World **Hemp Forum**

Les **rencontres** du **chanvre industriel**

Forum des chercheurs

Researchers' Forum

Pôle européen du chanvre

World Hemp Forum
Les rencontres du chanvre industriel

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Hemp phenology and possible impact of climate change on its cultivation

Stefano Amaducci

Department of Sustainable Crop Production
Faculty of Agriculture, Food and Environmental Sciences

19th November 2024

Hemp phenology and possible impact of climate change on its cultivation

Checking on my PhD experiments (Bologna, Italy, August 1996)

Personal "*Hemp Bio*"

UNIVERSITÀ CATTOLICA del Sacro Cuore

2002-2006

HEMP SYS (Design, development and up-scaling of a sustainable production system for hemp textiles: an integrated quality systems approach)

Researcher - University of Piacenza

2012-2017

MULTIHEMP (Multipurpose hemp for industrial bioproducts and biomass)

Ass. Prof .- University of Piacenza

2017-2022

GRACE (GRowing Advanced industrial Crops on marginal lands for biorEfineries)

SSUCHY (Sustaible Structural and multifunctional biocomposites from hybrid natural fibres and bio-based polymers)

Full Prof .- University of Piacenza

2020-2022

Multicanapa (PSR Emilia Romagna)

1999-2000

Multi-use Industrial Crops for Quality Raw Materials

Post Doc - University of Wageningen

2000-2004

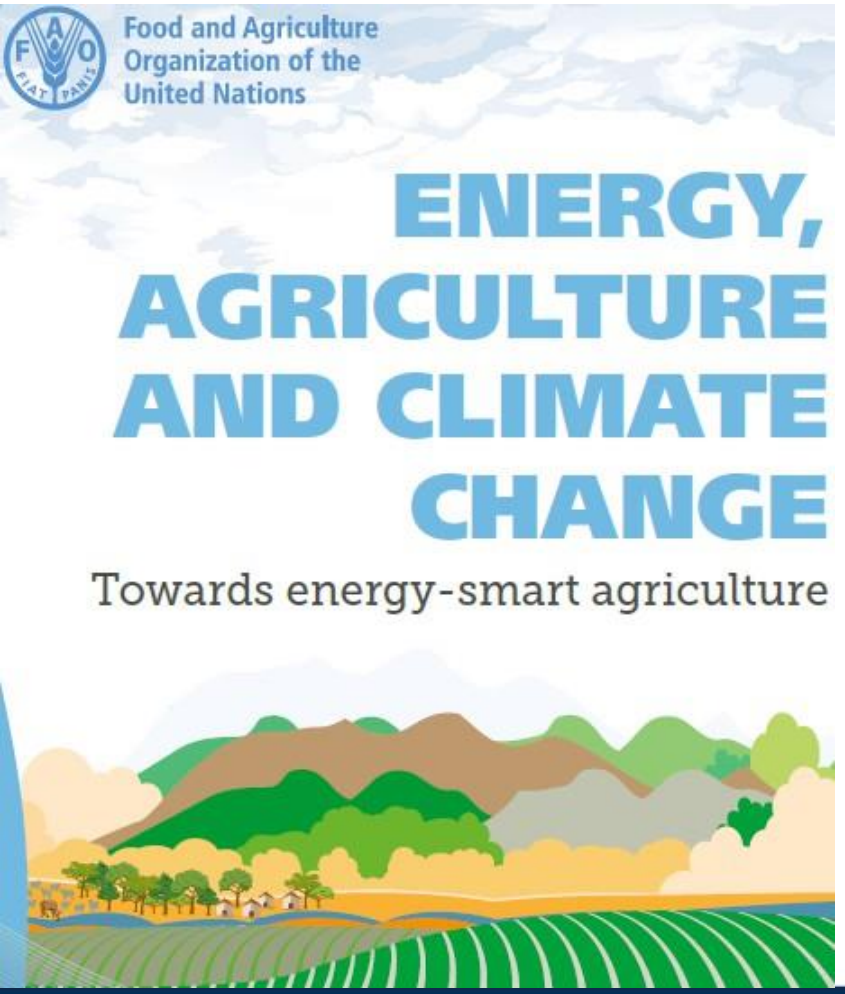
HARMONIA (Hemp as Raw Material for Novel Industrial Applications)

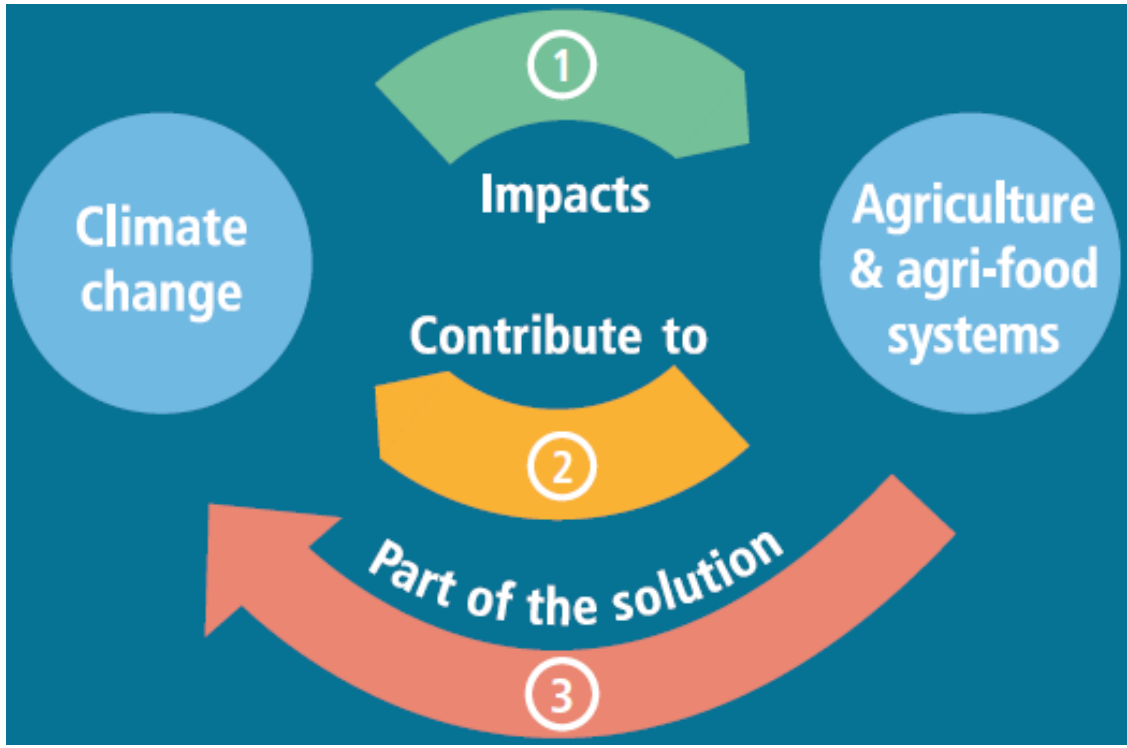
1996-1998

HEMP (Hemp for Europe Manufacturing and Production systems)

PhD - University of Bologna

Hemp phenology and possible impact of climate change on its cultivation





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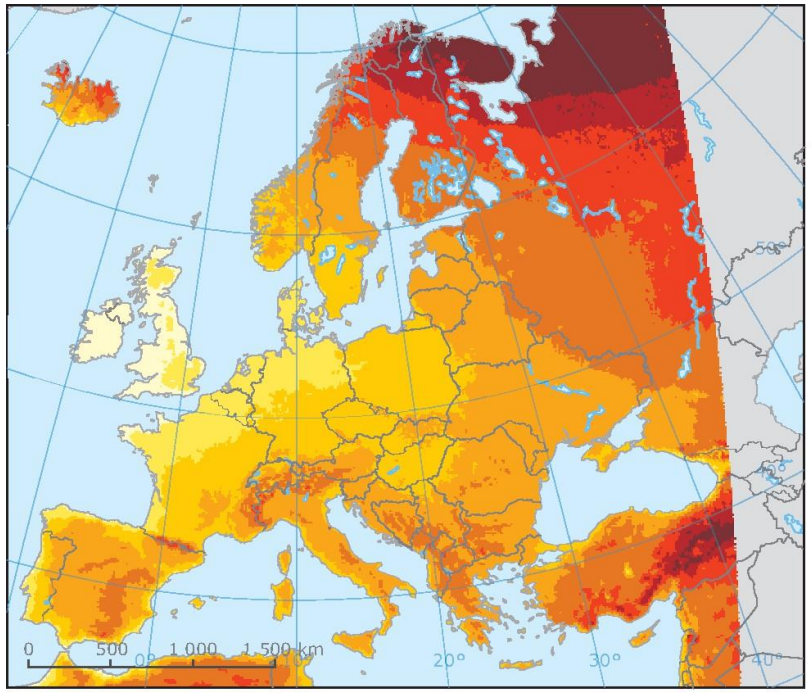
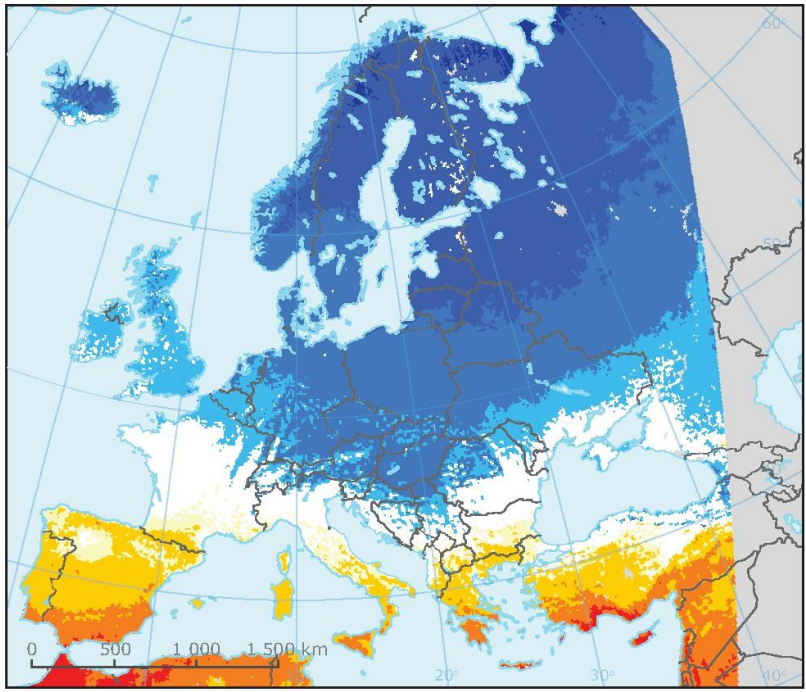
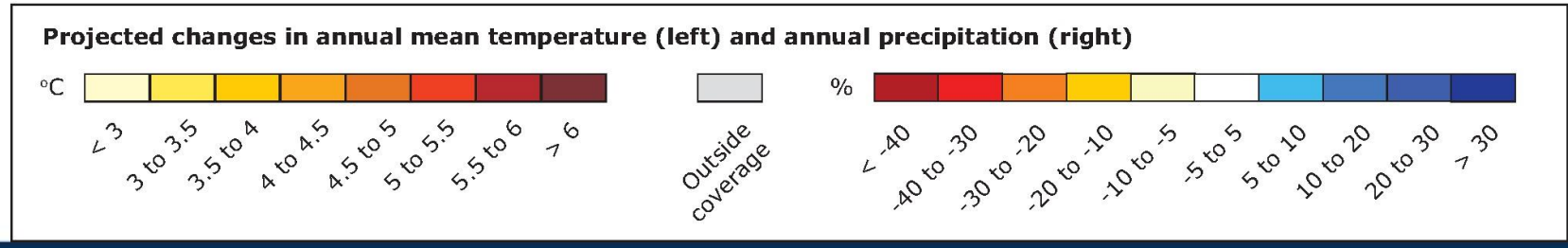
Climate change and hemp





Climate change projections for Europe based on an ensemble of regional climate model simulations provided by the EURO-CORDEX initiative



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Climate change impacts

- ✓ Raise global surface T° 2.6-4.8°C by 2100
- ✓ Increase of evapotranspiration
- ✓ Rainfall pattern, frost-free days
- ✓ Increased frequency of extreme events

- ✓ Crop yield
- ✓ Suitability of crops
- ✓ Insects (pollinators), weeds, and diseases
- ✓ Soil microbe relations
- ✓ C and Nutrients cycles
- ✓ Suitability of agricultural practices

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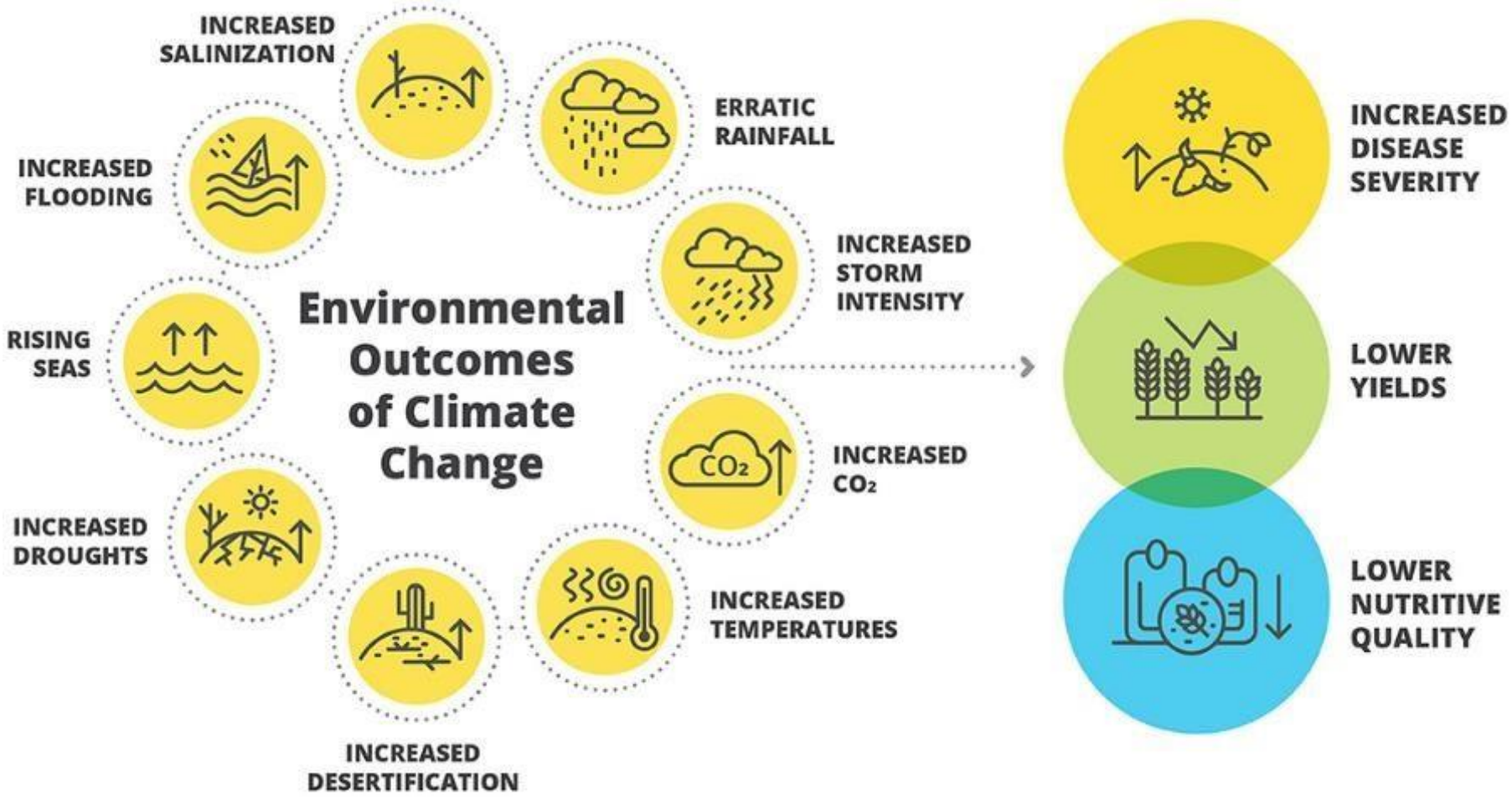
Climate change impacts



Karavolias et al, 2021 doi.org/10.3389/fsufs.2021.685801

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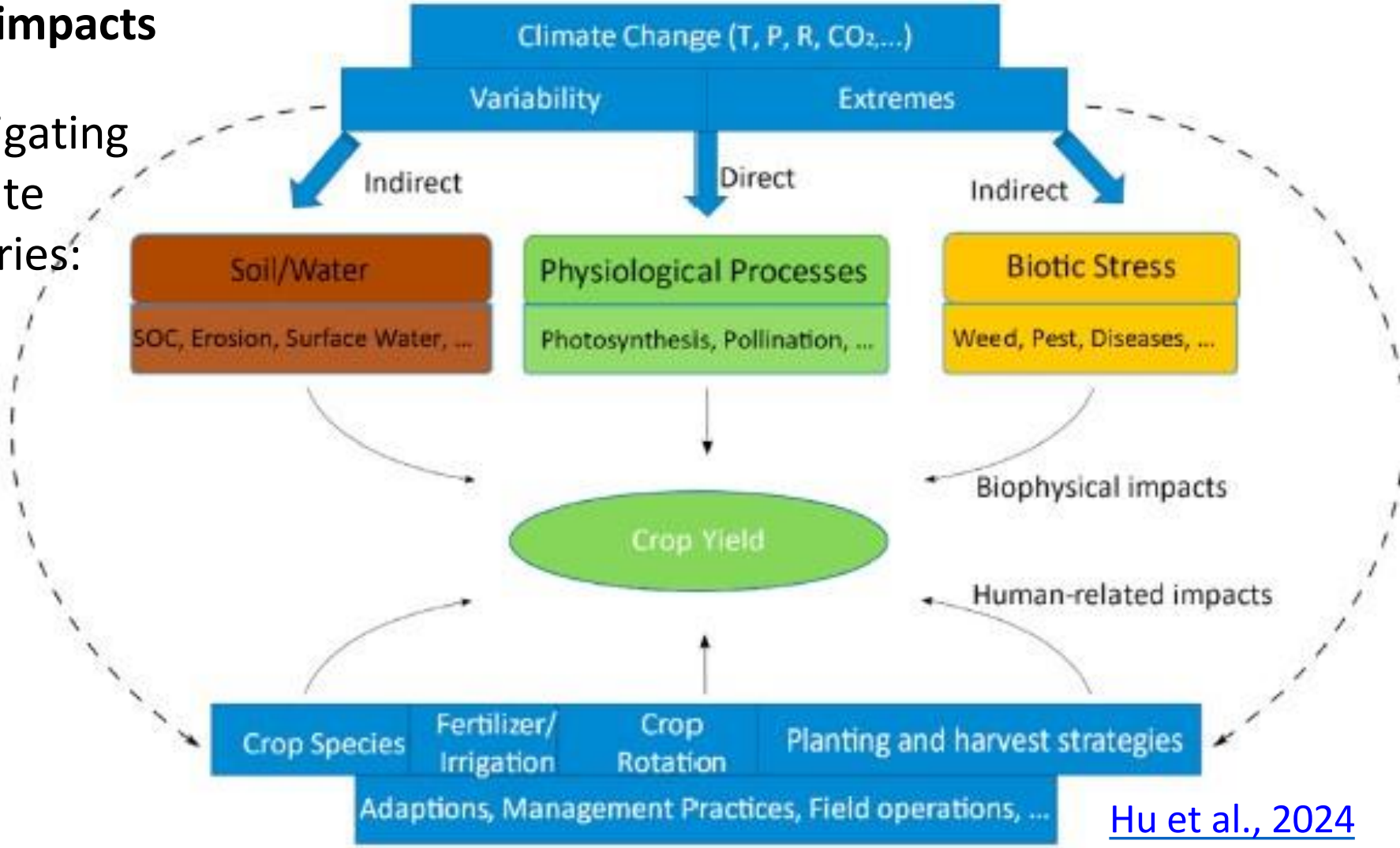
Climate change impacts

Scientific methods for investigating crop yield responses to climate change fall into three categories:

- Field experiments;
- Process-based modeling;
- Statistical modeling



Hu et al., 2024

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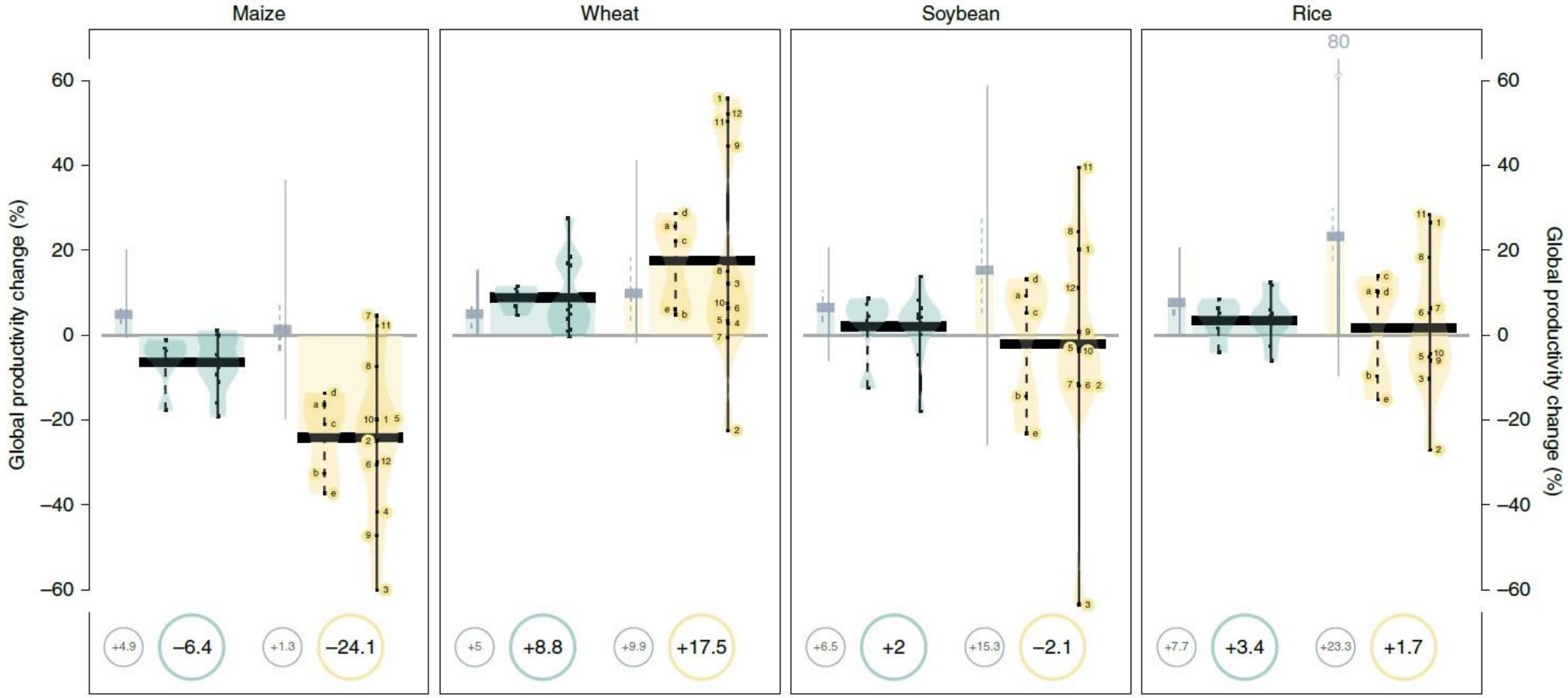
Climate change impacts



Jägermeyr et al, 2021 doi.org/10.1038/s43016-021-00400-y

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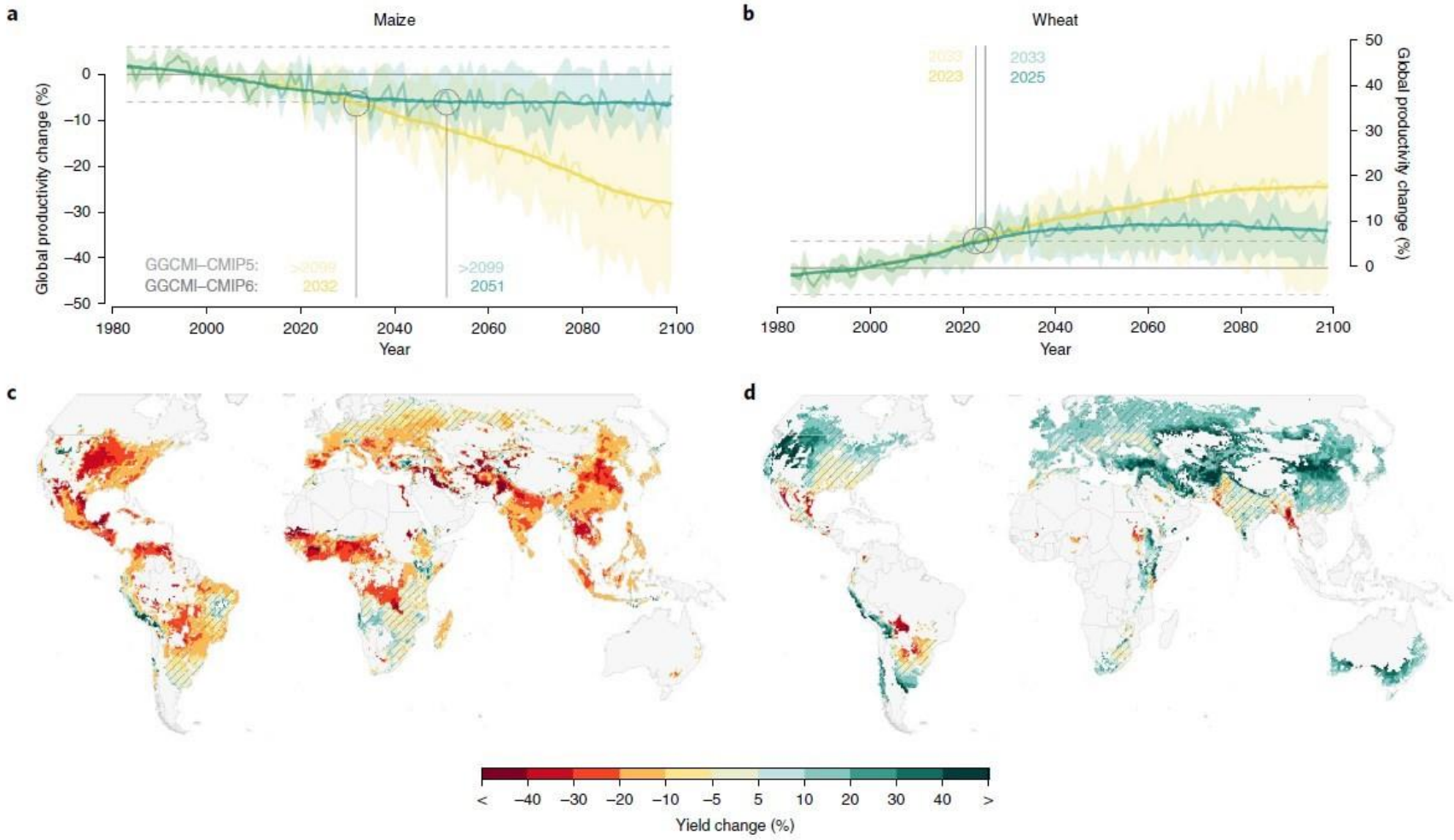
Climate change impacts



Jägermeyr et al, 2021 doi.org/10.1038/s43016-021-00400-y

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Adaptation

- ✓ Cultivars and breed improvements
- ✓ Changing management practices (e.g. sowing time)
- ✓ Switching crops, breeds, and farming systems
- ✓ Managing water
- ✓ Diversifying agricultural systems

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Impact of agriculture on climate change

- ✓ Greenhouse gas (GHG) emissions from agriculture 13–21% in 2010-2019
- ✓ The agricultural sector is the largest contributor of non-carbon GHGs, such as CH_4 and N_2O

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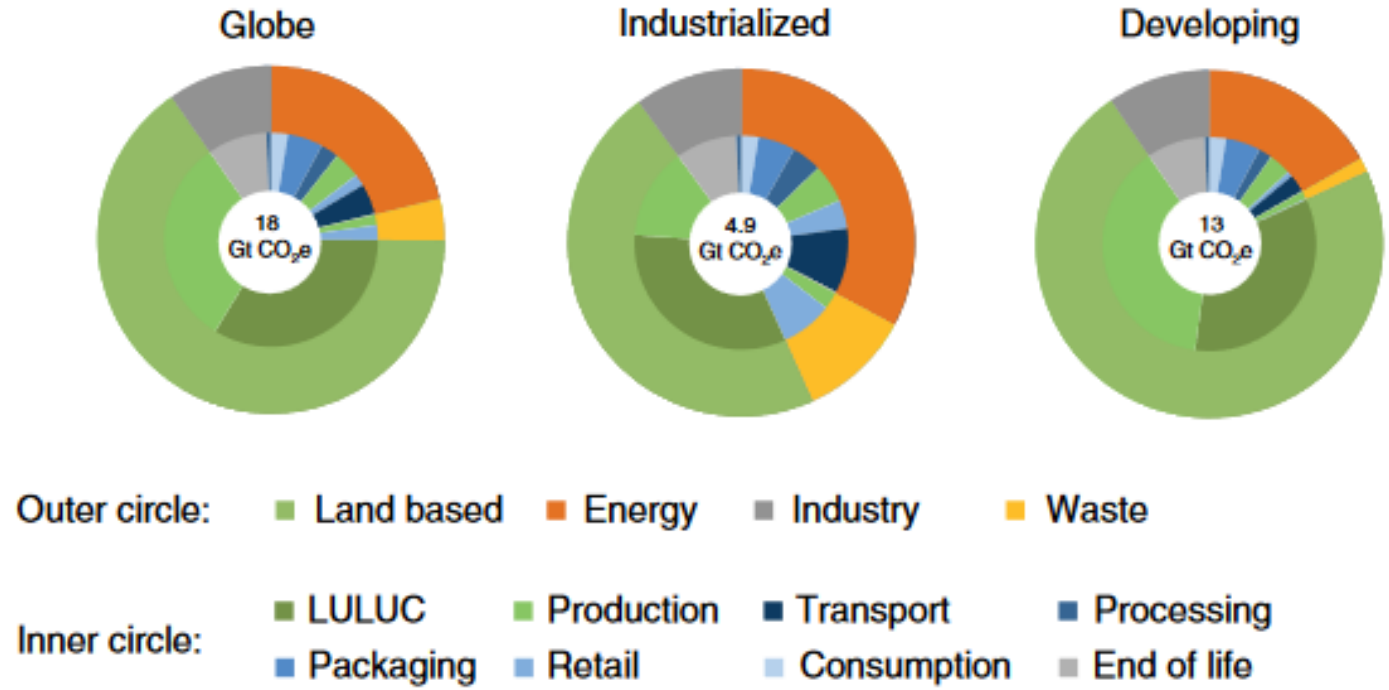

Fig. 1 | GHG emissions from the food system in different sectors in 2015. Total GHG emissions (including CO_2, CH_4, N_2O and F-gases) are expressed as CO_2e calculated using the GWP100 values used in the IPCC AR5, with a value of 28 for CH_4 and 265 for N_2O.

In 2015, food-system emissions amounted to 18 Gt CO2 equivalent per year globally, representing 34% of total GHG emissions, 71% of which (**24%** on global GHG emissions) from agriculture and LULUC activities

2021 Crippa et al. Nature Food https://doi.org/10.1038/s43016-021-00225-9

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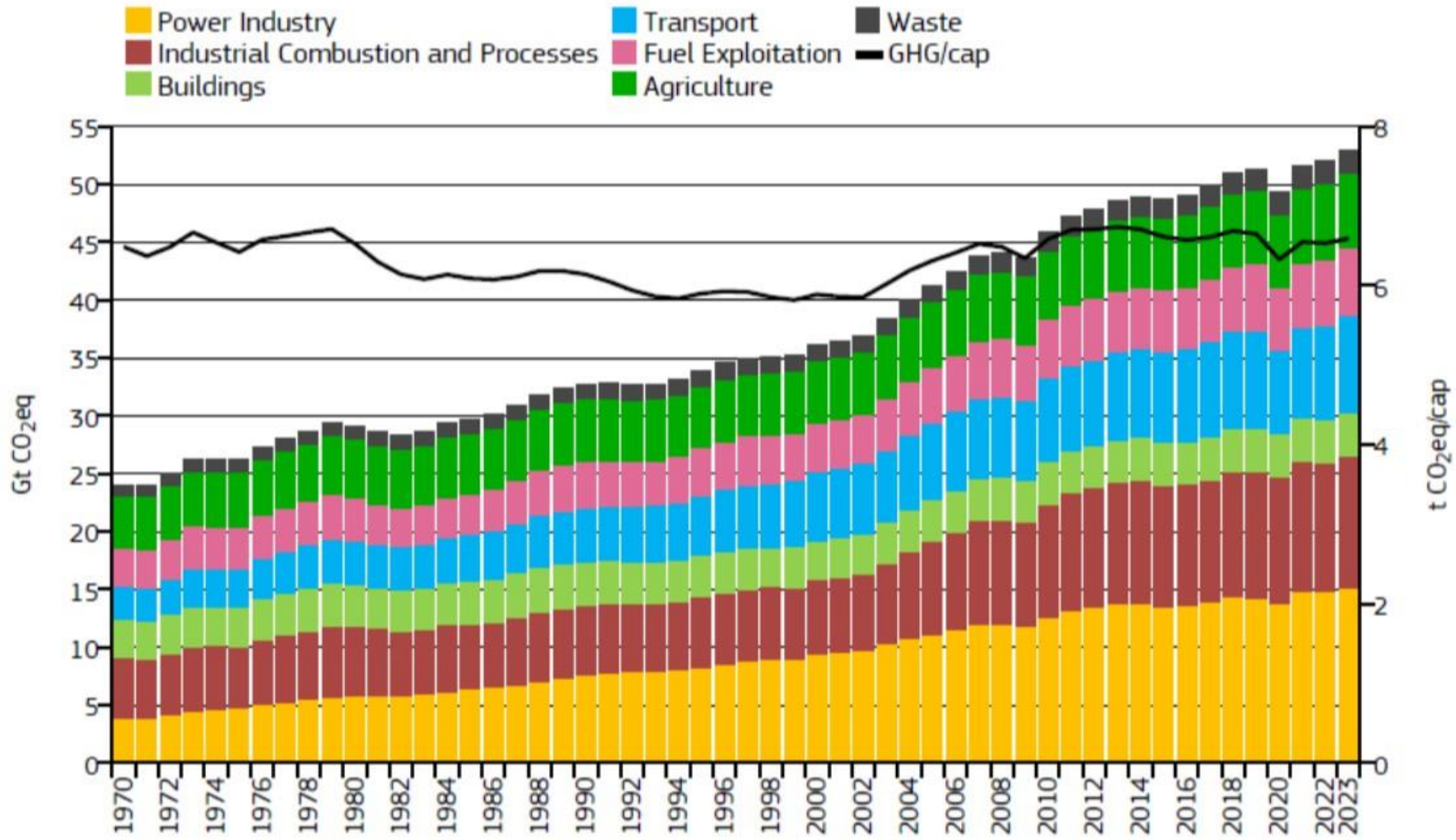

Global GHG emissions by sector (left axis, bars) and per capita (right axis, black line), 1970-2023

https://data.europa.eu/doi/10.2760/4002897, JRC138862

Source: JRC, 2024

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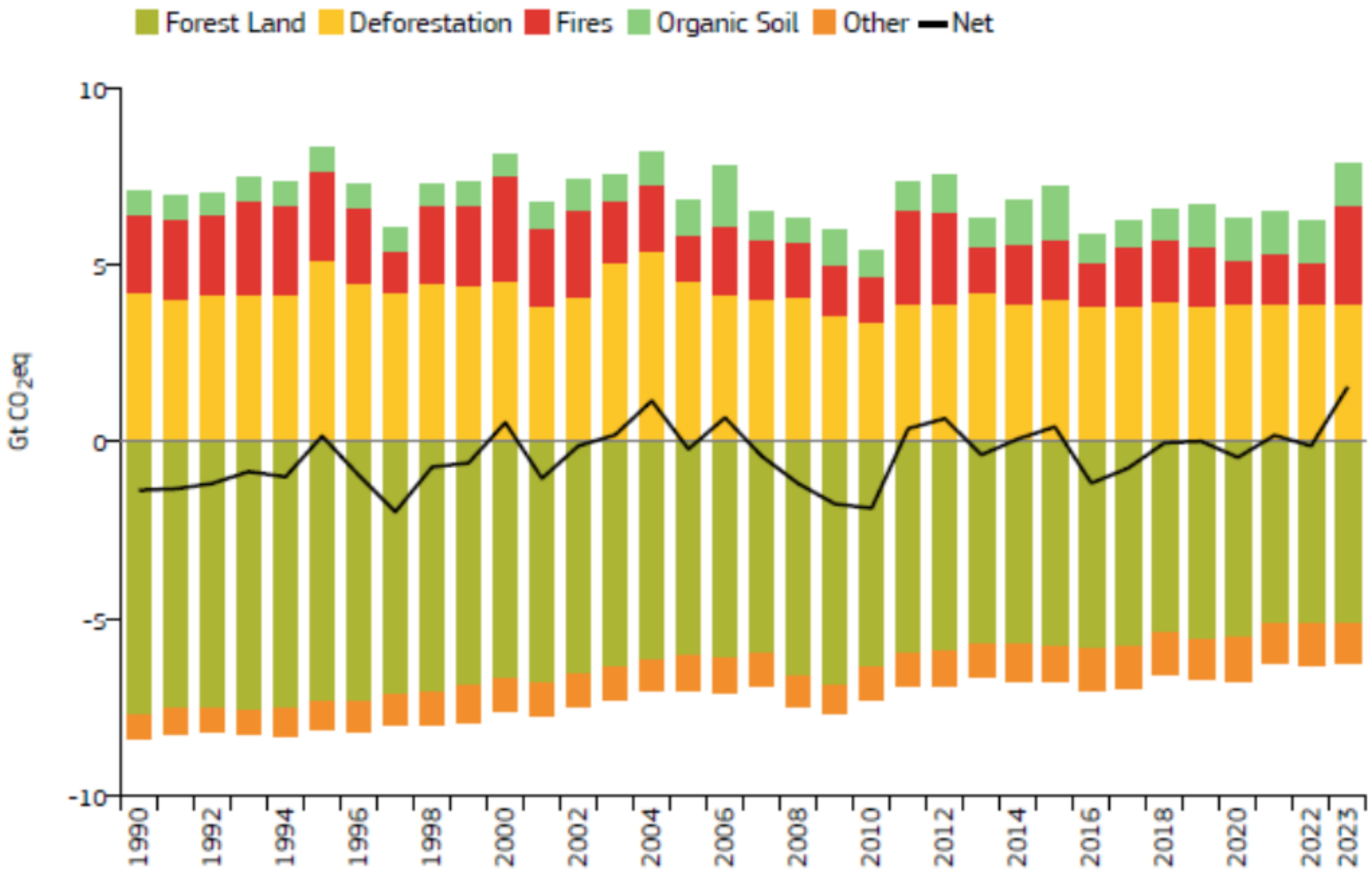
Global GHG emissions and removals from LULUCF sector (in Gt CO2eq), 1990-2023



Source: JRC, 2024

https://data.europa.eu/doi/10.2760/4002897

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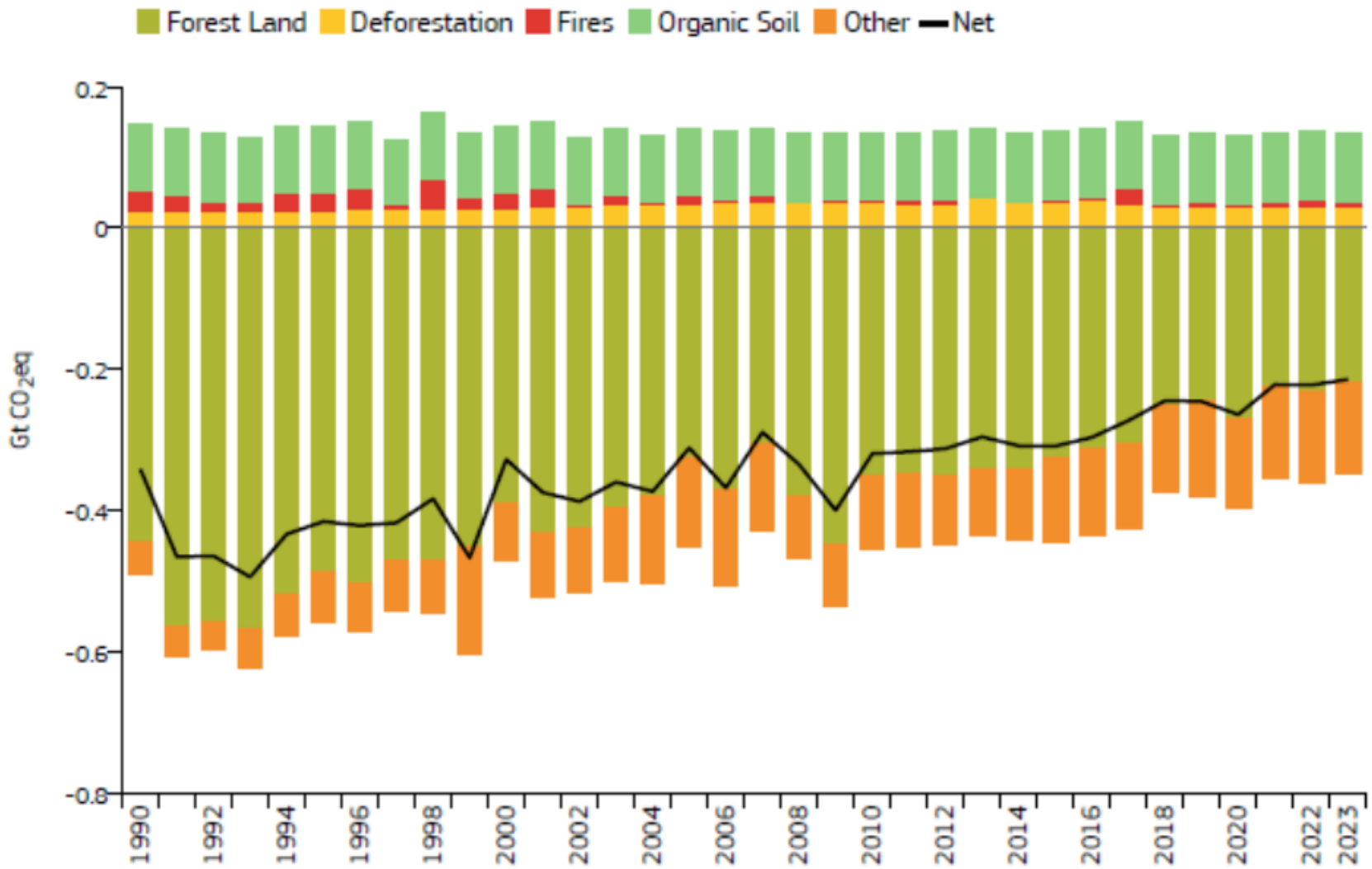
EU27 GHG emissions and removals from LULUCF sector (in Gt CO2 eq), 1990-2023



https://data.europa.eu/doi/10.2760/400

Source: JRC, 2024

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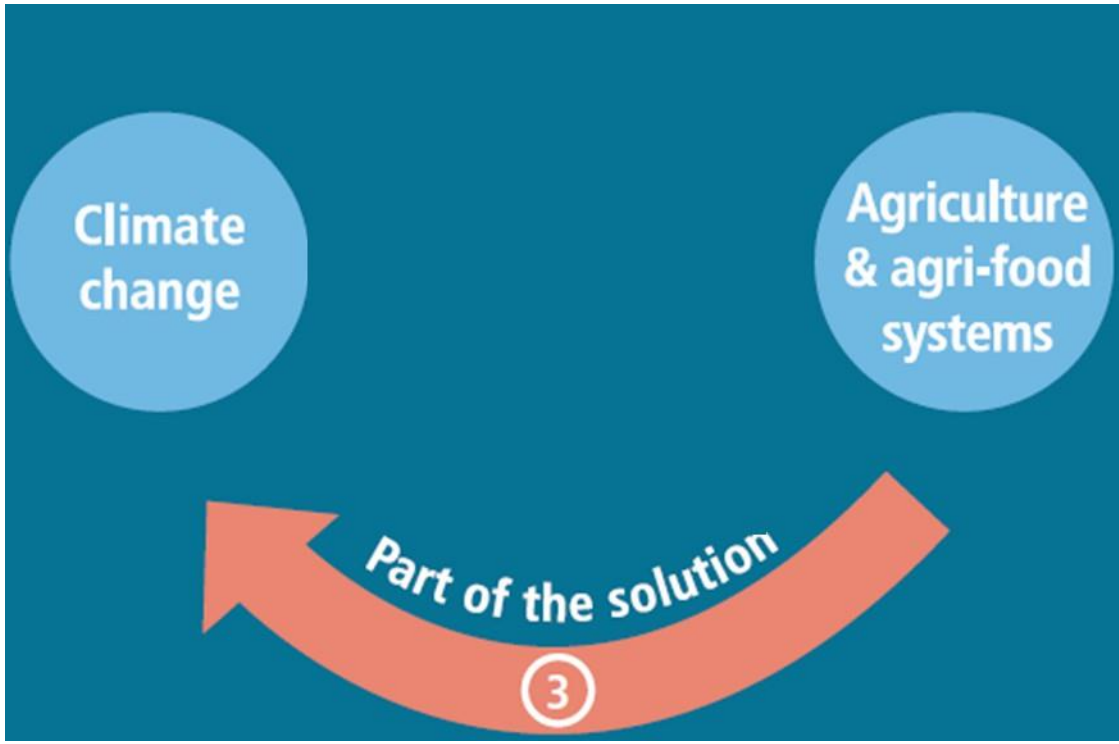
Mitigation option in agriculture

- ✓ Ferilizer use
- ✓ Soil management
- ✓ Residue management
- ✓ Water management (paddy rice)
- ✓ Animal husbandry/manure management

- ✓ Increase Soil Organic Matter
- ✓ Restoration of organic and degraded soils
- ✓ Set-aside, LUC, agro-forestry



Smith et al., 2007 IPCC

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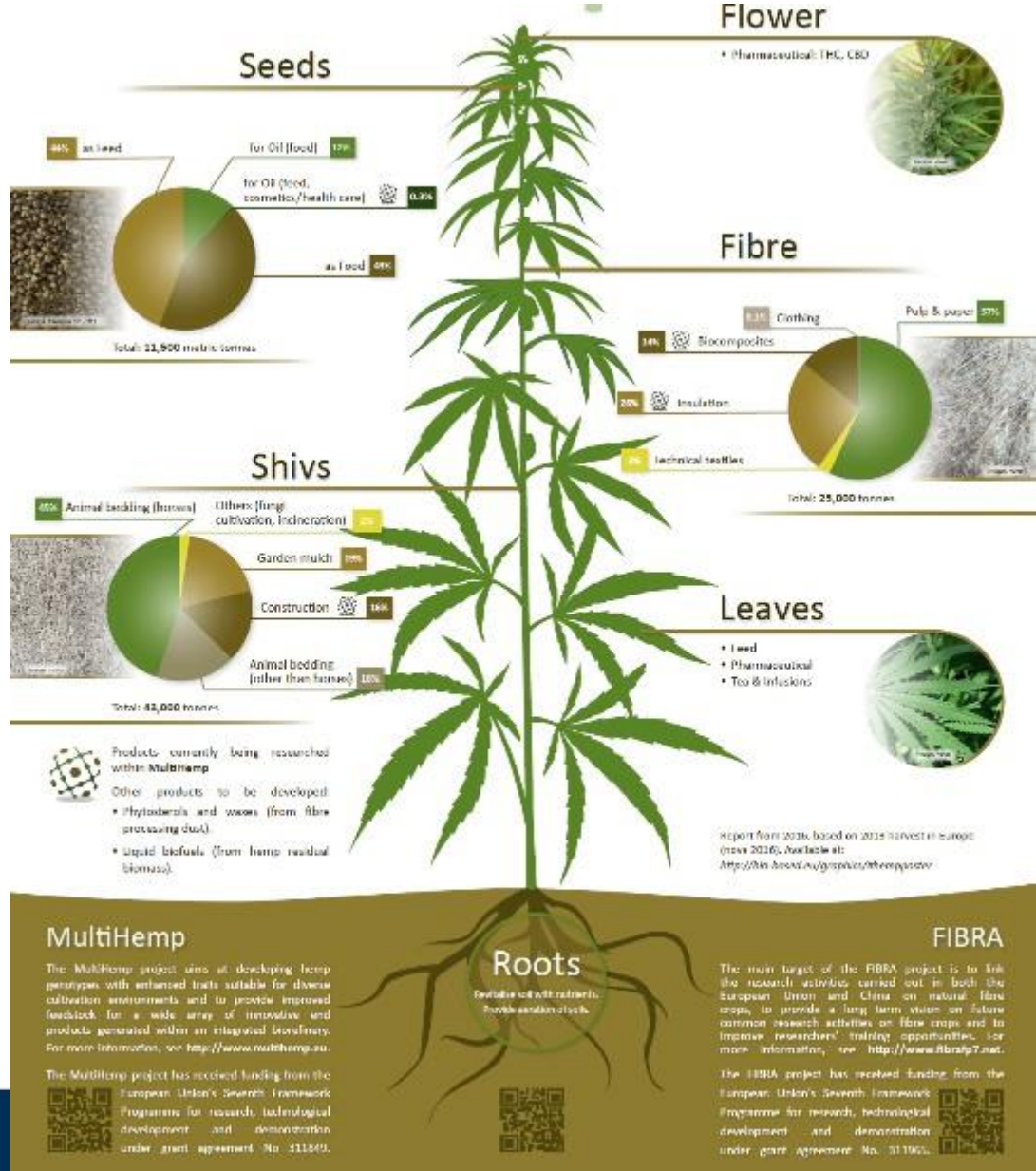
Mitigation option with hemp

- ✓ Bio-materials (C sink)
- ✓ Bioenergy
- ✓ Carbon Farming (C sink)

Is GHG mitigation with hemp cost competitive?

Does hemp offer other ecosystem services/ co-benefit?



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Climate change and hemp

- ✓ Temperature change

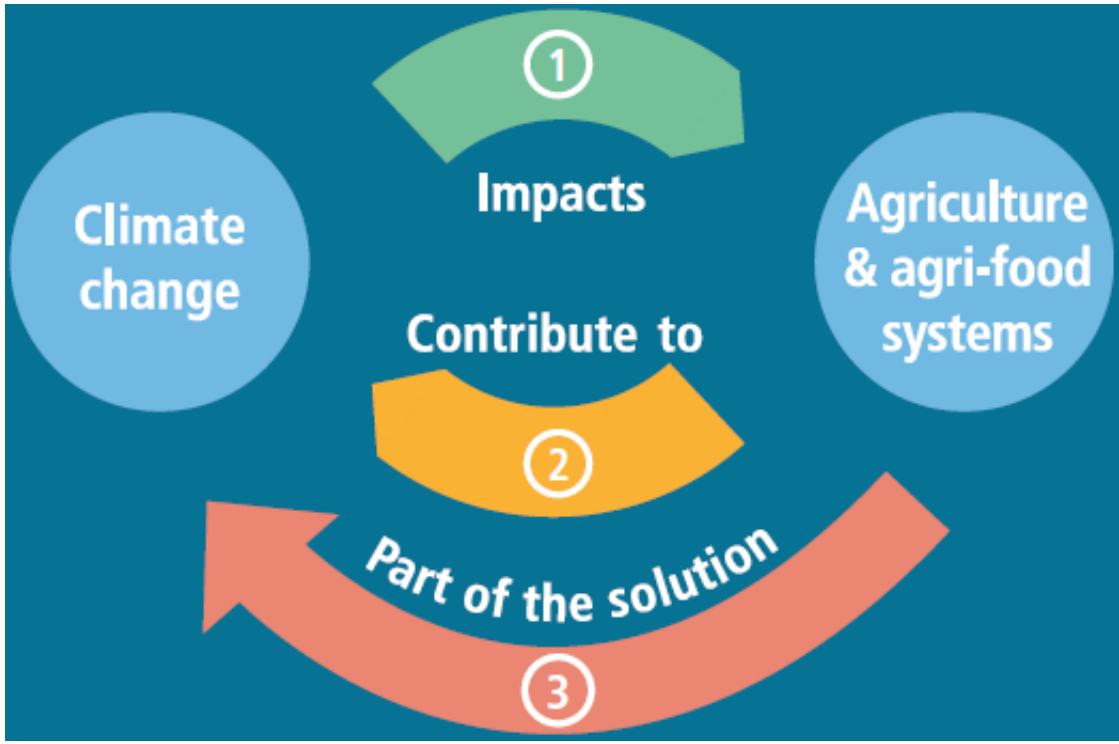
  Photosynthesis, Phenology

- ✓ Extreme climatic events

  Lodging, water logging, anoxia

- ✓ Water stress (drought, High VPD)

  Lower yield



Key role in mitigation

- *High nitrogen use efficiency*
- *C carbon capture in biomaterials*
- *Cultivation in marginal environment*

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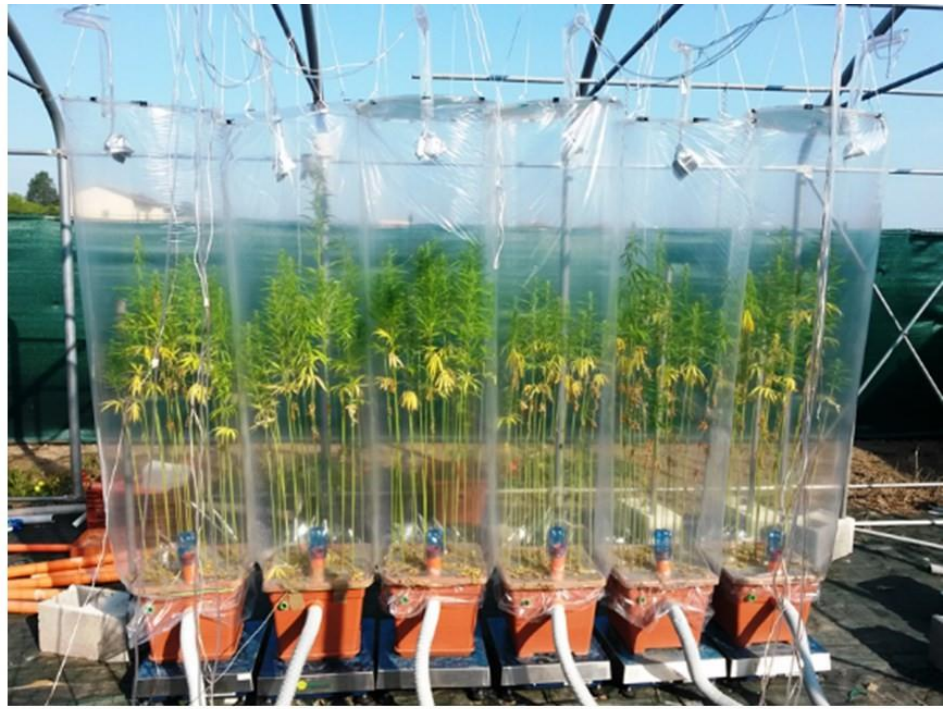

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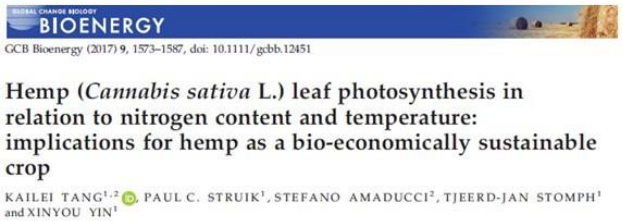
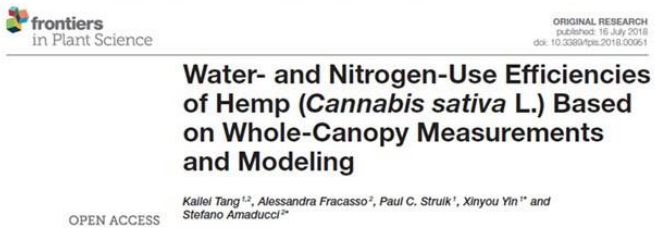


BIOENERGY

GCB Bioenergy (2017) 9, 1573–1587, doi: 10.1111/gcbb.12451

Hemp (*Cannabis sativa* L.) leaf photosynthesis in relation to nitrogen content and temperature: implications for hemp as a bio-economically sustainable crop

KAILEI TANG[1,2], PAUL C. STRUIK[1], STEFANO AMADUCCI[2], TJEERD-JAN STOMPH[1] and XINYOU YIN[1]



frontiers in Plant Science

ORIGINAL RESEARCH published: 16 July 2018 doi: 10.3389/fpls.2018.00951

Water- and Nitrogen-Use Efficiencies of Hemp (*Cannabis sativa* L.) Based on Whole-Canopy Measurements and Modeling

OPEN ACCESS

Kailei Tang[1,2], Alessandra Fracasso[2], Paul C. Struik[1], Xinyou Yin[1] and Stefano Amaducci[2]*

MultiHemp

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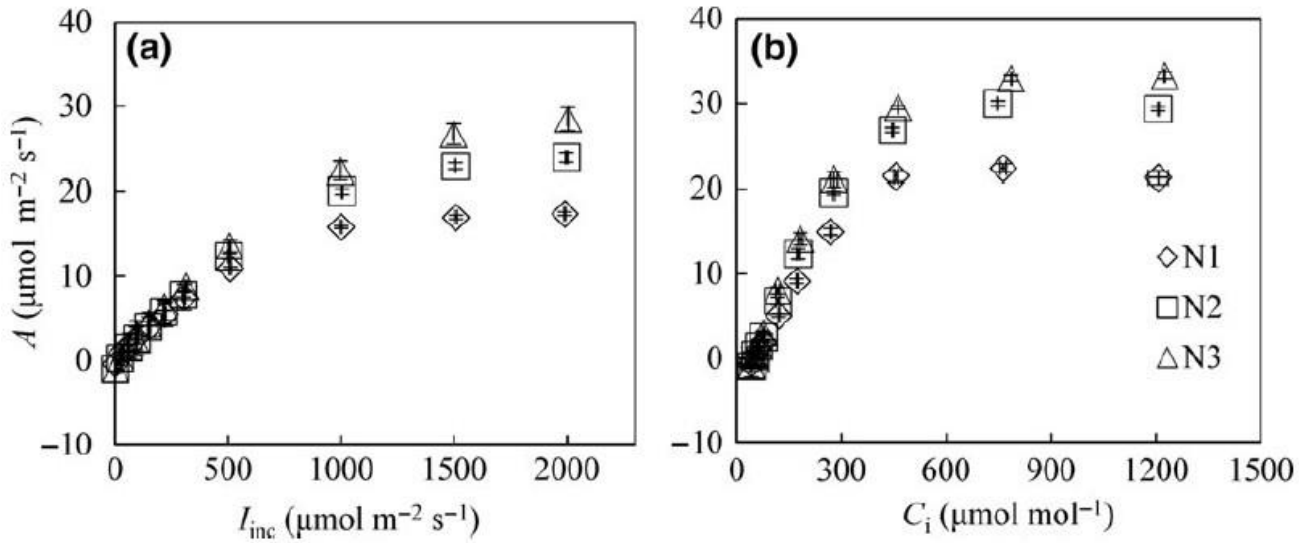

Tang et al., 2017 doi: 10.1111/gcbb.12451

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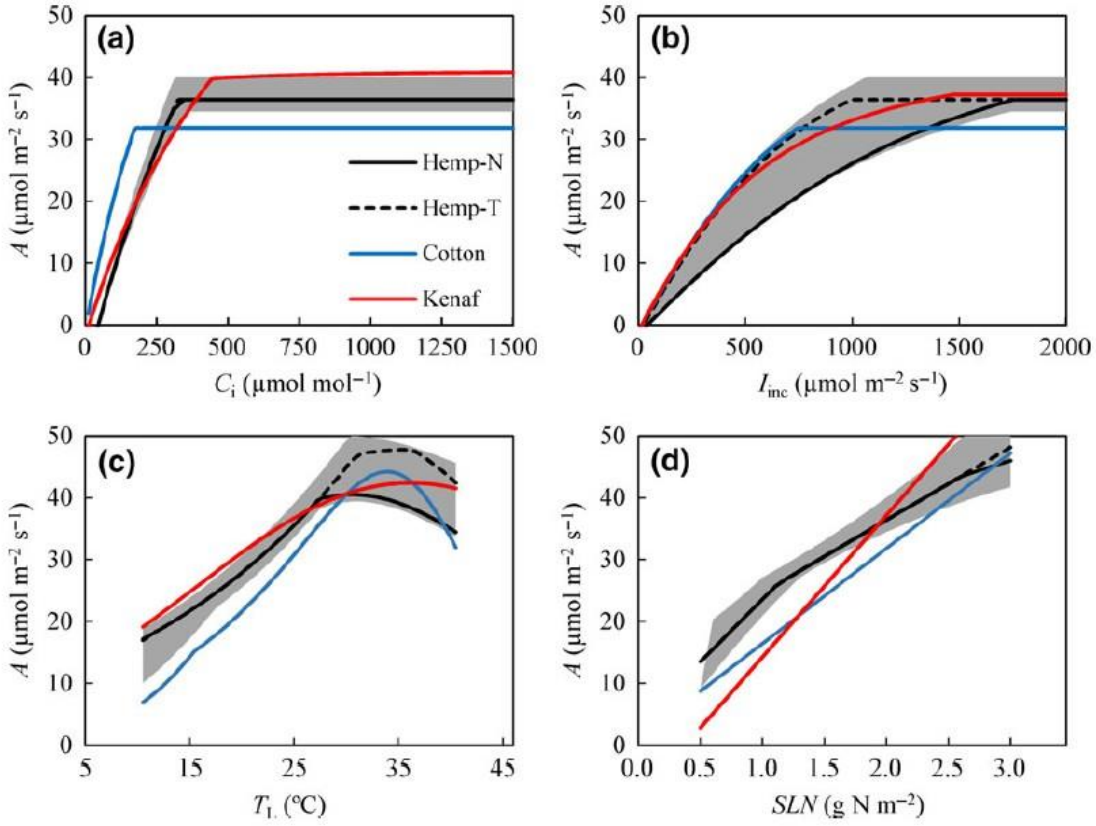
Compared with cotton and kenaf, hemp has higher photosynthetic capacity when leaf nitrogen is <2.0 g N m^2



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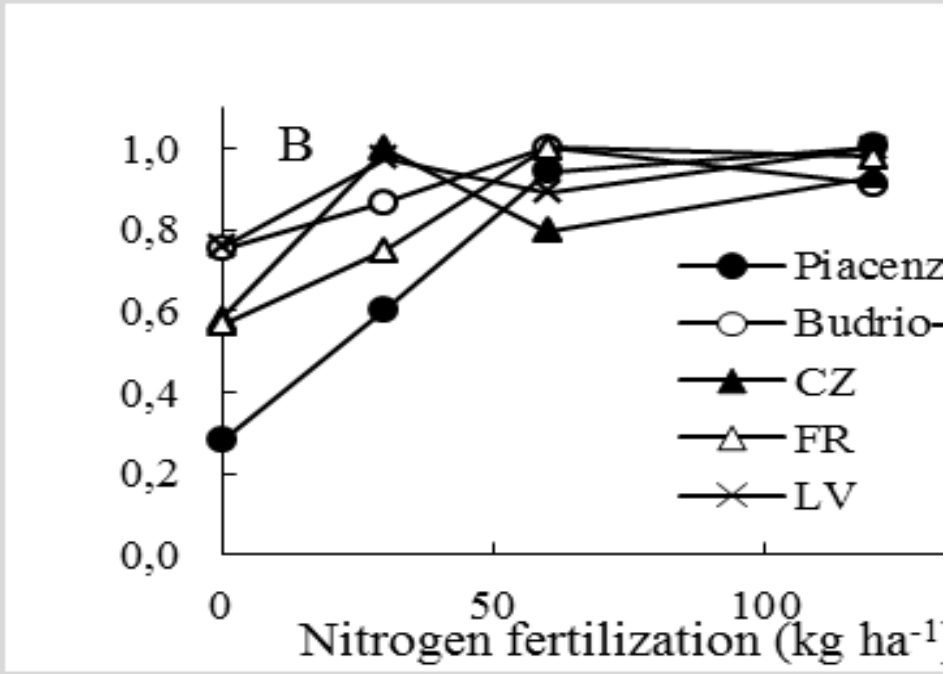
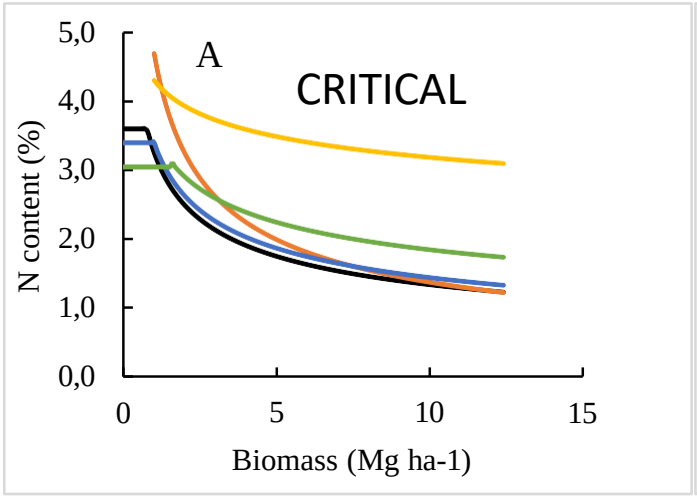
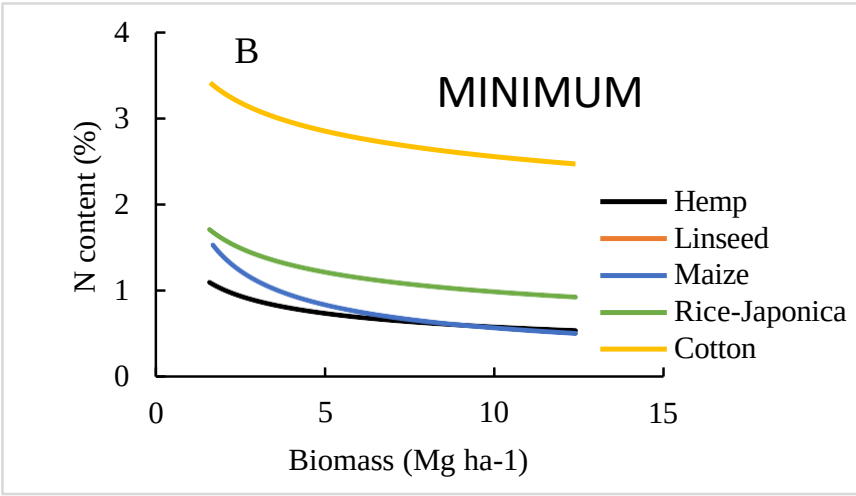


Nitrogen effect depends on the soil fertility but no effect over **60 kg ha^{-1}**





Comparison of hemp nitrogen dilution curve with that other crops

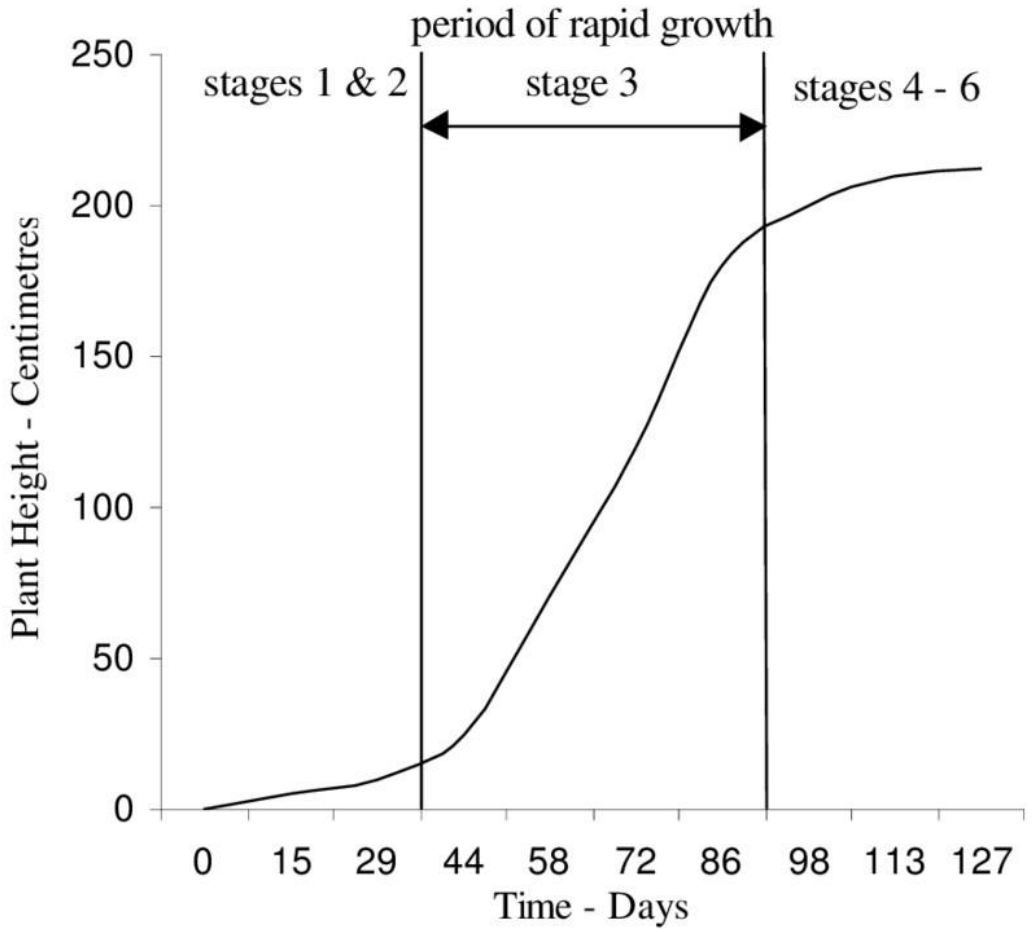
Contents lists available at ScienceDirect
Industrial Crops & Products
journal homepage: www.elsevier.com/locate/indcrop

A comprehensive study of planting density and nitrogen fertilization effect on dual-purpose hemp (*Cannabis sativa* L.) cultivation

K. Tang[a,b], P.C. Struik[b], X. Yin[b], D. Calzolari[a], S. Musio[a], C. Thouminot[c], M. Bjelková[d], V. Stramkale[e], G. Magagnini[f], S. Amaducci[a,*]

Hemp phenology and possible impact of climate change on its cultivation

Growth cycle of hemp (Bócsa & Karus 1998)



Emergence - Canopy closure

Factors affecting this phase

- Soil conditions
- Soil humidity and temperature
- Air temperature
- Rainfall

- Genotype
- Planting density
- Seed quality

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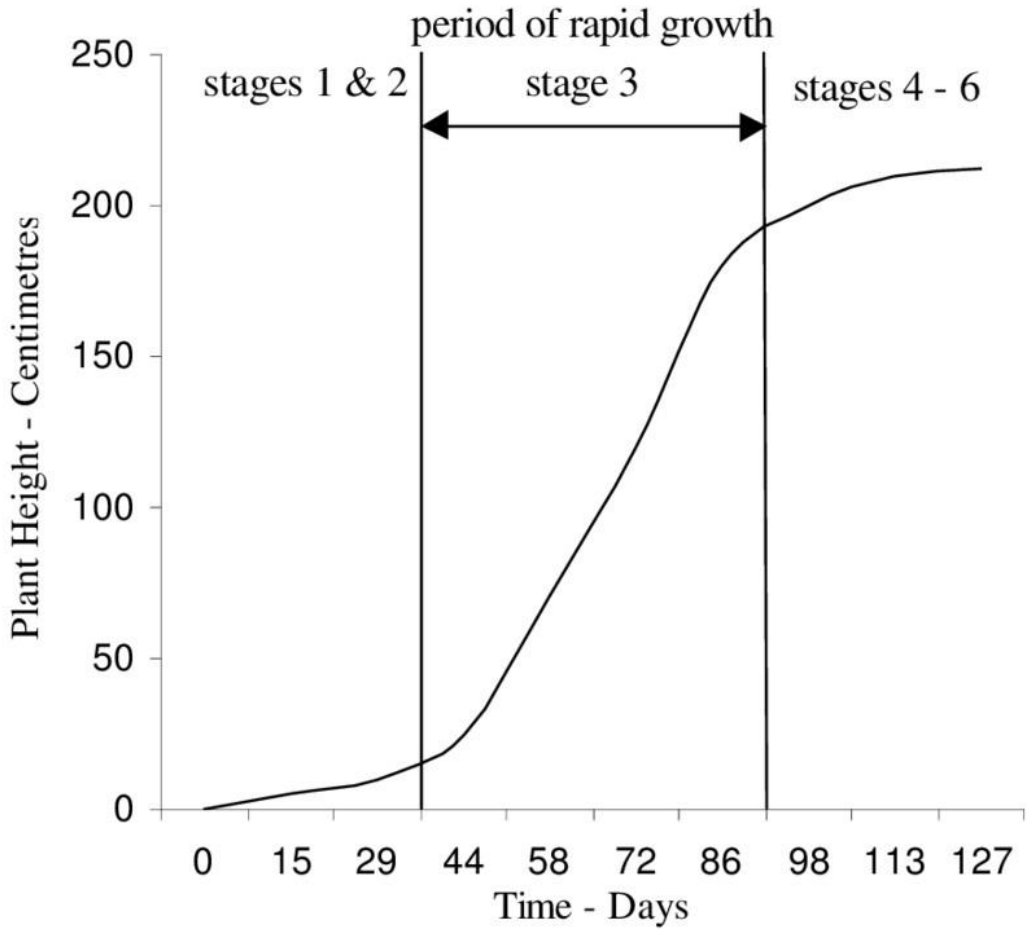

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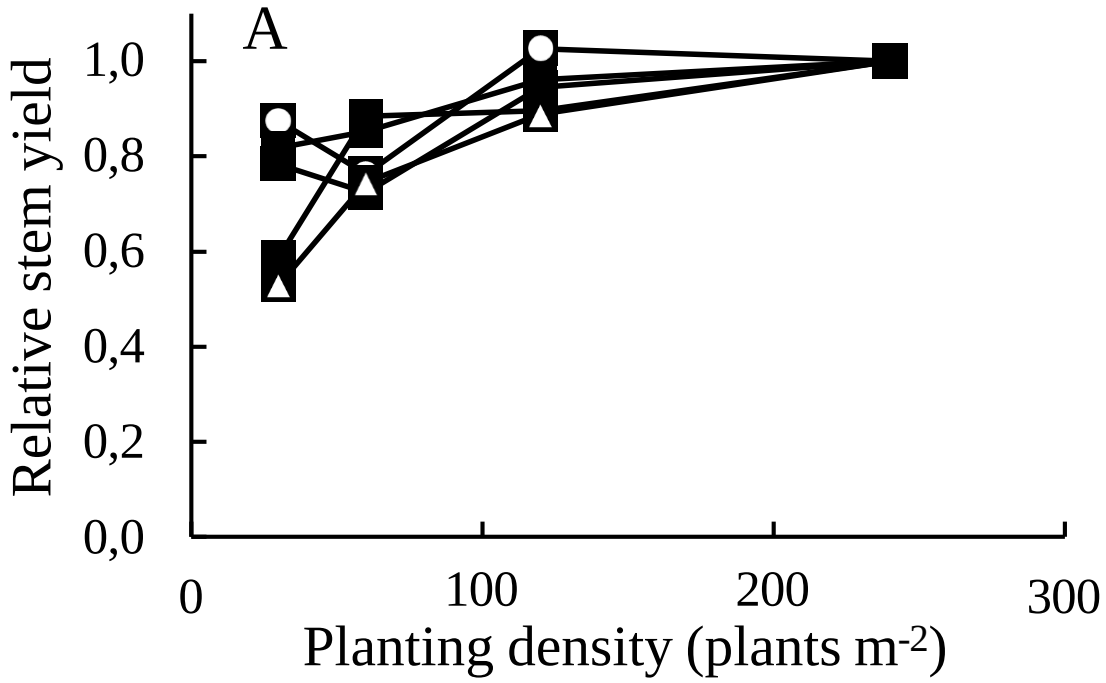
Planting density affects stem and fibre yield

Fibre production 90-200 plants m^{-2}

Seed production 30 - 75 plants m^{-2}

Dual-purpose **90-150** plants m^{-2}

D45 D90 D180



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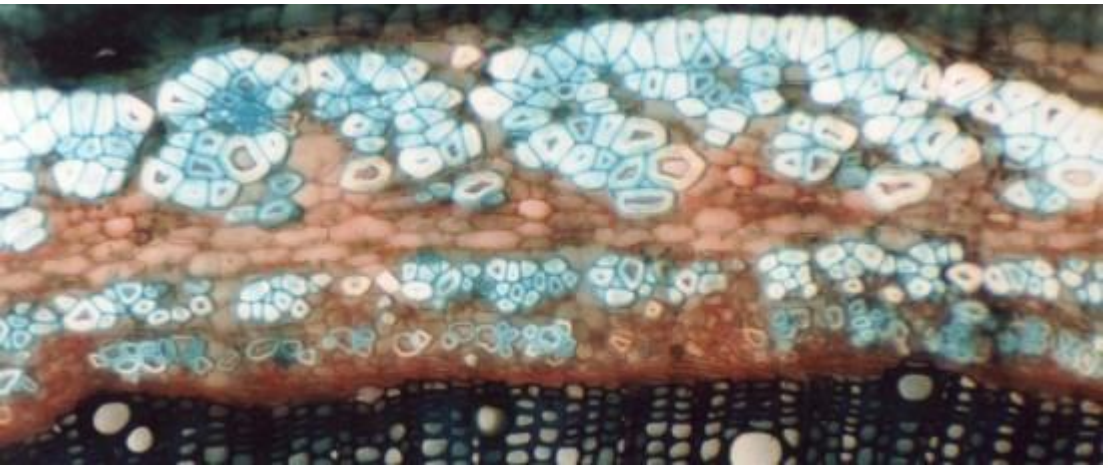
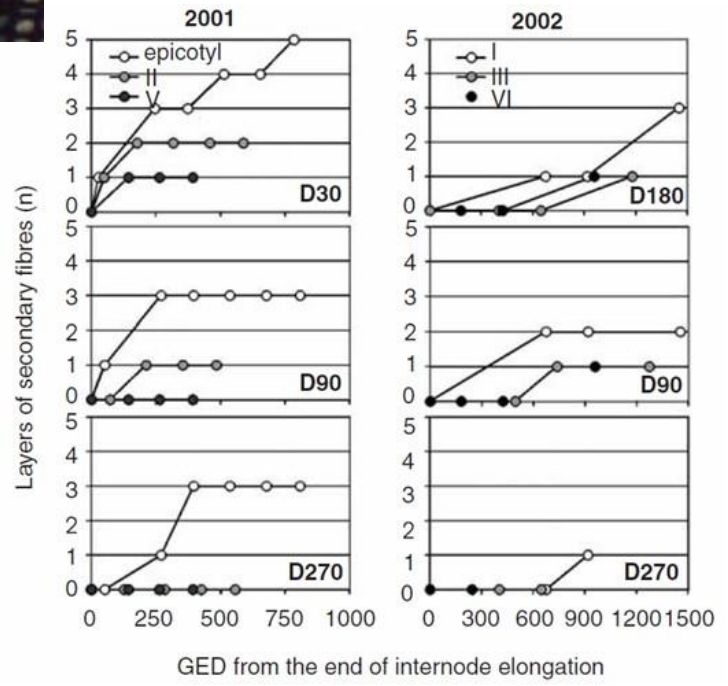


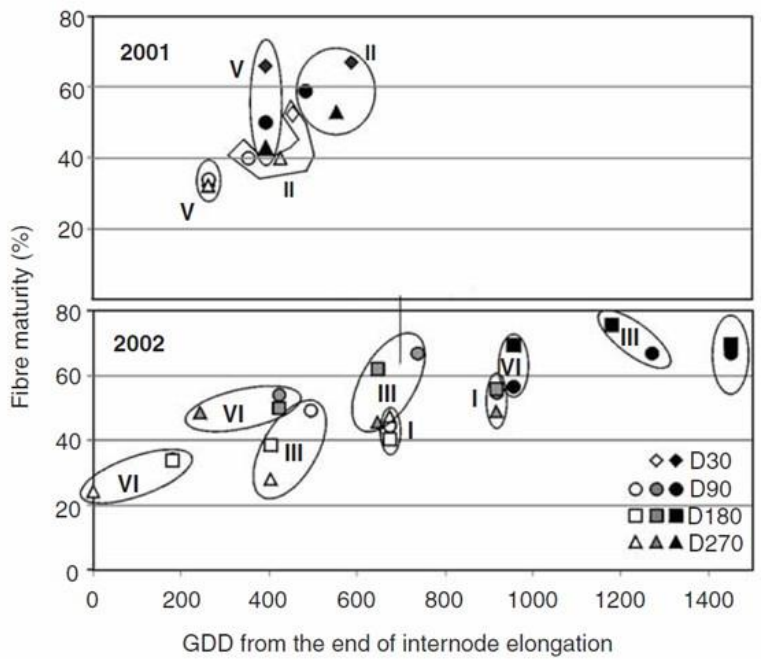
Planting density affects stem and fibre yield

…and fibre quality

TABLE 4. Average diameter (μm) and standard errors of primary fibres at internodes I, III and VI at the three stages of flowering (74, 85 and 107 DAS) and at three plant densities (90, 180 and 270 plants m^{-2}) in 2002.

		I		III		VI	
Density	DAS	Mean	sd	Mean	sd	Mean	sd
90	74	25.4	7.9	32.3	11.3	22.4	5.4
	85	40.6	9.2	29.1	7.2	23.0	5.2
	107	37.6	7.7	35.6	6.1	29.7	6.3
180	74	36.4	7.0	21.1	5.1	23.6	4.9
	85	32.2	7.8	26.2	5.7	18.7	4.8
	107	35.5	10.1	26.7	3.8	24.6	5.4
270	74	26.8	7.6	23.6	6.1	18.8	3.9
	85	31.4	11.2	23.4	6.1	17.1	2.0





Amaducci, S. et al., 2005. Journal of Industrial Hemp, Vol. 10 (1), 31-48.

Amaducci, S. et al, 2008. Field crops Research, 107,161-169.

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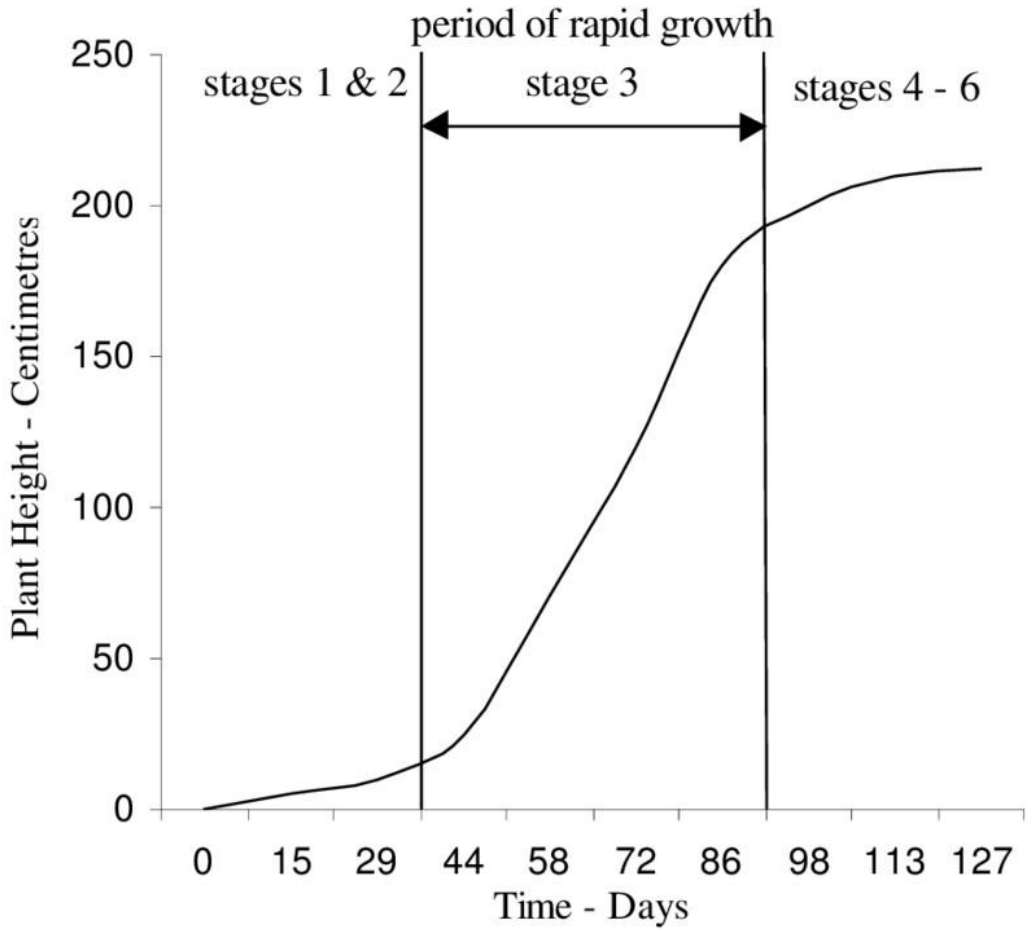

Elongation

Factors affecting this phase

- Soil humidity / rainfall
- Air temperature
- Photoperiod
- Wind/lodging
- Nutrition

- Genotype

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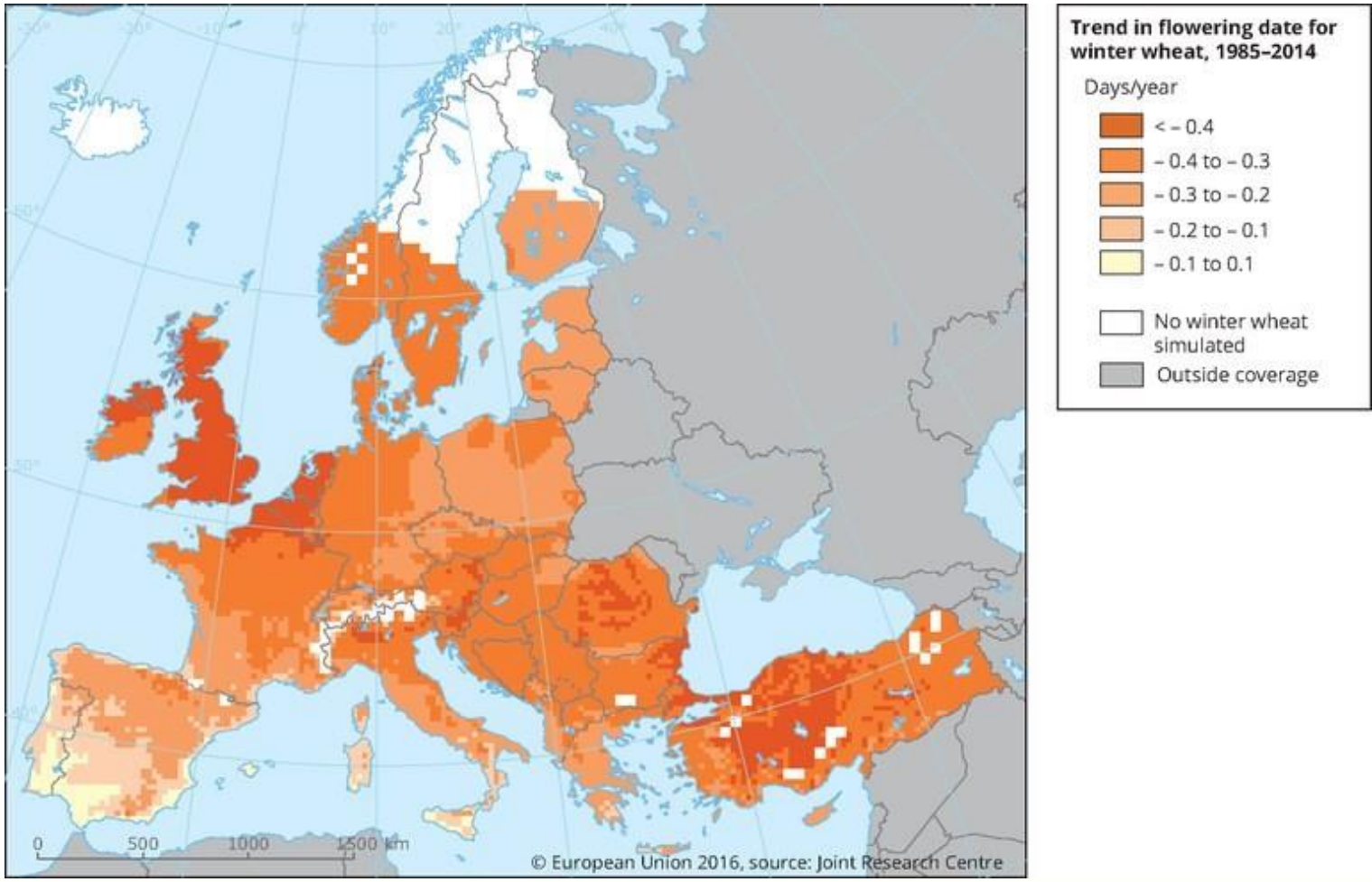
Effect of climate change on crop phenology

- Flowering of several crops has advanced by about two days per decade during the last 50 years.
- Changes in crop phenology are affecting crop production.
- Shortening of the growth phases of many crops is expected to continue (this may be altered by breeding and changing planting dates)

Rate of change of the flowering date for winter wheat



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Environmental control of hemp phenology is extreme!

Latvia

Italy

Finola

MultiHemp

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Industrial Crops and Products 87 (2016) 33–44

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Industrial Crops and Products

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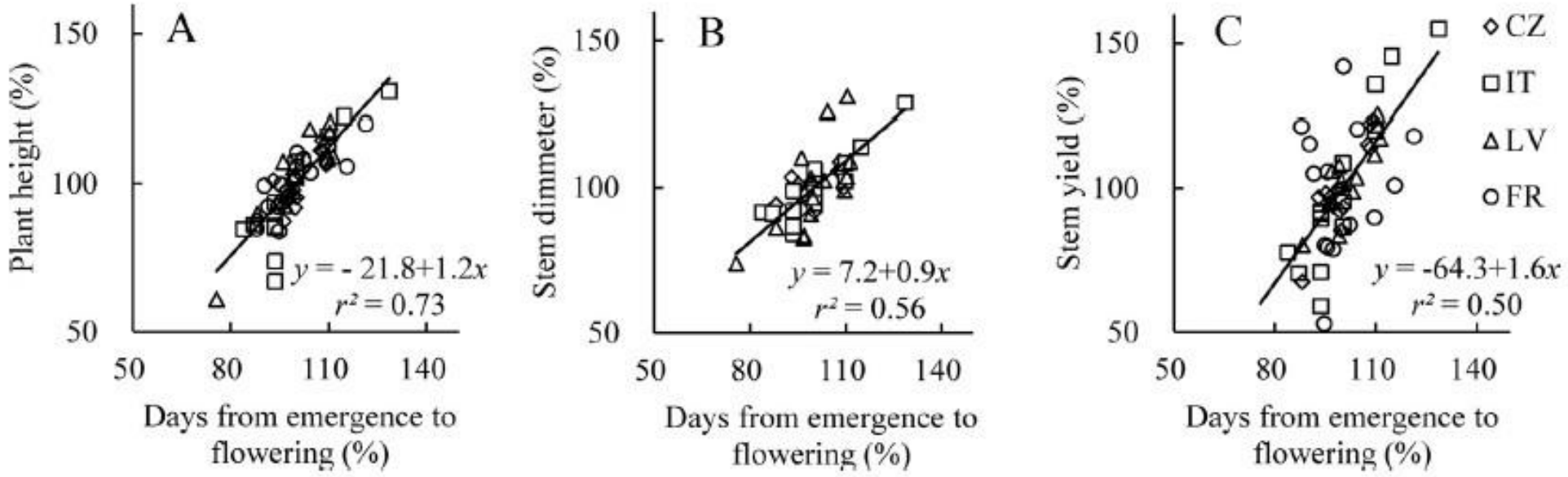
Comparing hemp (*Cannabis sativa* L.) cultivars for dual-purpose production under contrasting environments

K. Tang[a,b], P.C. Struik[a], X. Yin[a], C. Thouminot[c], M. Bjelková[d], V. Stramkale[e], S. Amaducci[b,*]

The longer is the vegetative phase, the higher is biomass yield…



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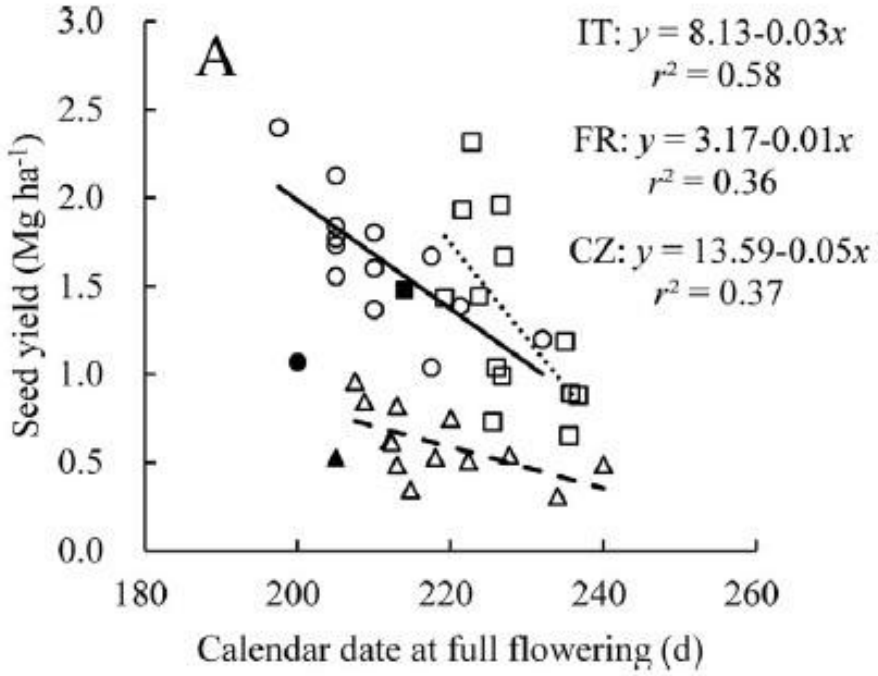
Industrial Crops and Products

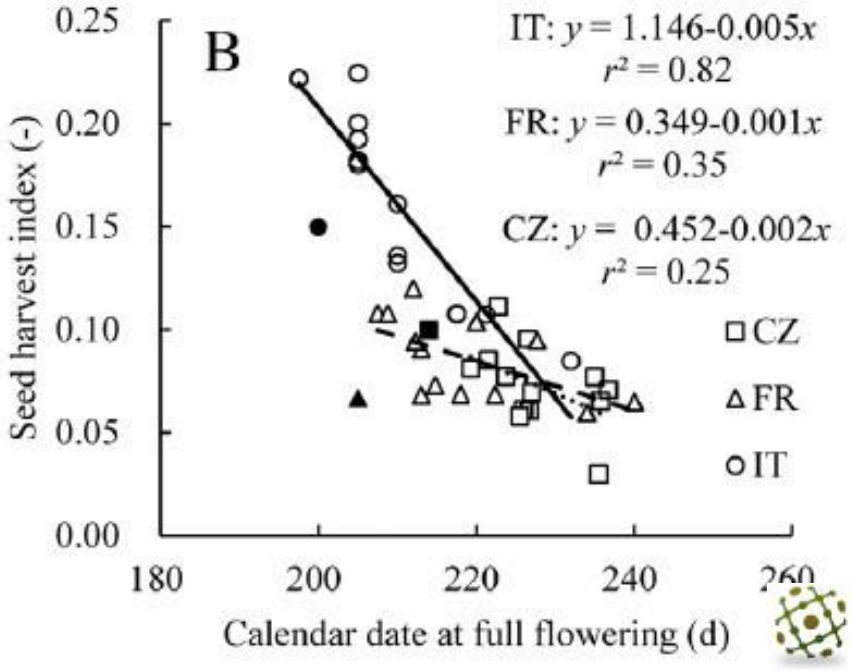
journal homepage: www.elsevier.com/locate/indcrop

Comparing hemp (*Cannabis sativa* L.) cultivars for dual-purpose production under contrasting environments

K. Tang[a,b], P.C. Struik[a], X. Yin[a], C. Thouminot[c], M. Bjelková[d], V. Stramkale[e], S. Amaducci[b,*]

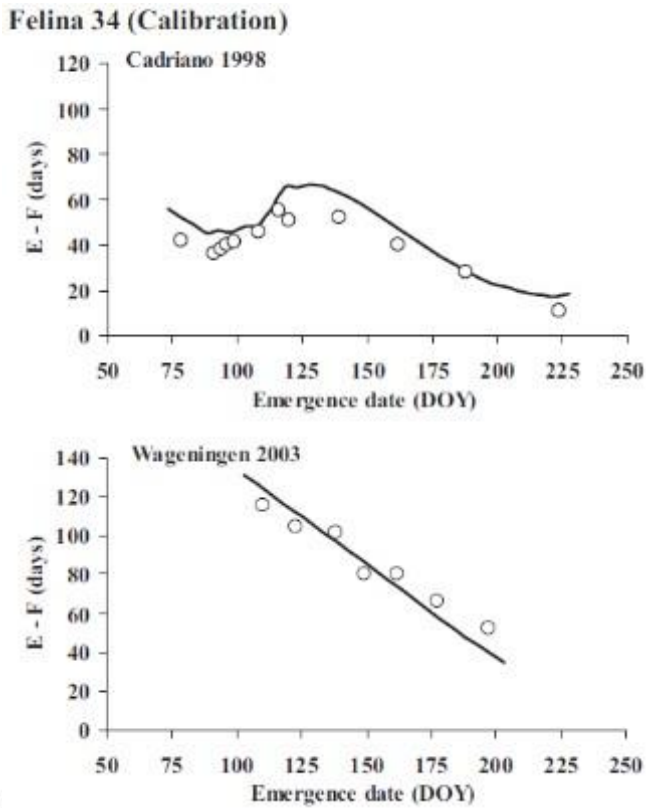
… the lower is seed yield.

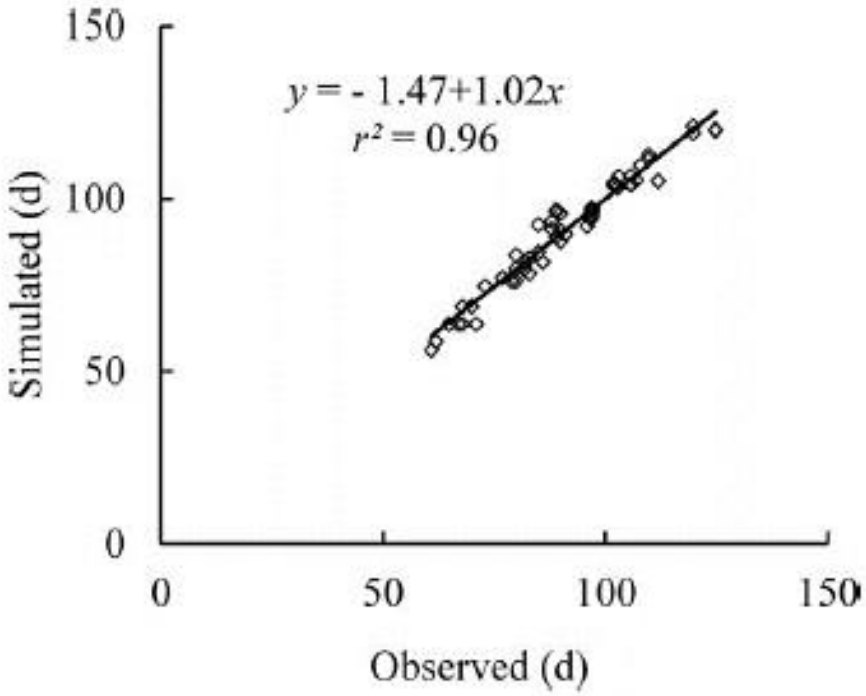


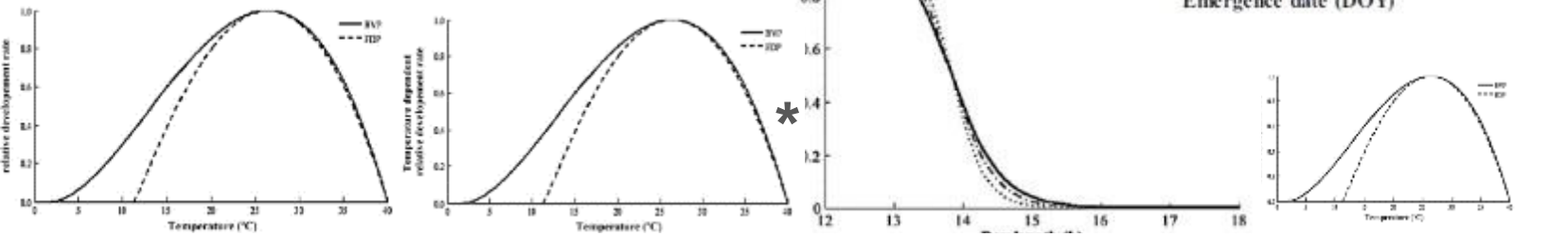


Hemp phenology and possible impact of climate change on its cultivation

$$R_{\mathrm{dev}}(x) = \begin{cases} \dfrac{\mathrm{fT}(1)}{D_1} & x = 1 \\ \dfrac{\mathrm{fT}(2)\mathrm{fP}}{D_2} & x = 2 \\ \dfrac{\mathrm{fT}(3)}{D_3} & x = 3 \end{cases}$$







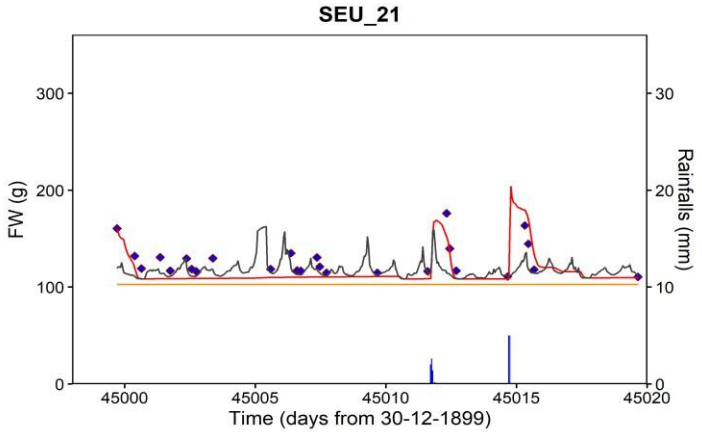
BVP | PIP | FDP

Arnaudeau, S. et al, 2008 & Arnaudeau et al., 2012

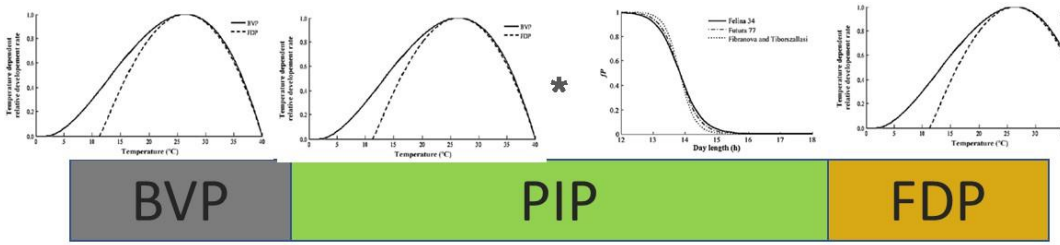
Tang et al, 2016

Hemp phenology and possible impact of climate change on its cultivation

Time to seed maturity (seed yield)

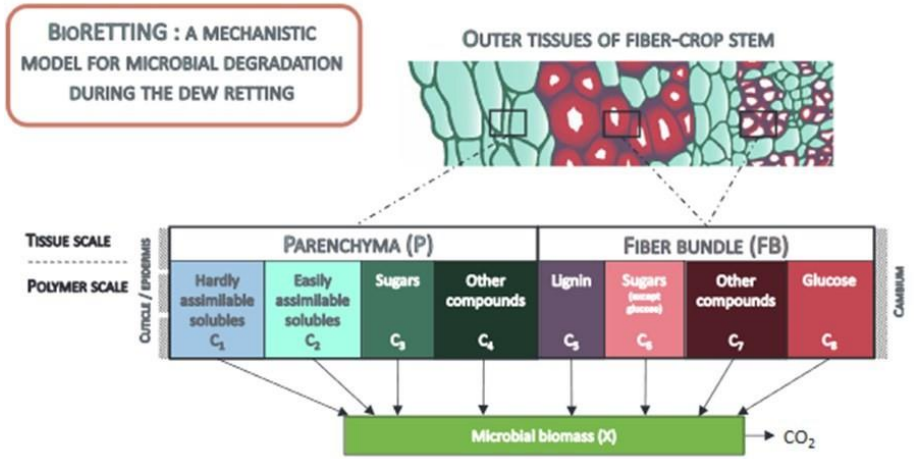


Time to dry (drying model)



Time to flowering (fibre yield)

Genotype X Environment x sowing time



Time to retting (retting model)

Lashermes et al., 2020

Hemp phenology and possible impact of climate change on its cultivation

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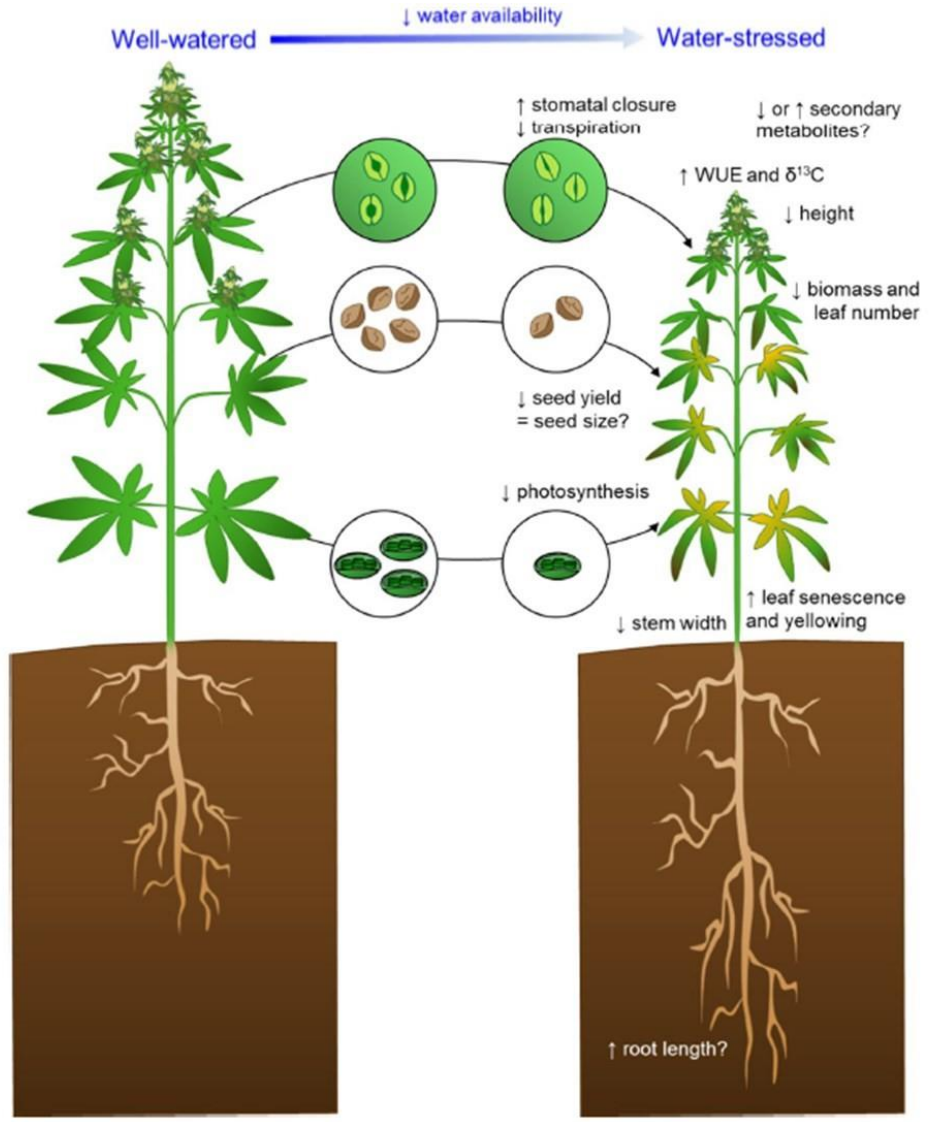
Hemp and water consumption



Hemp has the potential to grow under limited or variable water, with relatively low water requirements of 220 mm to 450 mm compared to other fibre crops;
Hemp shows great potential as a drought resistant crop, offering exciting possibilities to produce sustainable fibre in a changing climate

Gill et al., 2023 doi.org/10.1007/s11104-023-06219-9

Hemp phenology and possible impact of climate change on its cultivation

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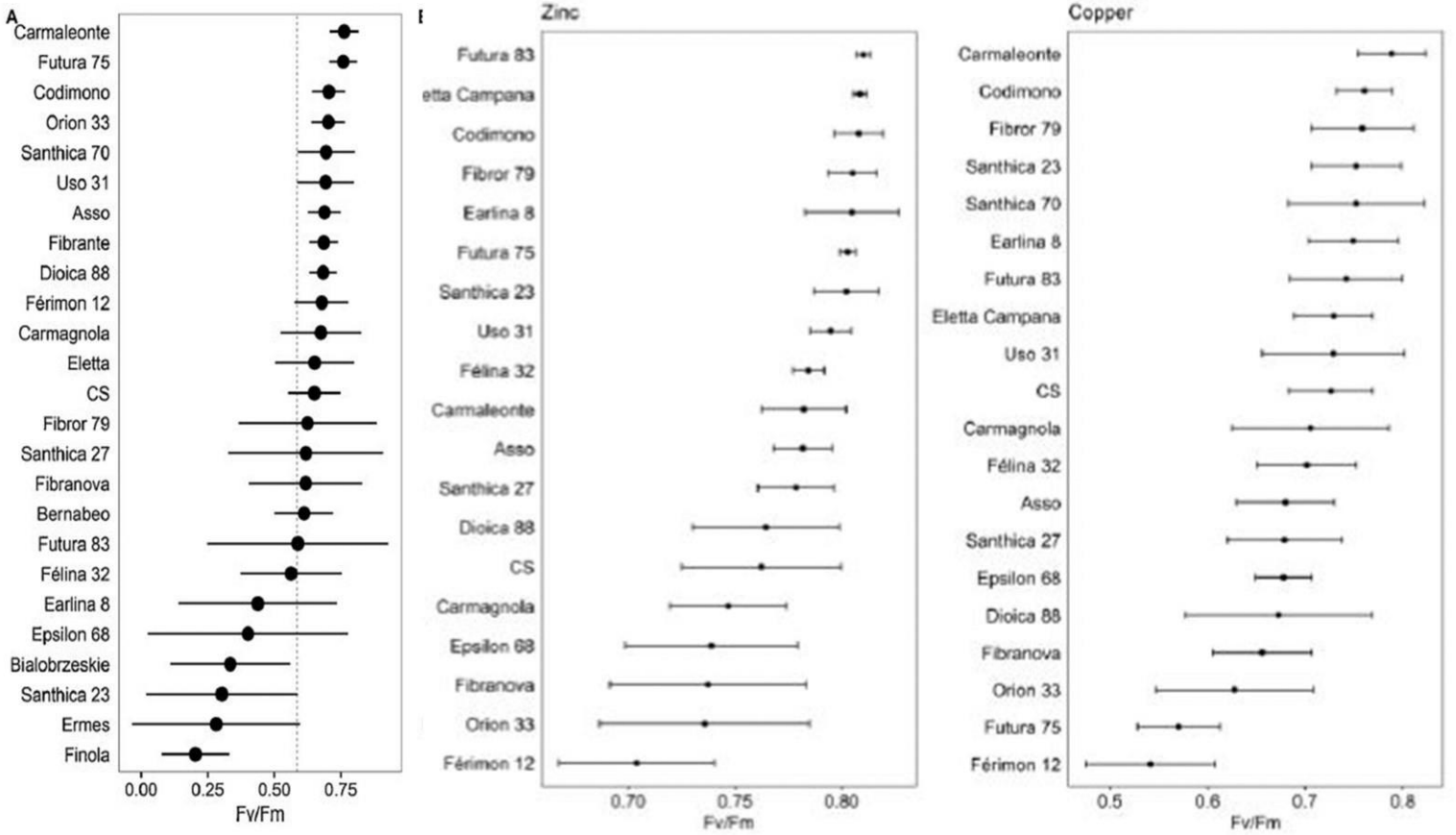
Hemp and water consumption

GRACE

Evidence of genetic variability in European germplasm for Stress tolerance



Osmotic stress	HM stress
Codimono	Fibror 79
Carmaleonte	Carmaleonte
Futura 75	Eletta Campana
Santhica 70	Futura 83
Férimon 12	Codimono

Industrial Crops & Products 170 (2021) 113774

Contents lists available at ScienceDirect

Industrial Crops & Products

journal homepage: www.elsevier.com/locate/indcrop

ELSEVIER

Ranking 26 European hemp (*Cannabis sativa* L.) cultivars for osmotic stress tolerance and transpiration efficiency

Henri Blandinières *, Martina Leoni, Andrea Ferrarini, Stefano Amaducci

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Suitability to marginal environment

- Productivity susceptible to HM (greenhouse scale studies)
- Tolerance to drought depends on soil characteristics / crop phase
- In marginal conditions multipurpose applications are limited:
  - To dual purpose in mountain area;
  - To stem only in HM contaminated lands;

GRACE

REVIEW | Open Access

Adapting the cultivation of industrial hemp (*Cannabis sativa* L.) to marginal lands: A review

Henri Blandinières, Stefano Amaducci

First published: 01 June 2022 | https://doi.org/10.1111/gcbb.12979

Hemp phenology and possible impact of climate change on its cultivation

Yellow varieties are easier to decorticate
Yellow varieties have higher albedo (CG mitigations)

Musio S, Müssig J and Amaducci S (2018) Optimizing Hemp Fiber Production for High Performance Composite Applications. Front. Plant Sci. 9:1702.

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Hemp vs climate change in brief

- ✓ Effect of temperature raise will affect phenology (genotype selection)
- ✓ Extreme weather will affect high-quality fibre uses through lodging
- ✓ Heavy rains and high temperatures might reduce crop establishment
- ✓ Effect on field retting to be evaluated
- ✓ Potential threat from pathogens

- ✓ Hemp can be an opportunity for adaptation strategies (diversification)
- ✓ Hemp is a low emission crop
- ✓ Hemp products can play a role in Carbon Dioxide Removal strategies

Where can you find me?

UNIVERSITÀ CATTOLICA del Sacro Cuore

Agrivoltaics @UCSC

- 507 kWp
- 850 MWh y^{-1}
- Height: 5 m
- Pitch: 15 m and 18 m
- Ground cover ratio:
  - 35% (pitch 15 m)
  - 30% (pitch 18 m)
- Area agrivoltaics 10000 m^2

Department of Sustainable Crop Production
stefano.amaducci@unicatt.it
Via Emilia Parmense 84, 29122 Piacenza, Italy

Life Cycle Assessments for hemp-derived products: do we need them, why and how? Learnings from bioeconomy LCAs

Lorie Hamelin (INRAE)

Professor Chair, based at INSA Toulouse (belonging to Federal University of Toulouse), TBI research unit

@hamelinlab

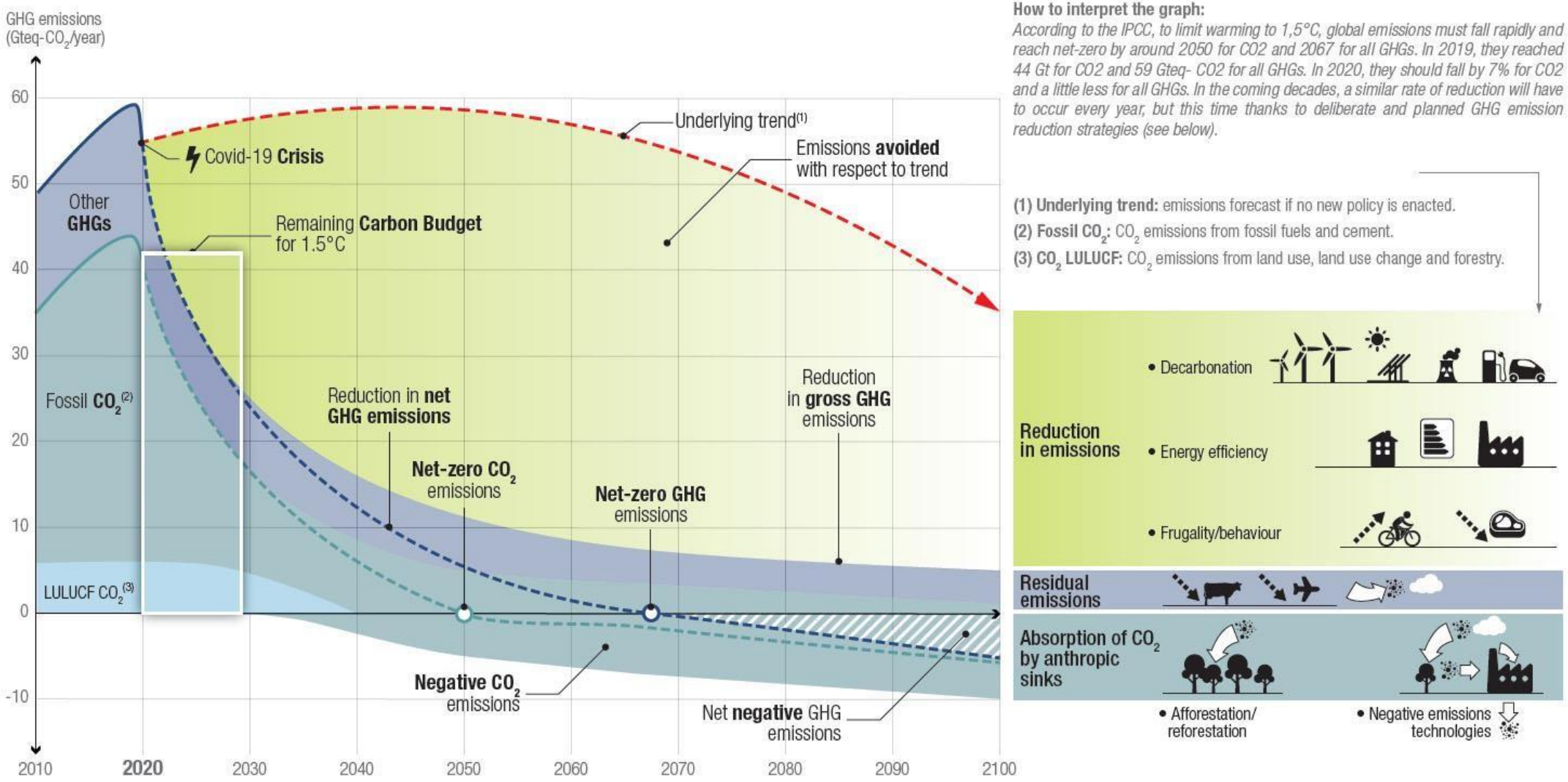
hamelin@insa-toulouse.fr

Horizon Europe grant agreement N° 10105D430. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency. Neither the European Union nor the granting authority can be held responsible for them.

World Hemp Forum 2024
Troyes, 19.11.2024

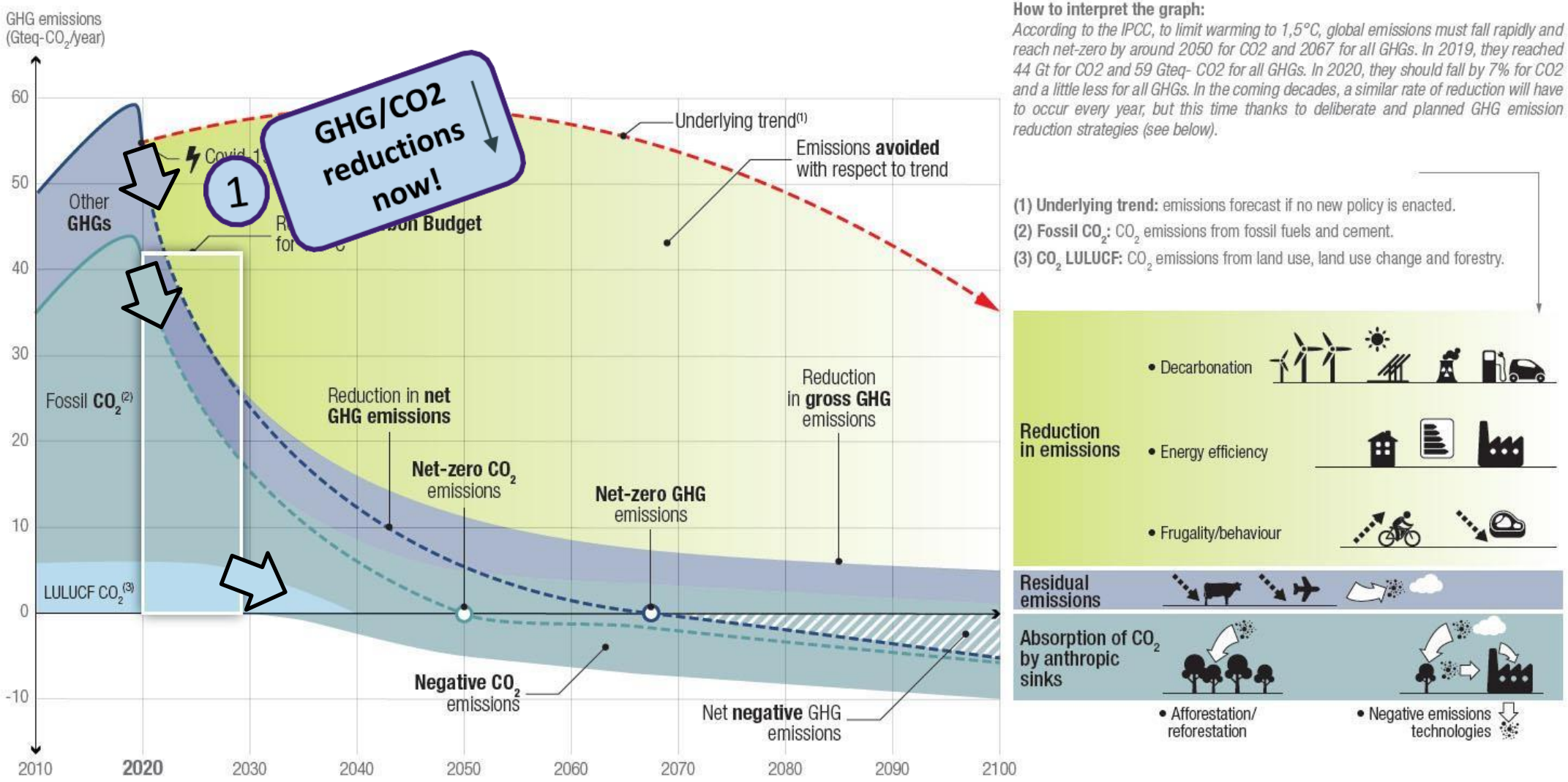
Towards neutrality

What does it mean to be CO2 / GHG neutral?



Sources: L'Institut Paris Region, based on the IPCC special report on 1.5°C, October 2018; UNEP, Emissions Gap Reports 2017, 2019 and 2020; Climate Action Tracker, December 2020.

What does it mean to be CO2 / GHG neutral?



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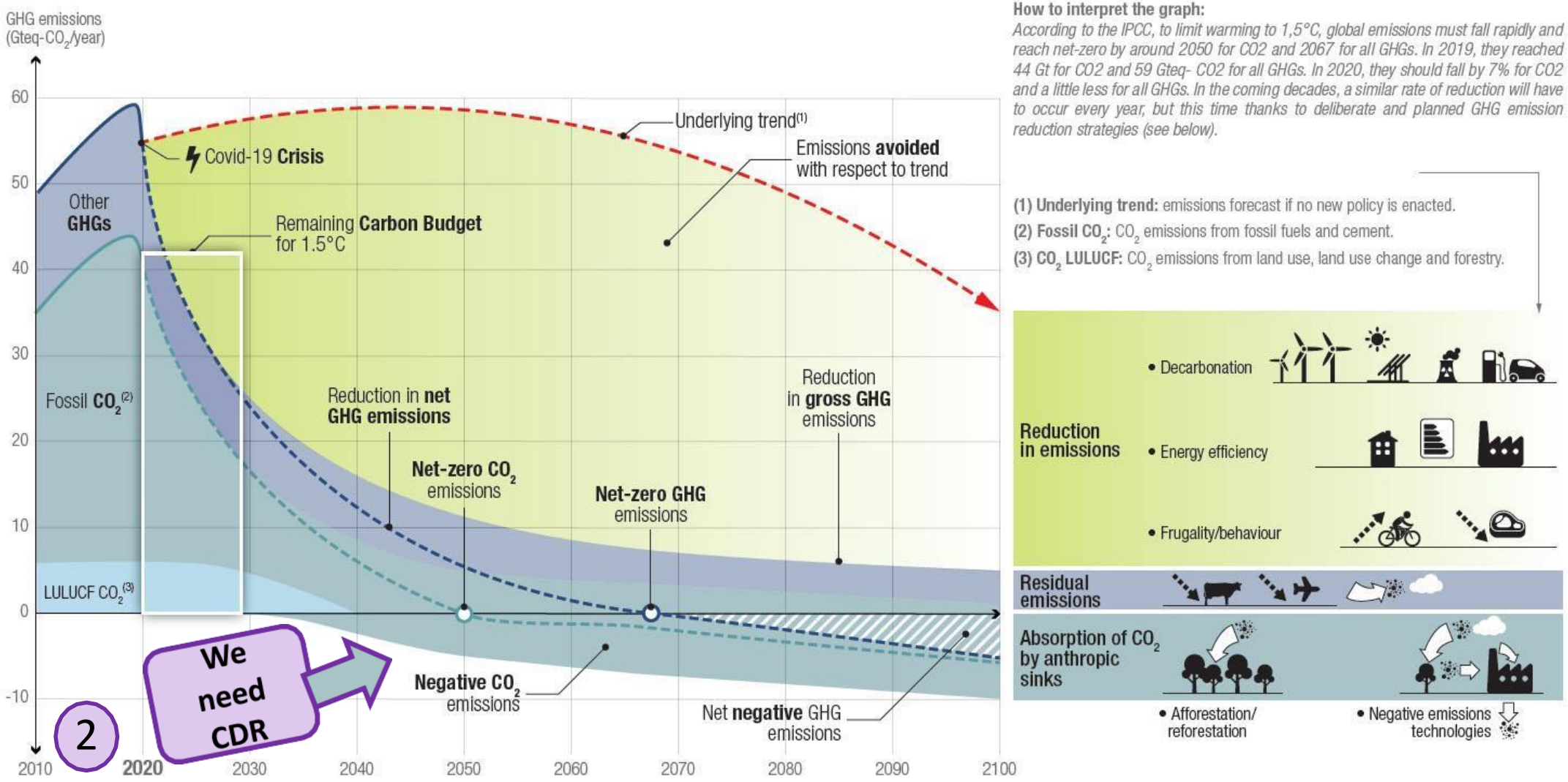

Sources: L'Institut Paris Region, based on the IPCC special report on 1.5°C, October 2018; UNEP, Emissions Gap Reports 2017, 2019 and 2020; Climate Action Tracker, December 2020.

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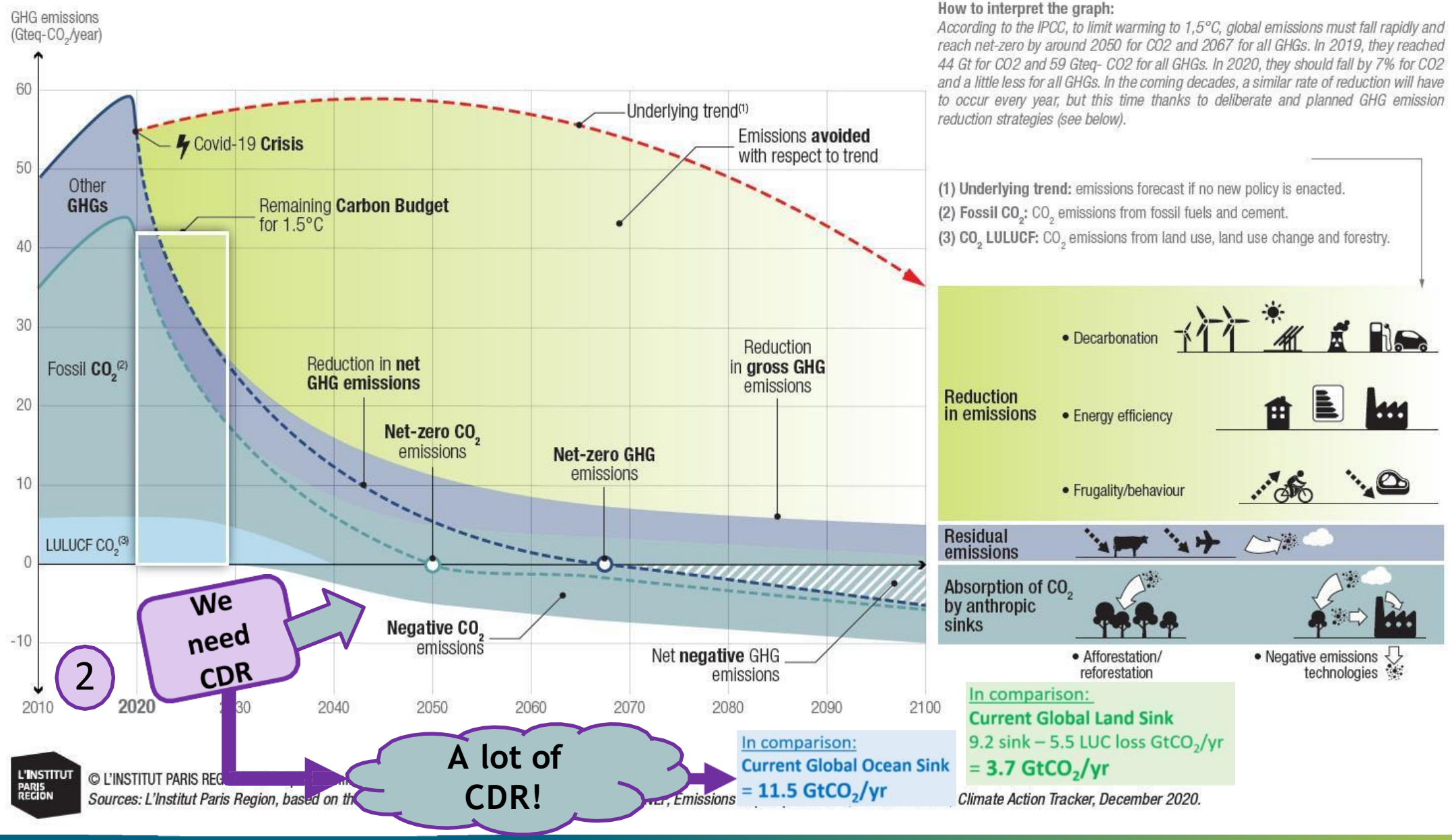

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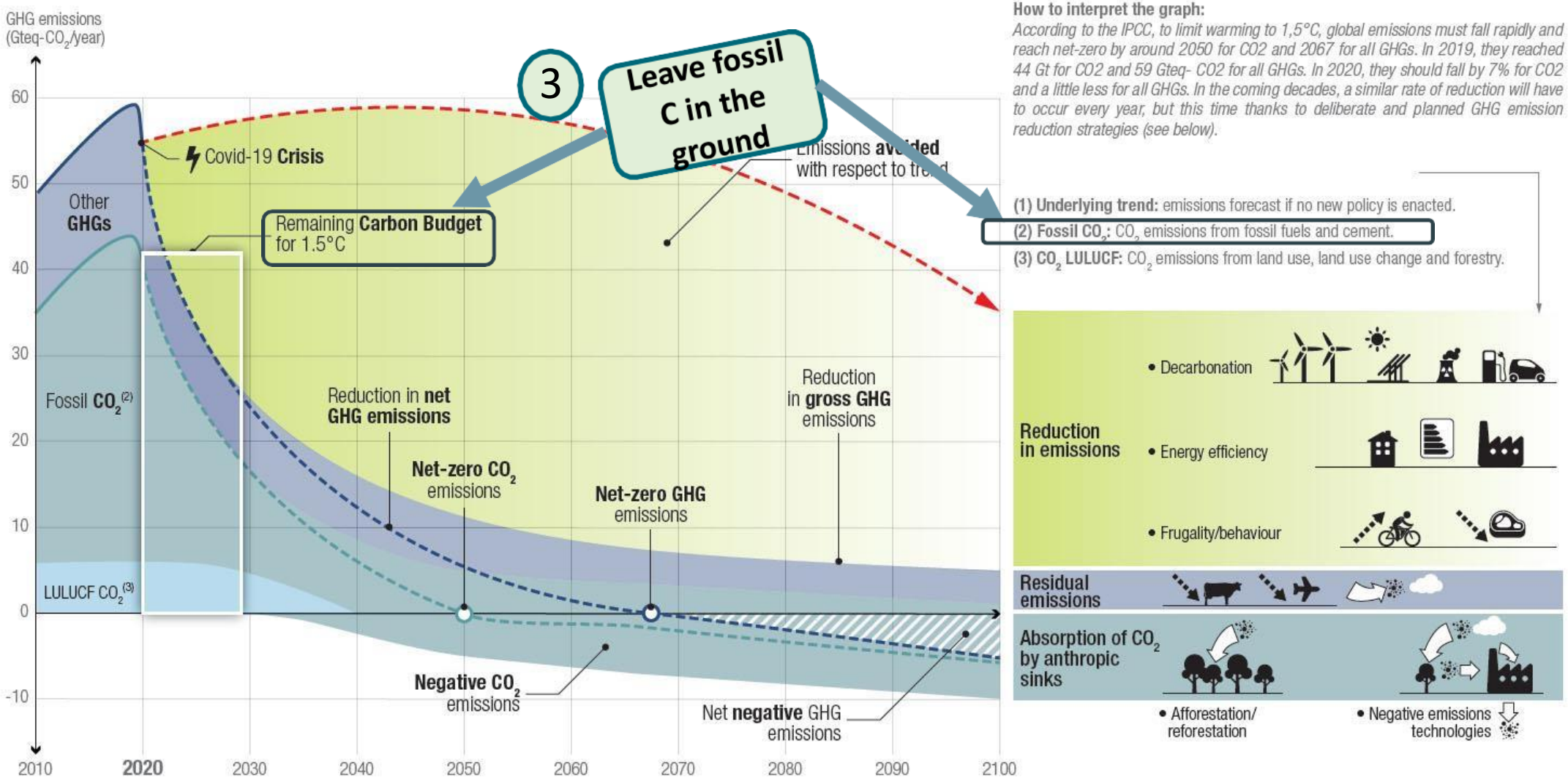

Sources: L'Institut Paris Region, based on the IPCC special report on 1.5°C, October 2018; UNEP, Emissions Gap Reports 2017, 2019 and 2020; Climate Action Tracker, December 2020.

Hemp in all this?

- The only crop that Feeds, Clothes, Shelthers, and Heals!

- All parts of the plant can be used!

- Fiber is like gold …fibergrass

Hemp: Food for life | Cameron Sims | TEDxAuckland

TEDx Talks
3,7 k vues • il y a 6 ans

Hemp Protein
(rather than soy/milk protein)

- Grows fast, unlike cotton, requires little to no pesticide, takes a fraction of the water, and half the land …!

Hemp holds the key to a sustainable future | Amy Ansel...

TEDx Talks
117 k vues • il y a 5 ans

- Strong & superior fiber, stronger than steel, but weight 1000 lb less

Hemp paper
(instead of forestry wood)

Green Hope: Hemp to the Rescue | Laura Rothgang |...

TEDx Talks
1,4 k vues • il y a 1 an

- Hemp paper requires less ‘dirty’ bleaching and gives more fiber/ha*y than wood pulp

Hempcrete…
- the healthiest building material, anti-fungal, anti-bacterial
- thermal and insulation properties off the hook
- an architech dream come true!

Building with hemp | Joni Lane | TEDxCharlottesville

TEDx Talks
125 k vues • il y a 9 ans

Hempcrete
(rather than gypsum/drywall)

Detoxifies soil!

- Binds up to 4 times MORE CO_2 than trees

Hemp as a Crop | Frances Tacy | TEDxAsheville

TEDx Talks
11 k vues • il y a 6 ans

Hemp fabric
(rather than cotton)

- Unlike plastic, it can biodegrade

- The World’s most nutrient-dense seed

Hemp in all this?

- The only crop that Feeds, Clothes, Shelthers, and Heals!

- All parts of the plant can be used!

Hemp: Food for life | Cameron Sims | TEDxAuckland

TEDx Talks

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Hemp Protein

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- Fiber is like wood …fibergrass

- Grows fast, unli… takes a… pesticide, …!

Hemp holds the key to a sustainable future | Amy A…

TEDx Talks

11…

…000 lb less

…s more

Gree… Resc…

TEDx T…

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Build… TEDx…

TEDx T…

125 k vu…

Detoxifies soil!

- Binds up to 4 times MORE CO_2 than trees

Hemp as… TEDxAshe…

TEDx Talks

11 k vues • il y a 6 ans

- The World's most nutrient-dense seed

…abric

…ther than cotton)

- Unlike plastic, it can biodegrade

And … can it be instrumental in reaching climate neutrality?

But … beyond acting on climate, what about impact shifting?

Where LCA comes into play

Opinions and Black Boxes

Much of green work is based on opinions and feel good

- "It is obvious that by doing X we can help solve Y"

Much is rooted in Life Cycle Analysis work

- This is good, in principle, because it is fact based
- Clearly there have been many excellent LCAs that have helped a lot
- But LCAs are mostly black boxes that most of us cannot usefully query
- And they can tip one way or the other via some sensitive inputs that most of us are unaware of
  - Which means that some LCAs have been tweaked to give the desired answer …
  - … sometimes under intense political pressure
  - And there is no way the rest of us can intelligently check for sensitivities

LCAs are needed to judge of the environmental performance of a future investment, but…

Why do we (unfortunately) get contrasting results?

1. Handling multifunctionality
2. Lignin-first or waste from pulp production? : Land-dependant biomass (or not)
3. Biogenic C
4. FU reflecting comparable final application
5. Quality of data

Science of the Total Environment 770 (2021) 144656

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journal homepage: www.elsevier.com/locate/scitotenv

Review

Review of life cycle assessments of lignin and derived products: Lessons learned

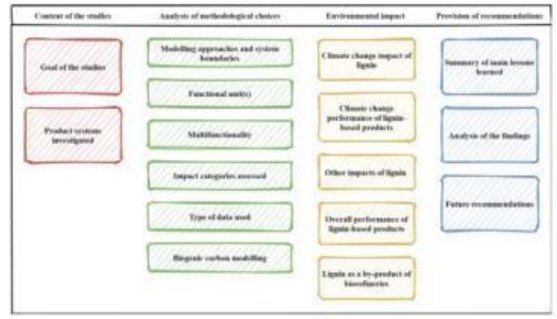
Christian Moretti [a,*], Blanca Corona [a], Ric Hoefnagels [a], Iris Vural-Gürsel [b], Richard Gosselink [b], Martin Junginger [a]

[a] Utrecht University, Copernicus Institute of Sustainable Development, Utrecht, Netherlands
[b] Wageningen Food & Biobased Research, Wageningen, the Netherlands

HIGHLIGHTS

- A first review of peer-reviewed LCAs of lignin and lignin-based products was conducted.
- Most of lignin-based applications showed promising climate change performances but trade-offs in other impact categories.
- The lack of harmonization in the application of LCA methodology hinders direct comparative analyses.
- Recommendations to increase consistency were provided.

GRAPHICAL ABSTRACT



Anatomy of an LCA

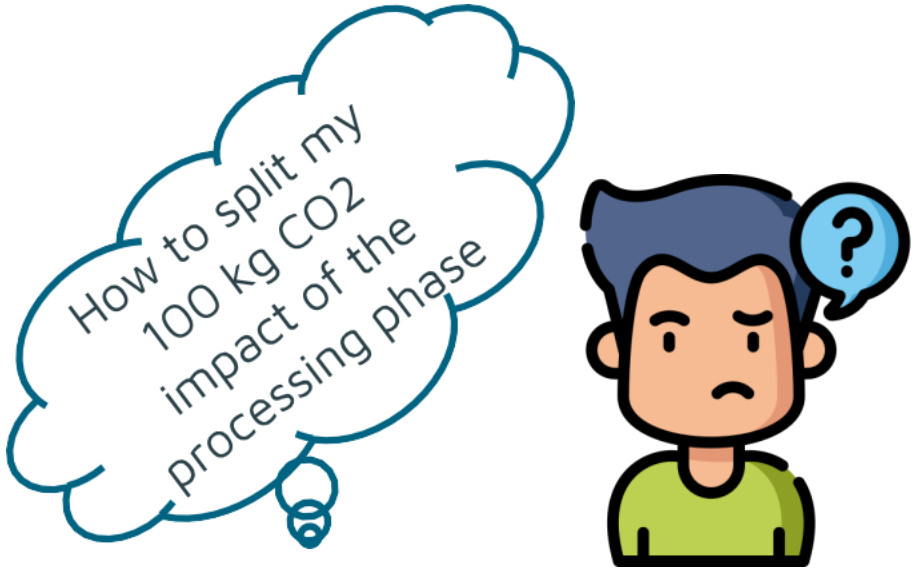
More than just the desired product?

Biomass feedstock production (or not)

Processing phase

Desired product

Co-product



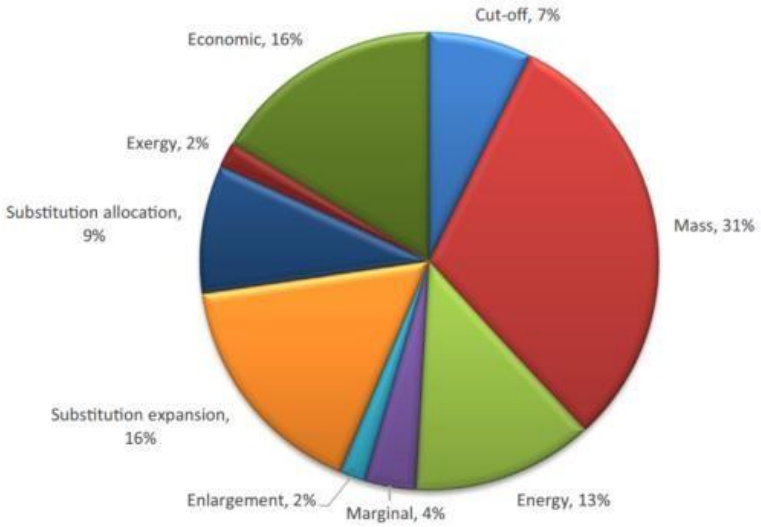


Fig. 4. Summary of the adopted multifunctionality practices in the selected 42 LCAs.

Anatomy of an LCA

More than just the desired product? ISO 14044 says that allocation should be avoided whenever possible, by system expansion

Biomass feedstock production (or not)

Processing phase

Desired product

Co-product

Used / processed in a certain way

Conventional supplier of service X

Supply of service X

Anatomy of an LCA

Type of biomass.

(1): NOT land-dependant

Residual biomass (e.g. lignin from pulp production)

Processing phase

Desired product

Co-product

Used / processed in a certain way

Conventional supplier of service X

Supply of service X

Anatomy of an LCA

Type of biomass.

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Residual biomass (e.g. lignin from pulp production)

Processing phase

Desired product

Co-product

Used / processed in a certain way

Supply of service Y

Induced production of Y

Used / processed in a certain way

Conventional supplier of service X

Supply of service X

Anatomy of an LCA

Concept of the counterfactual uses (or opportunity cost). You always mobilize your resource at the expense of something else!

Type of biomass.

(1): NOT land-dependant

Residual biomass (e.g. lignin from pulp production)

Processing phase

Desired product

Co-product

Used / processed in a certain way

Supply of service Y

Induced production of Y

Used / processed in a certain way

Conventional supplier of service X

Supply of service X

Anatomy of an LCA

Type of biomass.

(2): Land-dependant. Grown on purpose

Biomass feedstock production (ha)

Processing phase

Desired product

Co-product

Used / processed in a certain way

Supply of service X

Former use of the land

Supply of crop/woody biomass

Induced production of 'displaced crop'

Conventional supplier of service X

Anatomy of an LCA

(Indirect) Land use change is inevitable

Type of biomass.

(2): Land-dependant. Grown on purpose

Biomass feedstock production (ha)

Processing phase

Desired product

Co-product

Former use of the land

Supply of crop/woody biomass

Used / processed in a certain way

Induced production of 'displaced crop'

Conventional supplier of service X

Supply of service X

Anatomy of an LCA

Accounting for biogenic C

- **Biogenic:** carbon from biomass and its transformation
- There is accounting for carbon **flows** (inventory - LCI)
- …and accounting for carbon **impacts** (impact assessment - LCIA)
- Different combinations give the same result, for example:

Negative input of -10 kg "Carbon dioxide, fossil" (carbon uptake) …

…and positive characterisation factor (+1 kg CO_2e / kg CO_2fossil)

Positive input of +10 kg "Carbon dioxide, biogenic" (carbon uptake)

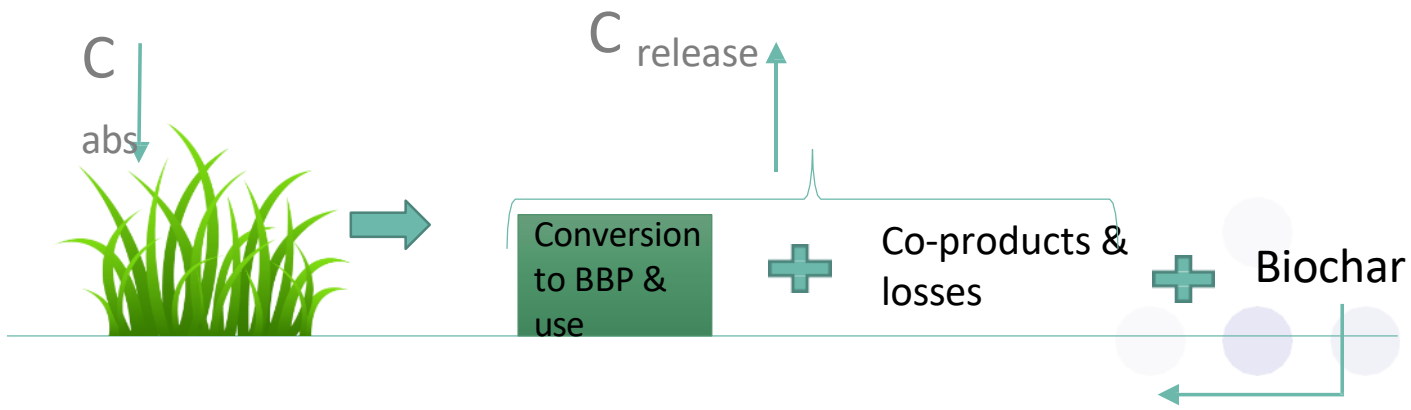
… and negative characterisation factor (-1 kg CO_2e / kg CO_2biogenic)

Give same result of -10 kg CO_2e

Credit: M. Pizzol (2024)

Ouellet-Plamondon et al. (2023).

Accounting biogenic C

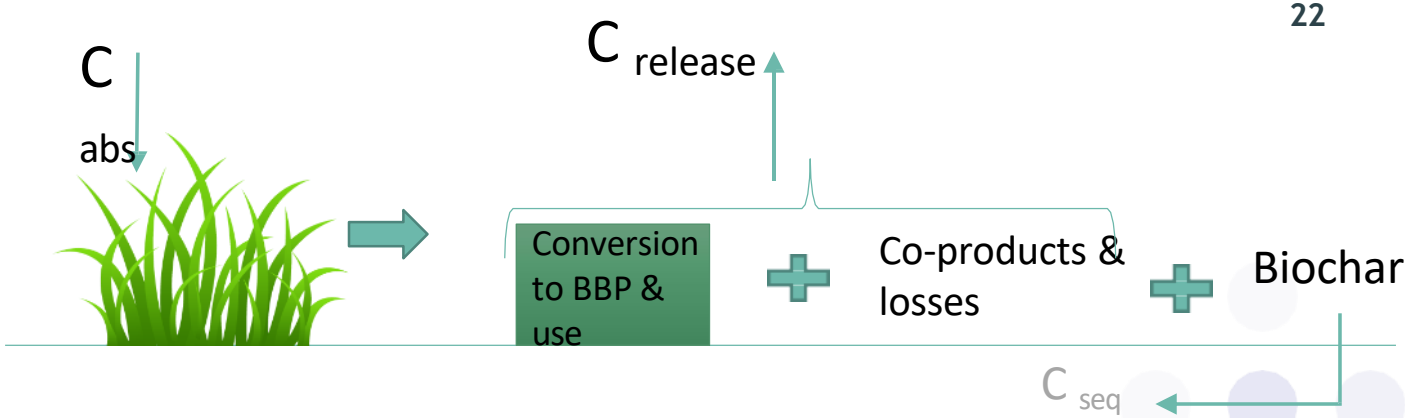


<u>Approach: 0/0</u> : Absorbed and released CO_2 with CF = 0 kg CO_2e/kg CO_2. Induced sequestration with a flux accounted as minus (and positive CF = +1)

Issues:

- Induce the idea that there are no climate effects from the use of biomass
- Important CO_2 flows invisible in results (thus also for decision-making)
- Mass balance distorted when C emitted back as CH_4, CO, etc. (not necessarily re-absorbed by plants)
- Temporary storage when biomass is harvested but not 'emitted' immediately is not reflected

Accounting biogenic C



<u>Approach: -1/+1</u> : Uptake from the atmosphere accounted as negative (e.g. negative inventory flow and positive CF), and vice-versa for release. Only net flows are accounted (so sequestration not assigned a flow).

Issues:

- Calculation potentially more difficult
- Eventual misinterpretation of results (C-negative products) because of system boundary inconsistencies in cradle-to-gate

Accounting biogenic C (and C dynamic)

ALIGNED recommendations

Funded by the European Union

Harmonizing climate change midpoint scores estimations
ALIGNED recommendations - baseline

- System boundaries: implement **cradle-to-grave**
- Inventory phase: document and report **separately all biogenic and non-biogenic carbon flows**
- Climate impact scores:
  - compute at least two indicators: **short-term** and **long-term** effects
  - implement the **-1/+1 approach** -biogenic carbon flows always accounted-
  - analyze at least the **"total" indicators** -including contribution of both biogenic and non biogenic flows-
  - at least include **time effects** with provided Tiered approach

Hamelin, L., Javourez, U., & Arbault, D. (2024). ALIGNED D1.2 Description of scientific methods (T1.3 Framework for Life Cycle Impact Assessment) (1.1). Zenodo. https://doi.org/10.5281/zenodo.11126481

03 Hemp case study on ‘C-vulnerable’ lands

PhD Defense Zhou Shen, May 2022

Science of the Total Environment 846 (2022) 157331

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

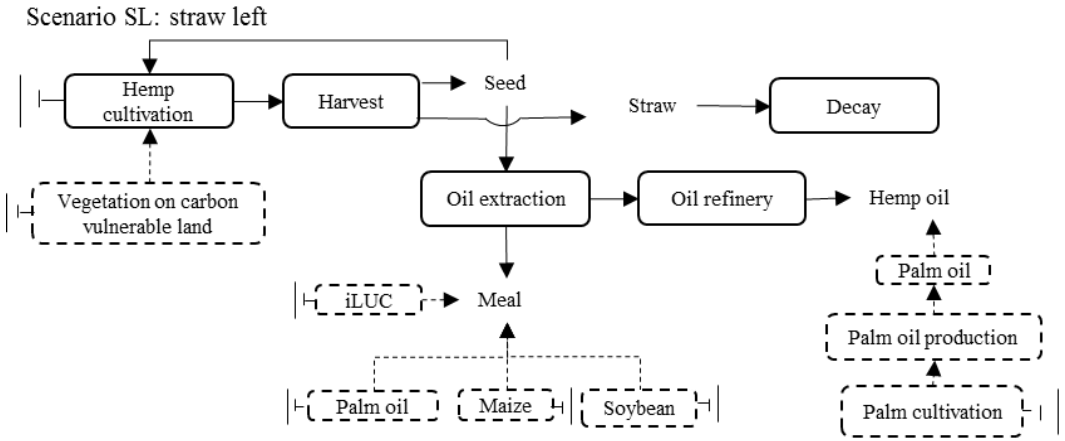
From hemp grown on carbon-vulnerable lands to long-lasting bio-based products: Uncovering trade-offs between overall environmental impacts, sequestration in soil, and dynamic influences on global temperature

Zhou Shen *, Ligia Tiruta-Barna, Lorie Hamelin

TBI, Université de Toulouse, CNRS, INRAE, INSA, Toulouse, France

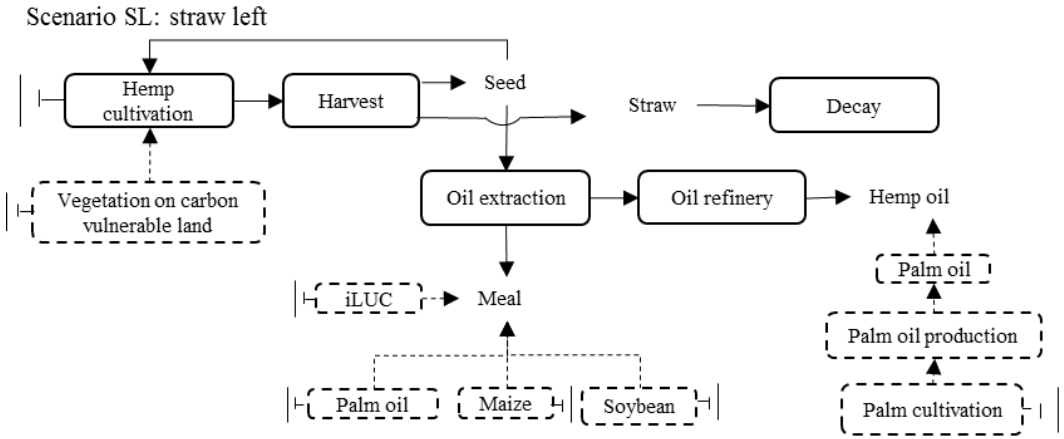
Scenarios

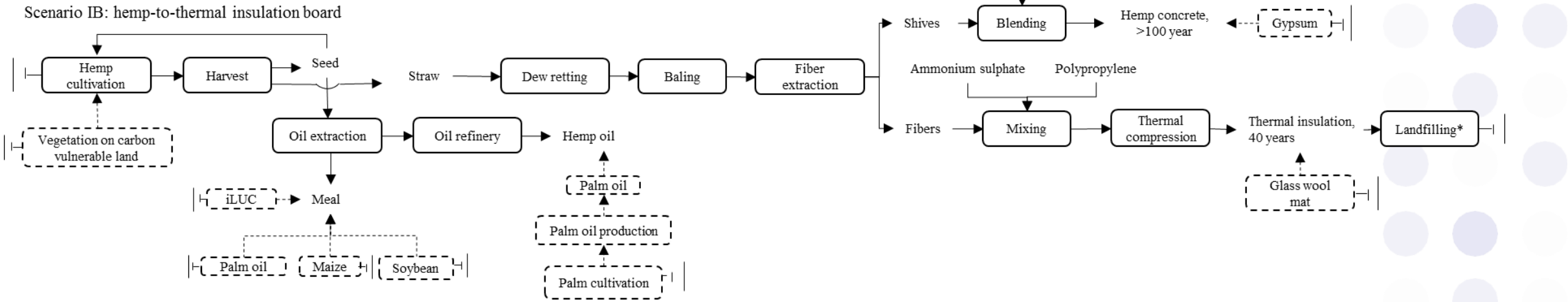
Functional unit: Annual management of 1ha CV land



Scenarios

Functional unit: Annual management of 1ha CV land

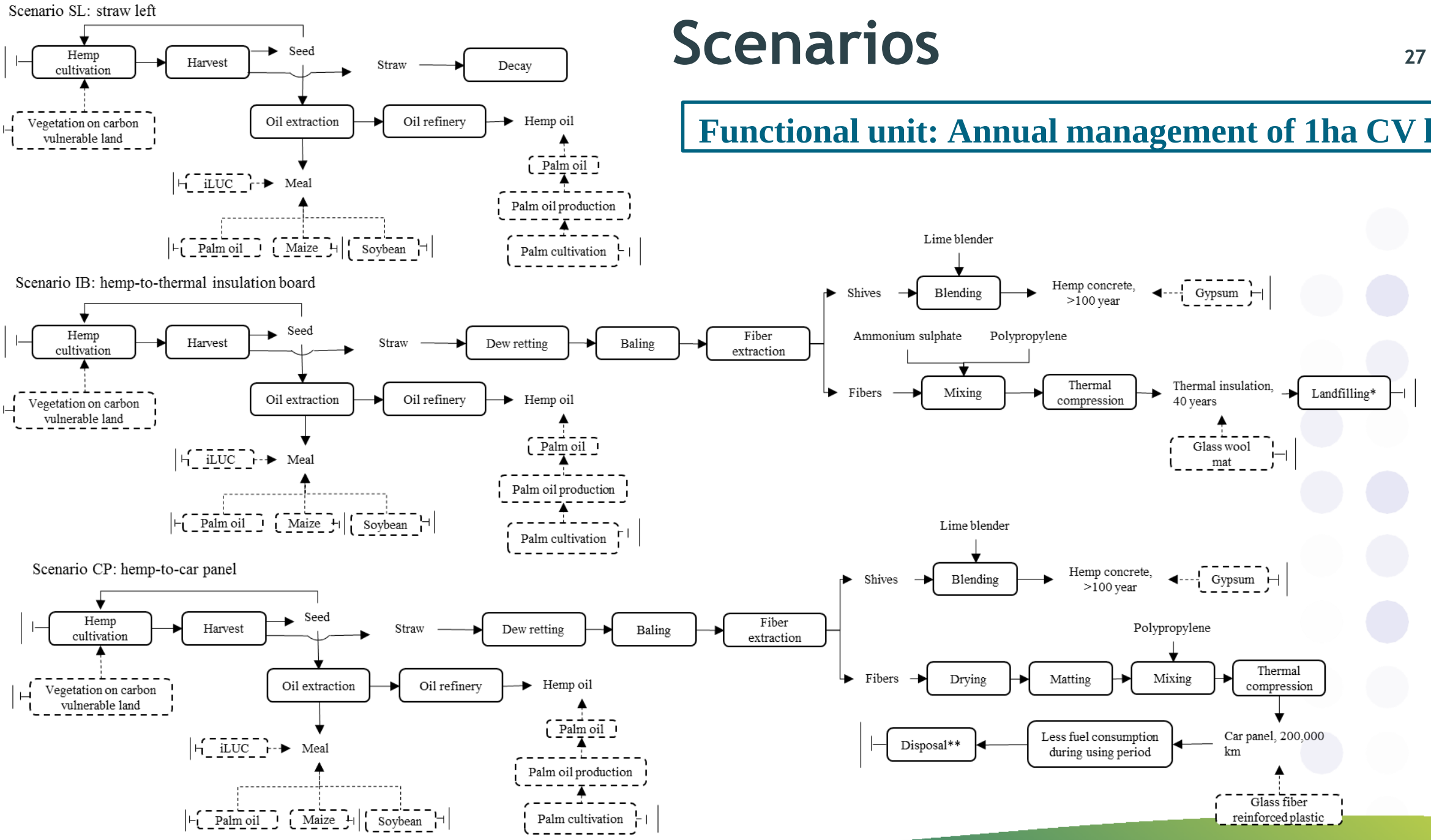




*Landfilling without CH4 recovery;

Scenarios

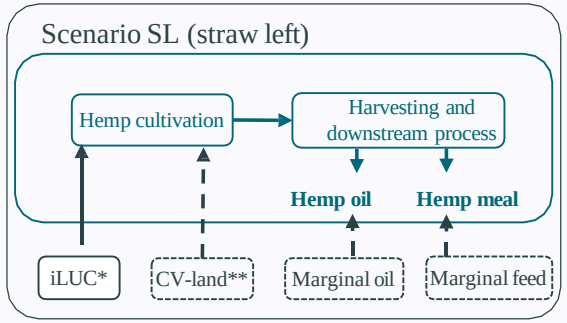
Functional unit: Annual management of 1ha CV land

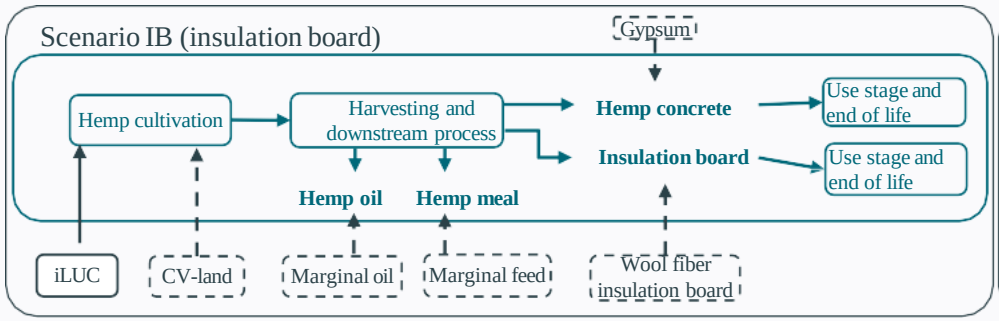


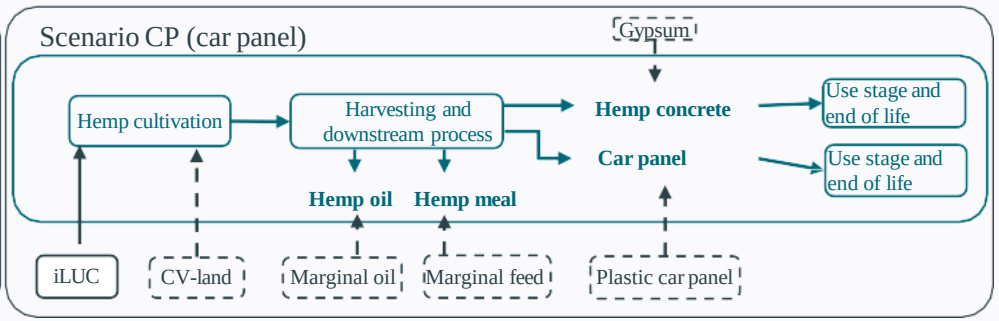
*Landfilling without CH4 recovery; ** 30% incineration, 70% landfilling without CH4 recovery

Scenarios

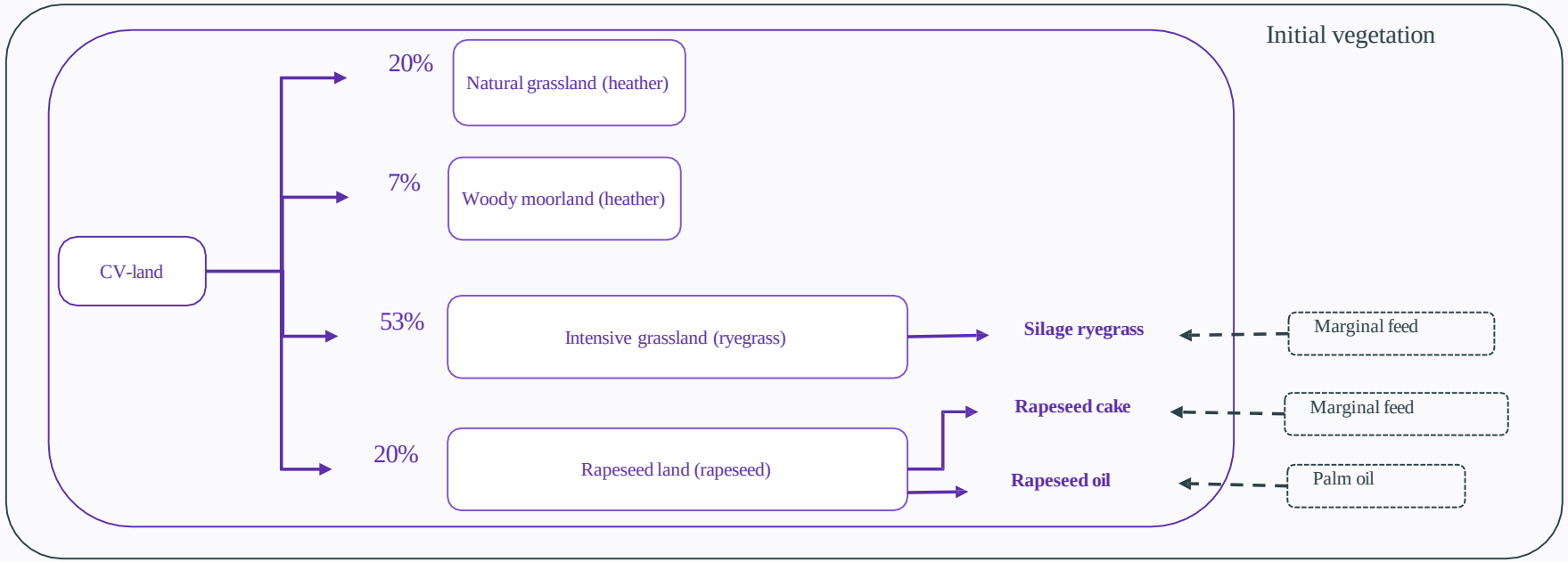
Hemp case study, Functional unit: 1 ha CV-land, 1 year.





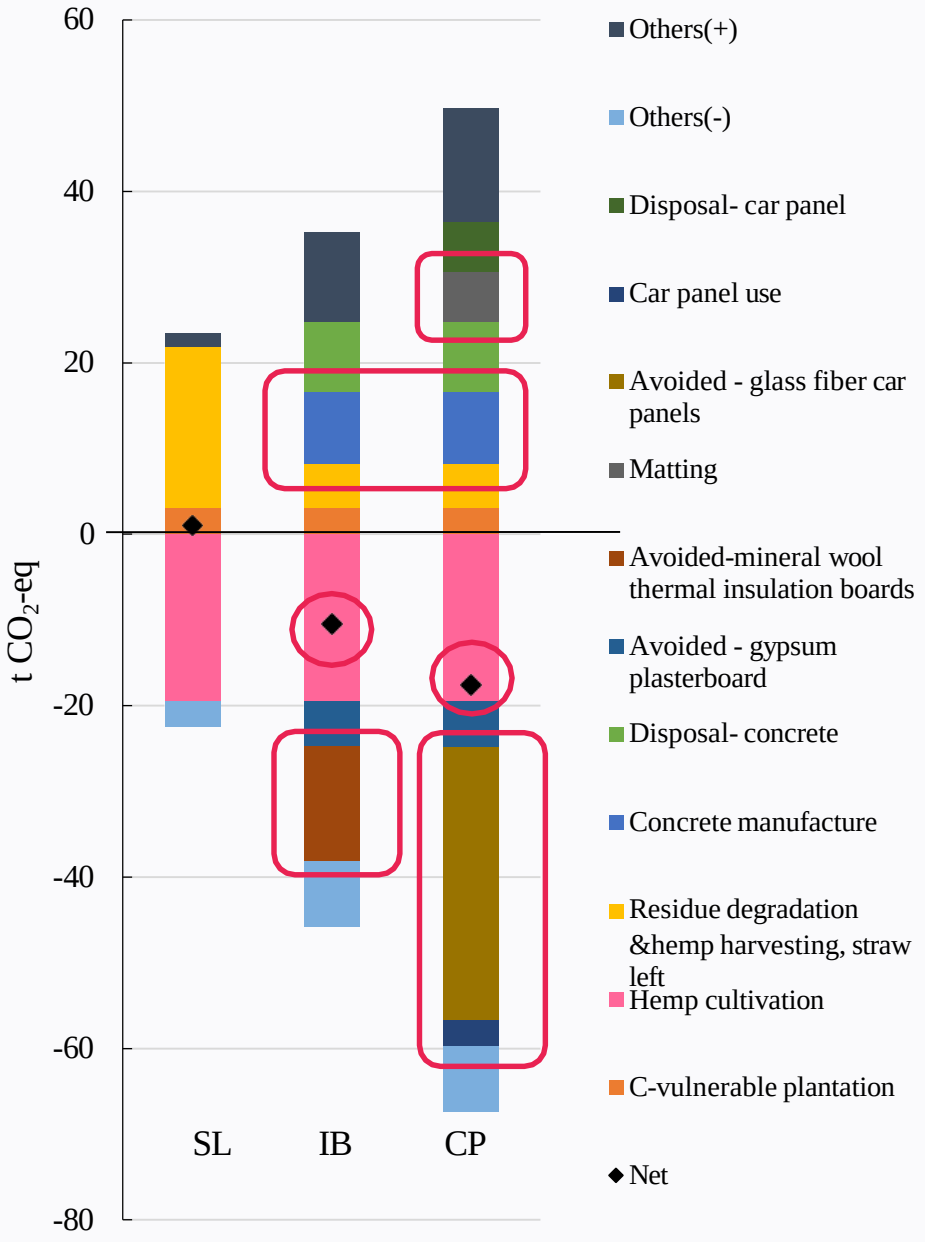


*: iLUC: indirect land use change
**: CV-land: carbon vulnerable land
Dash line means this process is an avoided process



LCIA method: Environmental Footprint (EF) V2.2
All C in the bio-based product is emitted at the end-of-life

Contribution analysis, climate change

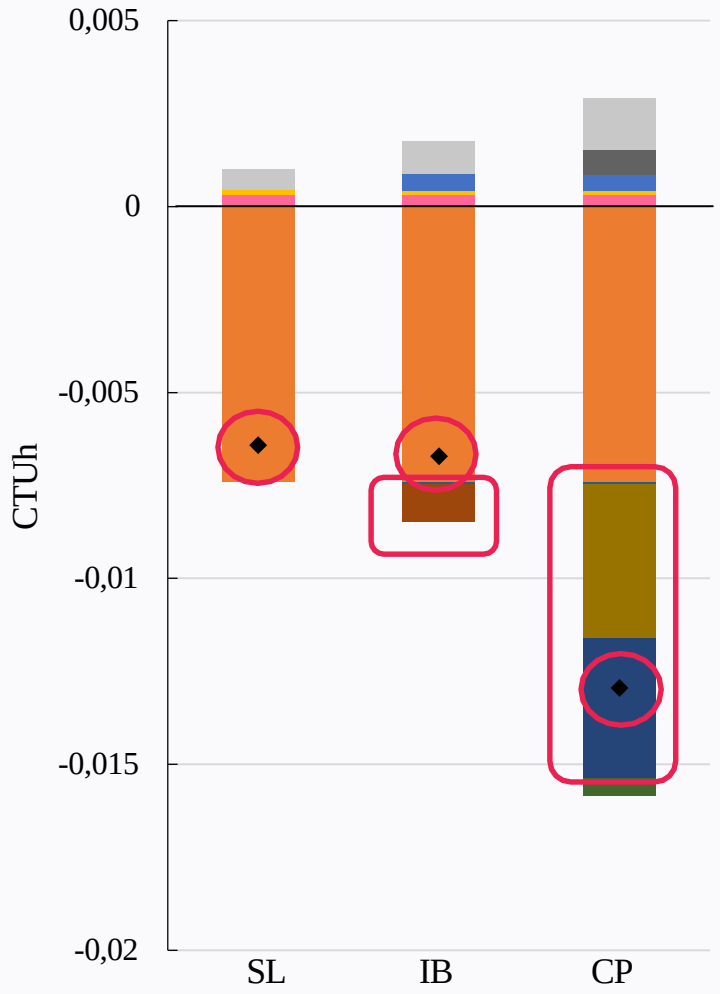


- ✓ IB and CP allow net negative – better than leaving system as is. Not true if stalks left on land
- ✓ Avoiding mineral wool (IB) and glass fiber + gasoline (CB) is key to the 'superior' environmental performance of IB and CP
- ✓ Hempcrete is net positive: the impact of limestone degradation + energy is greater than the impact from absorbed CO2
- ✓ Fiber content car panels half what is in insulation boards: therefore, more additives (PP) in CP (matting process)

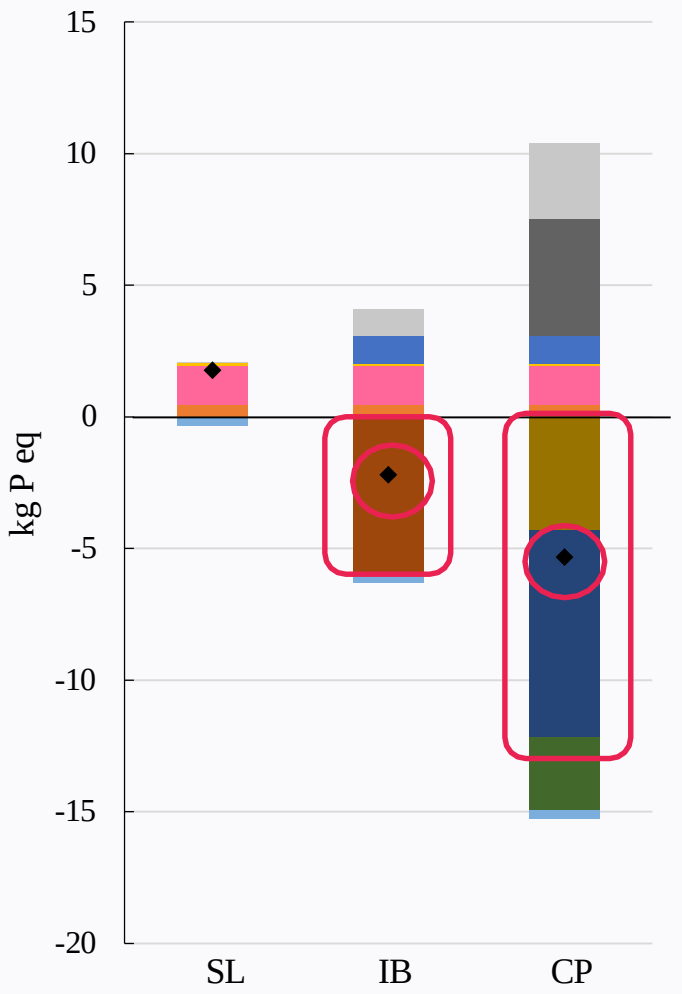
Landfilling: We assume 20% biogenic C degrade in first 100y, of which 87% as CO2, 13% as CH4 (IPCC 2019)

Other impacts (selected)

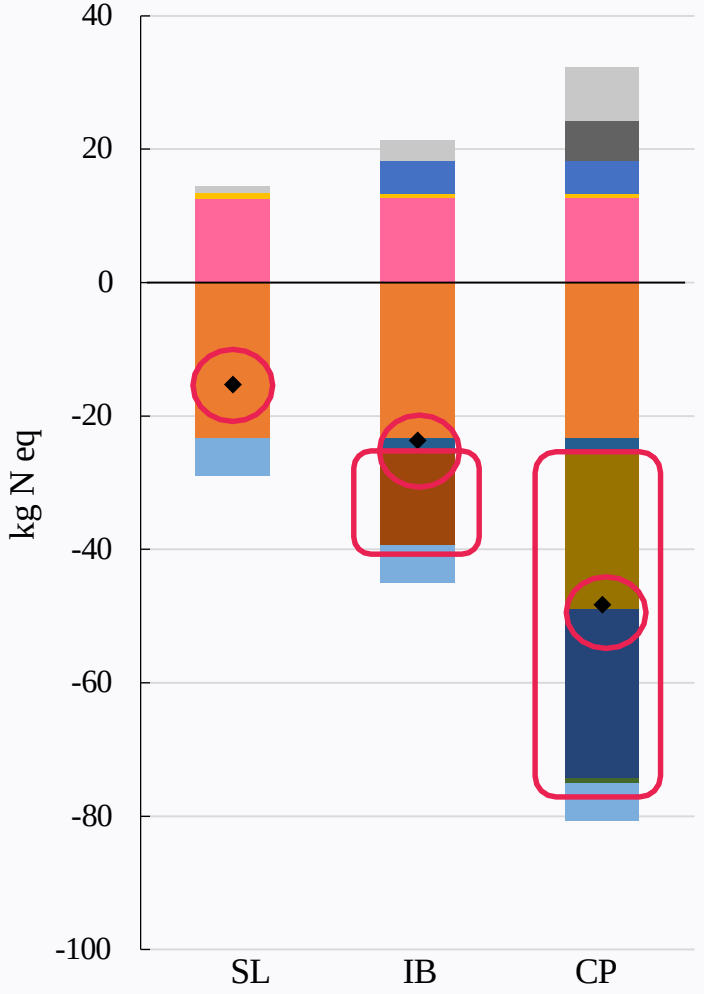
Non-cancer human health



Freshwater eutrophication



Marine eutrophication

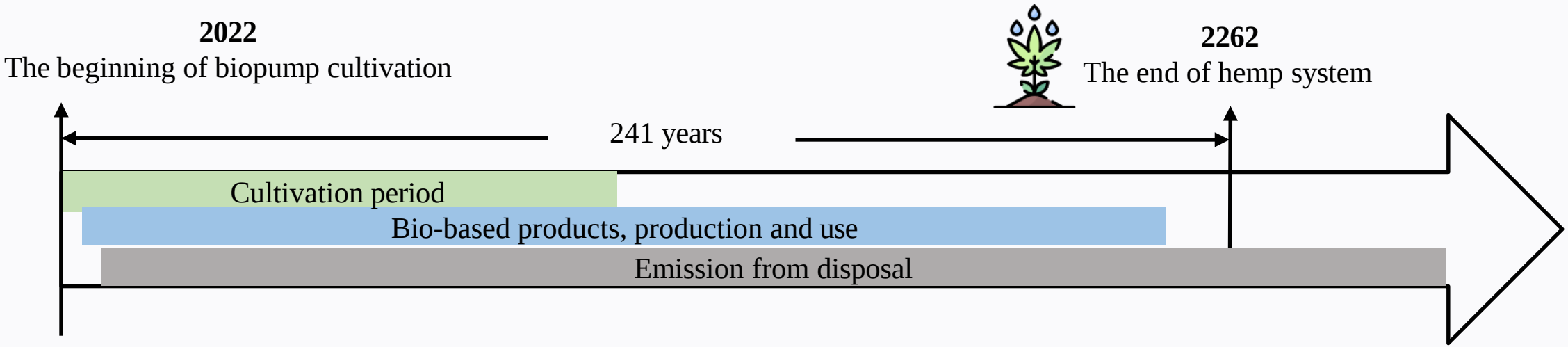


- C-vulnerable plantation
- Concrete manufacture
- Avoided-mineral wool thermal insulation boards
- Car panel use
- Others(+)
- Hemp cultivation
- Disposal- concrete
- Matting
- Disposal- car panel
- Net
- Residue degradation &hemp harvesting, straw left
- Avoided - gypsum plasterboard
- Avoided - glass fiber car panels
- Others(-)

Accounting for GHG in time …

Assuming hemp cultivation for 100 y, with subsequent products use

IB: 40 y
CP: 12 y
Hempcrete: 100 y



Climate Change Impact tool
Metric: Global mean temperature change (GMTC), unit in K
GHG list: IPCC/ Ecoinvent

Global mean temperature change in time

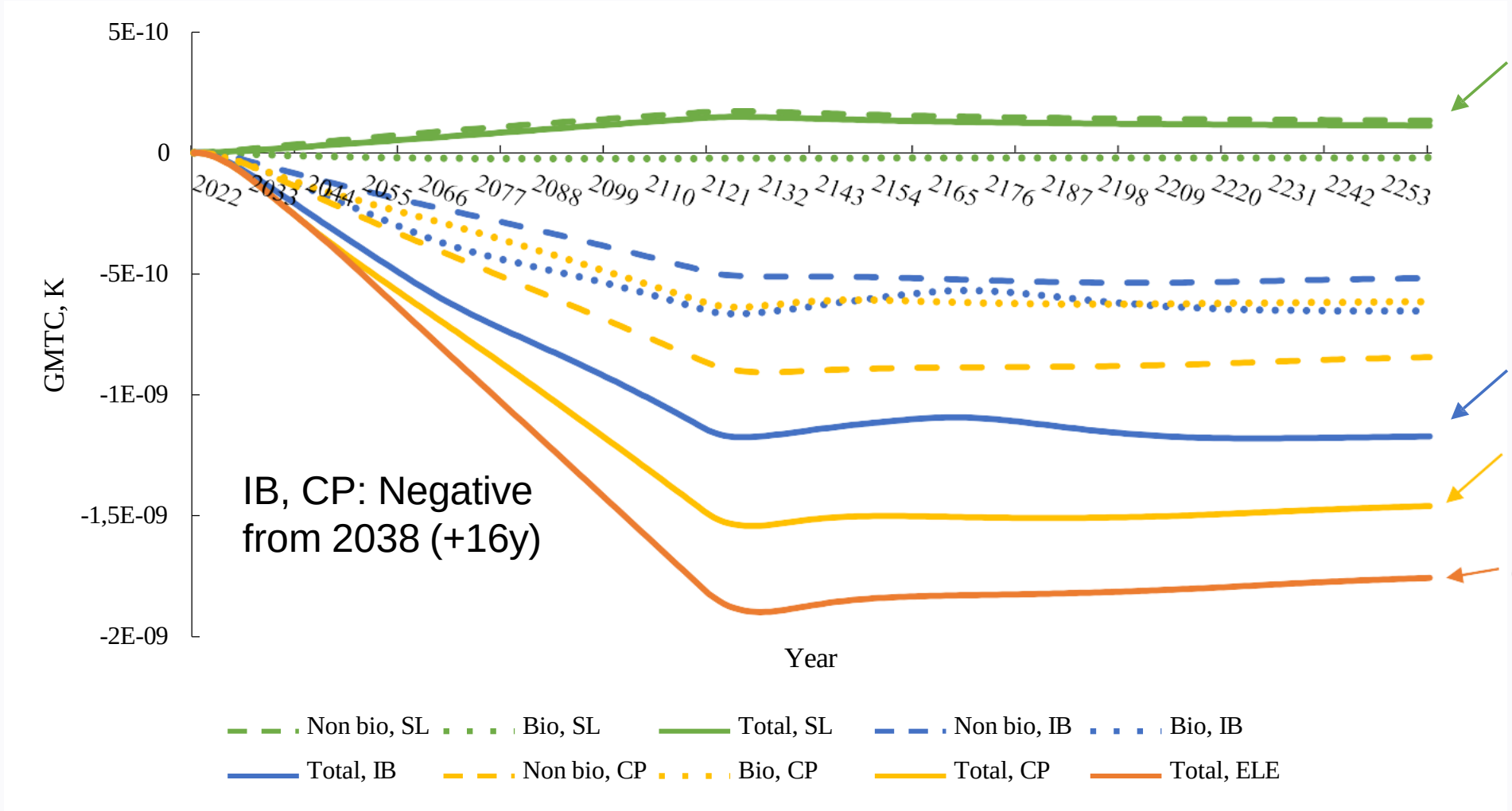


Fig. 5. Dynamic global mean temperature change (GMTC) resulting from the biogenic (bio) and non-biogenic (non-bio) flows for the SL, IB, and CP scenarios and the sensitivity CP sub-scenarios, where electric mobility is considered from 2040 with 42% photovoltaic in the electricity mix (ELE) biogenic: related to the hemp; non-biogenic: related to all other processes.

Some take home messages from this case study

- Beware where you grow it! It's not just SOC changes, but land use changes. Here, +16y for a net negative climate effect [= decreasing global surface temperature] compensating these!

- What you will replace from the 'fossil economy' is what matters most for the environmental performance. Target such applications! Related to 1ha, products appeared to matter more than food (oil) / feed (meal)

- Next steps: Scaling up to a country, in terms of land available, products demanded, and other options (e.g. residual biomass). In a low fossil C economy, how much of the land should we dedicate to hemp, and to produce what, so we have the best environmental performance?

Take home messages from this presentation

- LCA done right matters! ALIGNED project provides useful recommendations in that respect for bio-based products LCAs. Also to address the impact of GHGs in time.
- Accounting for biogenic C, and doing so in time matters for hemp products
- Several products?: track them all, don't make any disappear based on arbitrary, virtual rules
- We are not quite ready on supplying useful input on the biomass/land competition issues at scale (but getting there)
- Whatever can be done without C should be done without (i.e. what can be electrified). But not possible for all services

Acknowledgements

CAMBIOSCOP
Carbon management towards low fossil carbon use
Le Région Occitanie Pyrénées · Méditerranée
INVESTIR L'AVENIR
MAKE OUR PLANET GREAT AGAIN
Liberté · Égalité · Fraternité RÉPUBLIQUE FRANÇAISE
AMBASSADE DE FRANCE EN ÉQUATEUR
INSA
cnrs
INRAE
RÉPUBLIQUE FRANÇAISE Liberté Égalité Fraternité
Université Fédérale Toulouse Midi-Pyrénées
Funded by the European Union

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THANK YOU!

AND SEE YOU SOON

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Funded by the European Union

Horizon Europe grant agreement N° 10105D430. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency. Neither the European Union nor the granting authority can be held responsible for them.