sold – as may well be the case currently, with a huge surplus due to the financial crisis – would there be a net emission reduction.

Still, in carbon foot printing the actual emissions are counted, without regard for these indirect effects. Hence, the same should go for emission sinks.

2. Physical carbon stock

The increased carbon stock is physically located in wood, cork, roots, etc. The UNFCCC accounting framework calculates exactly what the physical carbon stocks are and corrects the stocks for any material that leaves the system through harvesting. This means that only the stock contained in the harvested material itself is guaranteed to be 'free' of indirect effects and as such could be counted toward the carbon foot print. This is, pretty much, what the CFP protocols recommend.

In a more extreme interpretation, one could say that the cork layer plays no role in the national accounting and as such apparently has no benefit according to the regulatory framework. None of the carbon uptake should go toward the cork CFP[28].

3. National parks

In Tunesia, Morocco, Algeria and Spain, significant areas of cork oak forest are actually protected as national parks (Aronson et al., 2009). In Portugal, only 2% is national park, but 20% is covered by Natura 2000. This can be interpreted as a sign that the revenue of cork production is not in itself adequate for the protection of the cork oak forests. Hence, their continued existence and their role as a carbon sink is not really the consequence of the demand for natural cork production. Rather, the natural cork could be considered a by-product of biodiversity conservation. This would still give cork an advantage from a foot printing or LCA point of view – namely zero land use and associated burdens – but not the extreme advantage of attributing all carbon uptake in the tree as negative greenhouse gas emission.

4. Allocation to products

The landowner of a cork oak forest gets direct ownership of carbon credits via forest management practices, e.g. via voluntary offset schemes or a policy such as in Australia/California. (Within the EU and most other countries, this is a largely theoretical case.) They would probably sell the credits, thus in a sense losing the right to claim the benefits for their own products.
However, foot printing standards are unanimous and unambiguous regarding the fact that it is not allowed to claim offsets in a product CFP. Hence, the selling party might count it in their own CFP as they still have the physical carbon stock, if not the market value. Which of their product(s) would the carbon benefit be attributed to? The most logical approach would be to attribute it entirely to the product 'carbon credits sold', as this essentially follows the physical flow. In that case, none of the carbon uptake in the (standing) wood goes toward cork CFP[29].

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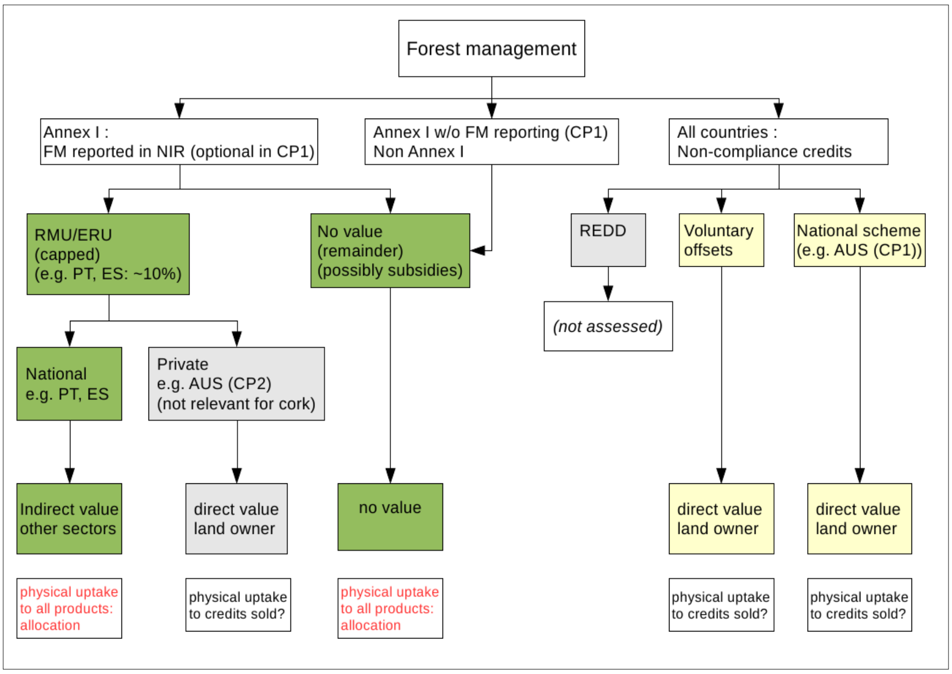
28 It is not clear from Portugal's national inventory report whether the cork harvest is explicitly counted or not. If it is, the effect of carbon removal would be overestimated, as all harvested volume is multiplied by the average density of 1.1 ton dry matter per m^3.

29 Whether carbon uptake into cork goes toward cork product depends on how the carbon credits are assessed.

Figure 29 Generating value from carbon through forest management. Green options are most likely for cork oak



We can elucidation Elucidation of the three main cases ('indirect value, direct value and no value') in Figure 29:

- 'indirect value'
  Credits with value at national level are generated from forest management within Kyoto Protocol framework. In practice, the value is very limited. Portugal and Spain will only be able to count about 10% of the sink function toward their national targets. Unless a significant amount of forest management credits is going to be sold to other Annex I countries[30], this means that indirect effects are small. Last but not least, drawing a parallel with credits/allowances from emission reduction shows that it would not be consistent to exclude carbon sequestration that is used toward the national reduction target from the physical product system.
- 'direct value'
  Credits with value for the private landowner are generated, either through compliance projects or for voluntary offset schemes. In this case the indirect effects - if sold - completely cancel the carbon sequestration, as this is the function of offsets. However, this is explicitly excluded from product carbon foot printing, so the carbon uptake is available for forestry products. A logical choice would be to attribute the carbon uptake to the product (or service) of 'offset credits', but one could take other allocation approaches.
- 'no value'
  no credits with value are generated (this is the current situation for the majority of carbon sequestration in cork oak forests). Land owners may receive subsidies for certain forest management practices but there is no direct value to sequestered carbon. This means the only guidance is provided by carbon foot printing protocols. Economic allocation might be an option. A special case would be cork from forests that are protected as national park.
  The 'main product' in that case may well be biodiversity protection and/or recreation, but these are not easily expressed in proper financial values.

[30] This will only be clear in 2014.

Another approach might be to use economic allocation. The product 'carbon credits sold' would then absorb some of the carbon uptake according to total value, as would the cork and other products or services of the forest.
Such allocation would not really be preferred conform the hierarchy of ISO 14040, but is not uncommon in practice. Using the value of Rives et al. (2012) of 18 kg of CO_2 fixed per kg or raw cork extracted, the additional revenue of carbon credits would be of the order[31] of 2 to 3% of the revenue of raw cork. This is a high estimate as the uptake calculated by Rives is very high and it is unlikely that all carbon sequestration could be turned into financial revenue. Economic allocation would thus pass most of the carbon uptake on to the cork and only a few per cent to 'carbon credits sold'.

Without carbon credits, cork represents about 80% of value generated per hectare in Spanish cork oak woodland but only of the order of 10% in Tunesia (WWF, 2006). In order to apply economic allocation in this case, it obviously has to be clear what products are actually generated by the forestry system and what their value (to the land owner) is. One of the products could be 'nature conservation' (see above regarding national parks) which may not have any direct value but may be subsidized and as such still generate revenue for the land owner.

6.5 Conclusion

The explicit exclusion of carbon offsets from product foot print assessments means that the regulations regarding carbon credits – both compliance and voluntary – offers no direct guidance on how to attribute carbon uptake to forestry products. Moreover, the market value of carbon uptake in cork oak forests is very low in practice and only a limited fraction may be used toward national commitment.

[31] Raw cork 1840 EUR/ton (Rives et al., 2012) and RMU 3 US$/ton (see earlier text box).

7 Other LCA issues

In the previous paragraphs the main methodological short comings of the carbon footprint calculation presented in the UAB thesis (UAB, 2011) were discussed.
In addition we have some other issues with the way in which the LCA was used to make some claims. The issues that we want to address are the following:
- Are the results for cork stoppers - regardless of the exact value for one stopper and type of allocation method - suited for comparison with alternative wine bottle closures?
- How do differences in fault rates for wine quality influence the overall footprint per average bottle?
- How representative is landfilling for the actual end of life phase of natural cork bottle stoppers and cork based champagne bottle stoppers?

7.1 Comparison of results of cork stoppers

Issue: are the results for cork stoppers - regardless of the exact value for one stopper and type of allocation method - suited for comparison with alternative wine bottle closures?

The UAB thesis (UAB, 2011) concerns a life cycle inventory for natural cork stoppers. The intention of the analysis of the integrated evaluation of the cork sector is defined as: 'to assess the current cork sector from an environmental perspective, but not a comparison between other sectors or products; however results will facilitate data for future comparisons'.

CE Delft has some critical remarks about this last statement, because some aspects of the life cycle of cork products are not included in the study:
- The use phase of the stoppers, during which the stoppers (should) keep the bottle closed and help to maintain product quality, is not taken into account. The use phase is a known aspect of difference between various closure types.
- The additional material for cork and bottle protection (both wine and champagne), like the aluminium cover of the neck of wine bottles or the wire frame around the champagne cork and neck of the bottle.
- The end-of-life phase is only marginally taken into account[32].
- The results of the study are not valid for technical cork stoppers and agglomerated cork stoppers, only for natural cork stoppers.

Conclusion

We argue that the results are not suited for comparison with other types of wine bottle stoppers.

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[32] For the end-of-life of cork, one scenario is considered: landfilling of the cork. To model the landfilling of cork, a proxy was used: the Ecoinvent process 'Disposal, concrete, 5% water, to inert material landfill/CH'. This proxy is not a representative proxy. Incineration of the cork is common practice in many countries.

7.2 Loss rates and carbon footprint

Loss rates due to faults in wine quality such as musty taint and sulphur range from 1-3% for plastic closures to 6-8% for natural cork bottle closures (Corsi, 2011; IWSC, 2011), caused by the closure. In other words, loss rates for natural cork bottle closures are 2–6 times higher than for plastic bottle closures.

As a bottle of wine has, according to UAB (2011) a carbon footprint of 0.6–1.3 kg CO_2 eq., the carbon footprint of every natural cork bottle closure of (according to UAB (2011)) 3.7 g should include a factor for product loss of $\frac{7\% \cdot 0.6}{0.0037} \textit{ to } \frac{7\% \cdot 1.3}{0.0037}$ = 11.4 to 24.6 metric ton of CO_2 eq. per metric ton of natural cork closure.

7.3 End of life of cork product

– *Issue:* How representative is landfilling for the actual end of life phase of natural cork bottle stoppers and cork based champagne bottle stoppers?

In the UAB thesis (UAB, 2011) the natural cork stopper and champagne cork stopper are assumed to be landfilled at the end of their functional life as part of municipal waste. The two products are assumed to behave as inert materials in the landfill.

Both assumptions deserve some discussion, as these can have a significant impact on net greenhouse gas balance.

First of all, part of the cork stoppers produced in Spain and Portugal will be exported as part of wine bottles to countries where landfilling of municipal waste is no longer allowed and municipal waste is incinerated.
Burning of the cork will result in release of the sequestered carbon, but also in power generated on the basis of the heat released during cork combustion. The power produced during cork combustion probably substitutes fossil fuel based power production and the associated greenhouse gas emission.
Assuming:

– a lower heating value for cork of 18 GJ/metric ton (average lower heating value for dry wood);
– a net electric efficiency for the municipal waste incineration plant (MWIP) of 20% (average efficiency of MWIP's in the Netherlands);
– an average emission of 91 kg CO_2/GJ_e[33].

The greenhouse gas emission saved by combustion amounts to
18 x 20% x 91 = 330 kg CO_2 eq./metric ton of cork

Secondly, if the assumption that cork is inert in a landfill and the interpretation of how the 18.3 ton of sequestered carbon per ton of cork was calculated are correct, an important sink of CO_2 has been ignored in the UAB thesis (UAB, 2011) in the first place.
The assumption that cork is inert would mean that the carbon sequestered in this product will be sequestered for as long as the landfill remains intact.
As cork has a carbon content of 55-60%[34], the amount of CO_2 sequestered amounts to 2.0–2.2 metric ton per ton of cork.

[33] See: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=Oj:L:2009:140:0016:0062:en:PDF.

[34] See: www.subertap.com/origen_composicio_quimica.php?leng=3.

On the other hand, it is unclear how cork will behave in a landfill. Wood partly decomposes at a slow rate over a prolonged period of time, producing methane during decomposition in this anaerobic environment. As wood decomposes slowly, most methane is produced primarily after landfill gas collection and utilization or flaring has stopped and most methane is probably emitted to the atmosphere.

Assuming that 60% of the cork decomposes in the landfill (see IPCC, 2006) and about 50% of the carbon in the decomposed cork is converted into methane (IPCC, 2006), the maximum contribution of the produced biogas to climate change could amount to 5,750 kg CO_2 eq./metric ton of cork.

Basic assumptions	
a. C-content	57.50%
b. Percentage cork decomposing in landfill	60%
c. Percentage CH_4 in biogas	50%
a x b c Amount of CH_4, kg per metric ton of cork	230
GHG-emission, no CH_4 capture (kg CO_2 eq./mt of cork)	5,750

Conclusion

Summarizing, end-of-life could yield both a significant reduction and a significant increase of the net greenhouse gas balance of natural cork stoppers and cork based champagne bottle stoppers is possible.
It seems worthwhile to analyze the emissions in the end-of-life phase in greater detail.

8 Conclusions

CE Delft concludes that although there would be merit in considering forest carbon sequestration into forestry products, that at the moment there is no standardization method which would capture how to do it.
Therefore, the rules have to be defined and any value reported in the literature cannot be used in LCA yet.

With respect to the amount of carbon sequestered in cork oaks per unit of natural cork bottle stopper according to UAB (2011), we have following remarks:

- There is a probability that preconditions under which carbon sequestration in cork oaks could be claimed are not met as cork oak landscapes have at least partially been created by removing original vegetation and as part of the cork oak landscapes has been converted into arable land after the economic life of cork oaks.
- The carbon sequestration rate assumed in UAB (2011) is in itself at the high end of the range found for cork oaks and is more representative for the early development of the tree in its first decades of growth – before cork of sufficient quality for wine bottle stoppers can be harvested. For the time being, CE Delft would suggest using a range from 0.95 to 1.25 C/ton cork. A more representative and region or location specific sequestration rate may be determined via modeling studies with models such as CORKFIT and SUBER.
- In UAB (2011) (an other LCA's of natural cork bottle stoppers) allocation has been taken into account incorrectly:
    - Allocation to other products from cork oak landscapes, like firewood, pork, wool and mushrooms and to 'subsidy products' related to subsidies for specific services and private payments for ecological services are systematically ignored.
    - Allocation to natural cork bottle stoppers and other cork products is done in an arbitrary way, which assigns disproportionally more impact to the cork stoppers compared to other cork products.

  This means that natural cork also gets too much credit for the carbon sequestration benefit in (UAB, 2011).
- Several phases of the natural cork bottle stopper are not taken into account (product loss, covers around bottle neck) or are taken into account only marginally (end-of-life).

We therefore argue that the results of this study are not suited for comparison with other types of wine bottle stoppers.

Cork oak forests and landscapes are ecologically important landscapes with a unique biodiversity and as such are worthwhile to be conserved. They also store a significant amount of carbon in the shape of cork oaks.

However, as indicated, the claim that the storage of carbon in cork oaks can be allocated to natural cork bottle stoppers and similar products and that this gives these products a lower carbon footprint compared with competing products is difficult to uphold.

This on the other hand does not change the desirability of preserving cork oak landscapes and forests. Other mechanism may be found and applied to finance conservation and indeed are partly already being applied.

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