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CropBooster-P

Deliverable 1.3

Title: Digested outcome and recommendations of the workshop regarding YIELD improvement

Start date of the project: **November 1st, 2018** / Duration: **36 months**
Planned delivery date: M8 (June 2019)
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Work package: WP1 / Task: 1.2

Work package leader: ULANC
Deliverable leader: VIB
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1. Introduction

The future demands for our crops will be tremendous, both in terms of level and stability of production and nutritional security. In addition, food systems will have to adapt towards a non-fossil carbon economy and will need to be able to cope with a climatic unstable environment. All these changes will result in the need for high-yielding sustainable crops while maintaining a high nutritional quality. So far, however, Europe has no long-term strategy for future proofing its crops.

How to sustainably increase yields and ensure nutritional quality, i.e. how adapting crops for the future climates of Europe, but doing so with a decrease in inputs such as water, chemical fertilizers and pesticides? To get insight into various aspects of plant improvement, we aim to generate an overview on the current state of crop production within Europe, including breeding methods and technologies, and breeding targets from traits to genes. Compiling this information could contribute to the development of a 'Research toolbox' to help establish the future directions of crop research.

The WP1-'Research toolbox' will comprise an overview of the current and future focus areas and approaches to improve yield. This will include a survey of published scientific literature for all major aspects of crop yield in major, minor and niche crop species. Current and future methods and technologies to improve yield and existing geographical trends will be included in this study. Actual crop yield is the result of yield potential and factors influencing yield, such as environmental stress (drought, heat, cold, etc.). In Task 1.2 (Yield), we will only focus on yield potential. At a later stage, however, the outcome of T1.2 will be combined with the outcome of T1.3 (Sustainability) to obtain an overall view of crop yield determination.

2. Objective

WP1-Task 1.2 aims to map the different existing and future subject areas for yield improvement. We expect these to vary across the diverse agricultural regions of Europe. Literature studies, technology studies (incl. models) and trait studies will be performed to list and collect all available strategies, options and technologies to improve yield in different crop species. This will be a cataloguing exercise ('mapping'), yielding a bibliographic repository and internal database. Ultimately, common strategies/technologies/traits linking yield (T1.2) with nutritional quality (T1.3) and sustainability (T1.4) objectives will be identified and will serve as a basis for discussions with the stakeholders group (SHG). Their expert advice will be an important input to the 'Research toolbox' (T1.5).

3. Work plan for Tasks 1.2, 1.3, 1.4 and 1.5

Overall work plan

To facilitate data collection, and in line with Tasks 1.3 and 1.4, WP1 Task 1.2 is divided into distinct phases:

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1. Definition of the template for data collection (see below), task division among the partners according to their expertise and areas of interest (see below, by end M5)
2. Alignment of the template for data collection with Tasks 1.3 and 1.4
3. Data collection/filling templates (by end M11)
4. Compilation, harmonization and filling the gaps in the collected data
5. Arranging the collected information in a comprehensive format and upload to a central location (as part of T1.5, by end M12)
6. Integrate and digest the output of Task 1.2, 1.3 and 1.4, identify overlaps, trade-offs, etc. and align the data obtained by the different subtasks to generate a 'Research toolbox'.

Data collection template

MAPPING - Bibliography: a comprehensive literature survey to identify traits, and when available, pathways, processes and genes that have the potential to contribute to an increase in yield potential

GAPPING - Gaps: identification of the gaps there are in our current knowledge that may optimize yield in crop species

➔ **A 'mapping' and 'gapping' approach to identify traits, processes, and when available, pathways, processes and genes of which the potential can be exploited using a range of different technologies to increase Yield potential in distinct crops.**

A common template between the subtasks of WP1 (yield, nutritional quality and sustainability) was proposed to be developed to facilitate data collection and assimilation of overlaps between the subtasks for the final deliverable. This template would form the basis of a longer document outlining the current scientific progress and approaches known to improve plant traits. A technical annexe may finally also be included to summarize key technologies and methods to improve crop yield, nutrition quality and sustainability.

4. Partners and fields of expertise

Organisation name	Short name	Country	Area(s) of specialization
Københavns Universitet	UCPH	Denmark	- photosynthesis; regulation of photosynthesis, chloroplast biology, thylakoid membrane - plant development, microProteins, tissue culture
Consiglio Nazionale delle Ricerche	CNR	Italy	- photosynthesis: estimation of the diffusion resistances to CO2 in leaf mesophyll; study of the relationship between electron transport rate and photosynthesis; study of CO2 refixation in leaf mesophyll. - Stress physiology: study of the effect of biotic and abiotic stresses on photosynthesis limitations and plant productivity.

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Organisation name	Short name	Country	Area(s) of specialization
			- Biosynthesis and emission of biogenic volatile organic compounds: study of the relationship between isoprenoid emissions and photosynthesis; study of the relationships between biogenic emissions and environmental pollution. - protein synthesis, structural maturation, transport and degradation in the secretory pathway of plant cells, Protein co-translational and post-translational modifications, Molecular chaperones and enzymes assisting protein structural maturation, Abiotic stress response, Seed storage proteins, Ribosome-inactivating proteins, Wheat structural genomics
Europese Organisatie voor Wetenschappelijk Plantenonderzoek	EPSO	Belgium	EPSO's mission is to improve the impact and visibility of plant science in Europe, providing advice on science policy towards a strategic approach and critical mass funding for basic and applied research across Europe
Heinrich-Heine-Universitaet Duesseldorf	UDUS	Germany	- photosynthetic carbon assimilation and yield, such as C3/C4 photosynthesis, photorespiration, synthetic biology approaches to mitigate the effects of photorespiration. - source/sink relationships and their influence on yield - the role of rapid acclimation to fluctuating environmental conditions (i.e., change in light intensity)
Julius Kuehn-Institut Bundesforschungsinstitut fuer Kulturpflanzen	JKI	Germany	- employing new molecular technologies in agriculture (classic GMO, GE, Synthetic biology), but also novel crops, from basic science to molecular farming or agricultural production/passing statements on the safety of GMO - exploring the application of GE methods in different plants with different traits, technologies to get an overview of GE applications and impacts at the molecular/plant level - genome editing in different plants
Centre National de la Recherche Scientifique	CNRS	France	transmembrane ion transport with strong connexions to: - plant nutrition: nitrate uptake and distribution as well as essential and toxic metal (Fe, Mn, Zn) uptake, transport and seed storage - toxic metal uptake in plants - control of stomatal aperture

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Organisation name	Short name	Country	Area(s) of specialization
			- photosynthetic electron transport, especially regulation of photosystem II, alternative electron transport pathways, production site of the different reactive oxygen species and acclimation responses - biochemistry, metabolic engineering and functional analysis of plant metabolism
University of Nottingham	UNOTT	UK	plant and crop physiology, photosynthesis, agronomy, drought, nutrient use efficiency, nitrogen (predominantly wheat and rice)
Institut National de la Recherche Agronomique	INRA	France	- quantitative genetics, genetic control of tomato fruit quality (sensory and nutritional), fruit and vegetable quality in general - plant and crop physiology (maize, wheat, soybean, pea…), breeding, cultivar and species mixtures - Large-scale phenotyping, genomics, metabolomics… - agronomy, drought, nutrient use efficiency, water use efficiency, nitrogen, major crops, legumes, non-food crops - crop modelling, crop management, GxExM interactions, yield gap analysis, grain yield, biotechnology, - sunflower, soybean, fruits, vegetables
ARVALIS Institut du vegetal	ARVALIS	France	crop nutrition (quantity-quality) and its link with genetics, physiology, nutrient cycling in the soil, climatic and abiotic stress (cereals, maize and potatoes)
Lancaster University	ULANC	UK	improving yield and water/nutrient use efficiency of crops (including tobacco, wheat, rice and cowpea) primarily by manipulating photosynthesis, both by exploiting natural variation and by creating new variation using gene editing, conventional GMO and synthetic biology
Vlaams Instituut voor Biotechnologie	VIB	Belgium	understanding determinants of plant yield (Arabidopsis, wheat, maize) focusing on the identification of the genetic mechanisms underpinning plant organ growth (e.g. cell division and cell expansion) and abiotic/biotic stress responses
Wageningen University and Research	WUR	The Netherlands	photosynthetic physiology and plant environmental physiology, with some crop and plant physiological modelling expertise - both C3 and C4

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5. Meetings and teleconferences

The following F2F meetings and teleconferences took place between D1.2 and D1.3 to discuss the project status and refine the work done in T1.2 (specific for T1.2, or related to T1.1/3/4/5):

- **20th of November 2019 – F2F meeting**
  What? Kick-Off meeting CropBooster-P project in Wageningen
  Who? Partners involved in CropBooster-P project
  Where? WU/WUR, Wageningen, The Netherlands
- **28th of November 2018 – TELECONFERENCE**
  What? Teleconference to set space and general framework of the CropBooster-P project
  Who? Task leaders of WP1 + several WPL
- **13th of December 2018 – TELECONFERENCE**
  What? Kick-off call with SR - Teleconference to explain the concept of scenario building and define an outline of Task 1.1
  Who? Task leaders of WP1 + Sommerrust (SR)
- **17th of January 2019 – TELECONFERENCE**
  What? Status quo call with Sommerrust (overview of trends and key uncertainties obtained through the brain downloading exercise)
  Who? Task leaders Tasks 1.1 and 1.2 + SR
- **22nd of January 2019 – TELECONFERENCE**
  What? Update teleconference with Task leaders of WP1
  Who? Task leaders of WP1
- **24th of January 2019 – F2F meeting**
  What? Handover WPL1 from VIB (Marieke Louwers) to ULANC (Martin Parry)
  Who? Rene Klein Lankhorst, Marieke Louwers, Martin Parry, Jeremy Harbinson and Alexandra Baekelandt
- **31th of January 2019 – TELECONFERENCE**
  What? Status quo call with SR (concerns, comments, initial long list of trends, manage expectations for workshops)
  Who? WPL1 + SR + task leaders WP1
- **18th of February 2019 – TELECONFERENCE**
  What? Update call Task 1.4
  Who? Task leaders WP1 + People of INRA involved in Task 1.4
- **27th of February 2019 - TELECONFERENCE**
  What? Teleconference to provide task update + define the scope of data assimilation and collection format
  Who? Task leaders of WP1
- **15th of March 2019 - TELECONFERENCE**
  What? Teleconference to discuss the format of data collection, level of detail, deliverables and assigned responsibilities according to expertise and areas of interest. Created shared folder for internal data collection. Data collection in progress.
  Who? WP1 Task 1.4 partners
- **3rd of April 2019 – F2F meeting**
  What? F2F Meeting to finalize the common understanding of the output of WP1
  Who? Leader WP1 and task leaders of WP1
  Where? VIB, Ghent, Belgium
- **4th of April 2019 - TELECONFERENCE**
  What? Status quo call with SR (define/rephrase proxy variables, set expectations for 2-day workshop, which are key for the Scenario building exercise)
  *Who? SR + Task leaders of WP1***11th of April 2019 - TELECONFERENCE**

What? Update call Task 1.2 APRIL (overview yield determinants, Milestones & Deliverables, Update on Task 1.1 - Scenario building exercise)
Who? WP1 Task 1.2 partners
Meeting minutes?

- *YIELD POTENTIAL <-> ~~actual yield~~ (YIELD POTENTIAL+SUSTAINABILITY)*
- *Table of content for YIELD determinants needs to be re-circulated to optimize*
- *Keep close contact with Jerome Enjalbert (Task 1.4) – Sustainability → Yield and Sustainability are highly interconnected → Philippe Nacry (new Task 1.4 leader)*
- *~~Crop-centered approach~~ <-> Trait-centered approach -> USE TRAIT AS FOCUS*
- *Processes/Genetic pathways/Genes/Markers as starting point → Transferable/heritable traits → that could be exploited in breeding programs*
- *Crop list → proposed to work with SPECIMEN crops*
  - *orphan species are difficult to include because some favorites may appear, which may result in a dis-equilibrium*
  - *Major versus Minor crops*
  - *~20 crop species are proposed to be feasible to work with*
  - *Proposition: CROP CATEGORIES → SPECIMEN/EXAMPLE crops*

- **12th of April 2019 - TELECONFERENCE**
  What? Preparation for 2-day workshop event WP1 Task 1.1
  Who? Task leaders WP1 + Sommerrust + some SHG participants
- **16-17th of April 2019 - F2F meeting - WORKSHOP**
  What? 2-day Scenario building workshop event; Day1 → scenario building workshop, Day2 → impact workshop
  Who? Day1→ core team (Project coordinator + WP leaders, Task leaders of WP1, Sommerrust), Day2 → core team + SHG (determined by Task1.1) + EU policy members
  Where? plantETP, Brussels, Belgium
- **7th of May 2019 – F2F meeting**
  What? F2F Meeting to define the scope of WP1 (Determine Crop list, Determine which data the Database should capture)
  Who? Project Coordinator + WP leaders + Task leaders of WP1
  Where? VIB, Ghent, Belgium
- **10th of May 2019 – F2F meeting**
  What? Initiation to Database Sharepoint (Surveys) – Marc Cornelissen
  Who? Task leader T1.2 – Marc Cornelissen
- **13th of May 2019 - TELECONFERENCE**
  What? Update call Task 1.2 MAY (Update on Task 1.1 Scenario building exercise, Milestones & Deliverables, Crops: need to have vs. nice to have, proposition of Database outline that may be used for data collection)
  Who? WP1 Task 1.2 partners
  Meeting minutes?
  - *There should be a tight/close interconnection between Yield (Task 1.2) and Sustainability task (Task 1.4). Also regular discussion to avoid redundancy/too much overlap.*
  - *The Crop list was overall well approved by the partners involved in Task 1.2, there were few suggestions:*
    - *change the Crop category 'OTHERS' to 'FRUITS'*
    - *change the category 'ROOT STAPLES' to 'ROOT STAPLES/BELOW-GROUND PARTS'*
    - *ALGAE, for the moment only macroalgae/multicellular algae are represented → Example species/Specimen crops will have to be revised with the group of Jonas Collen (Roscoff).*
  - *In this task, we are NOT collecting text and/or writing text, we are collecting literature/references. In a later stage, however, the collected references could be summarized in short paragraphs of text, but how this will be done is not clear for now.*

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- *The Table of content for YIELD (Yield determinants) is a pillar for Task 1.2. Table of content will be used to collect the literature data in a TRAIT-CENTERED manner (<-> crop-centered). It is an absolute requisite to re-circulate the Table of content for YIELD (YIELD DETERMINANTS).*
- *The Database proposed for Data collection should also be usable from non-Microsoft based systems such as LINUX or APPLE. Also it should contain a structured language, allowing too much free text will unnecessarily complicate the Data collection procedure.*
- *The deadline for Data collection is mid/end of September.*
- *Quite a lot of stakeholders are interested to be involved in the process of Data collection (e.g. to identify or fill putative gaps with references/literature based on their expertise). Therefore, it would be good to involve the Stakeholders in this process at a later stage of Data collection allowing them to further complete the Data collection/Database.*

- **14th of May 2019 - TELECONFERENCE**
  What? Database format discussion - Sharepoint (Survey) – Marc Cornelissen
  Who? Task leaders WP1
- **28th of June 2019 - TELECONFERENCE**
  What? Update call Task 1.2 JUNE (overview of the revised Yield determinants, Database headers, Sharepoint vs. Microsoft forms vs. Google forms)
  Who? WP1 Task 1.2 partners
  Meeting minutes?
  - *Ideally the Database should be designed in such a way that it allows to extract information on how relevant a certain trait is for a certain crop (e.g. by including more crop-specific questions).*
  - *It could be extremely useful to automatically extract information based on the DOI (e.g. author, year, abstract, etc.). This would drastically reduce the time needed to enter a publication.*
- **25th of June 2019 – F2F meeting**
  What? ExCom meeting discussing the progress of the CropBooster-P project
  Who? Project coordinator + WP leaders + Task leaders of WP1
  Where? ULANC, Lancaster, UK
- **2nd of July 2019 – TELECONFERENCE**
  What? Linking Yield and Sustainability for the Database format
  Who? Task leader T1.2 and T1.4

<u>The following F2F meetings and teleconferences are scheduled in the future:</u>

- **July 2019 (exact date to be determined) - TELECONFERENCE**
  What? Finalize template and data collection model
  Who? Task leaders WP1
- **August 2019 (exact date to be determined) - TELECONFERENCE**
  What? Follow up call Task 1.2 JULY-AUGUST
  Who? WP1 Task 1.2 partners
- **September 2019 (exact date to be determined) - TELECONFERENCE**
  What? Follow up call Task 1.2 September
  Who? WP1 Task 1.2 partners
- **11th of September – F2F meeting**
  What? Update F2F meeting on progress within WP1 and discussion of the transfer to WP2
  Who? Participant list is not yet finalized
  Where? VIB, Ghent, Belgium

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6. WP1 Task 1.1 – Input for 2-day Scenario Building workshop (Brussels)

In preparation for the 2-day Scenario building workshop (Brussels), a list of trends/issues was collected within T1.1, involving all the partners. These lists were compiled, duplicates were removed and additional trends were added, rendering a final list of trends considered to be relevant for CropBooster-P since they can affect crop Yield (T1.2), Nutritional quality (T1.3) and/or Sustainability (T1.4).

These trends were then further processed into trend cards which capture the key aspects of each trend, including facts and figures, examples of key stakeholders and influencers, related sub-trends and the relevance for the CropBooster-P project. Subsequently, the trends cards were used during the 2-day Scenario building workshop event (T1.1) to generate the distinct scenarios.

List of trend considered for Scenario Building

Trends (in alphabetical order):

1) Aging Population
2) AI & Big Data
3) Alternative Nutrition Sources
4) Animal Welfare
5) Biofortification
6) Biotech
7) Blockchain
8) Cheaper Food
9) Circular Bioeconomy
10) Climate Change
11) Cultivar / Species Mixtures
12) Decline of Pollinators & Biodiversity
13) Declining Chemistry for Pest Control
14) Diet-related Chronic Diseases
15) Do-it-Yourself
16) E-Commerce
17) Economic Pressure on Farms
18) Electrification
19) Environmental Concerns
20) Fair Trade
21) Globalization
22) Healthy Lifestyle
23) ICT on the Rise
24) Increased Mechanisation
25) Intellectual Property
26) Land-Use Pressure
27) NBTs & Genetic Modification
28) Offering of Meat Alternatives
29) Organic Farming
30) Plant Beneficial Microbes
31) Population Growth
32) Power of the Online Public
33) Product & Research Regulation
34) Public Engagement in Research
35) Reduction of / Altered Genetic Resources Circulation
36) Renewable Energy
37) Resource Scarcity
38) Rising Disposable Income
39) Risk Sensitivity
40) Robotics
41) Self-Tracking / Quantified Self
42) Sustainability
43) Transparency
44) Urban Farming / Greenhouses
45) Urbanization

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Example of a trend card

Trend Card

Plant Beneficial Microbes

Description

As the discovery of new synthetic pesticides has become increasingly costly, the biopesticide market has been growing, including the exploration and use of plant beneficial microbes. These can act preventatively, suppress diseases, enhance the availability of nutrients and promote plant growth and rooting.[1]

Facts & Figures

- Increasing investment of agri start-ups in microbiome[2]
- Ca. €400M spent on "microbiome related research" in the first 2 years of H2020 (EU), investment up to €130M foreseen until 2020[3]
- The global human microbiome market would be worth USD 0.3 billion by 2019, and reach USD 0.7 billion by 2023[4]
- Rising number of scientific papers on microbiome research (2769 [2012] to 8431 [2016][5]

Stakeholders & Influencers

- Researchers/startups (seek funding, innovate)
- Consumers (demand)
- Farmers (supply)
- Supermarkets/retail (promotion)
- Government (regulation)
- NGOs (certification)

Related (Sub-)Trends

Pesticide free agriculture, Sustainability, Bio Boom

Relevancy: CropBooster-P

- Influence on land use, crop sustainability and productivity
- Reduced acceptance of conventional CPM
- Influence on food prices
- Enable new business models
- Certification and regulation (synthetic pesticides/fertilizers vs. biologicals)

Sources: [1]Poleatewich, A. (2018), "Utilizing beneficial microbes in a systems approach to plant disease management". [2]Waltz E. (2017), "A new crop of microbe startups raises big bucks, takes on the establishment", Nat Biotechl. 8;35(12):1120-1122. [3]EU MICROBIOME R&IMAPPING, DG RTD presentation. [4]OECD (2017), "The Microbiome, diet and health: Towards a science and innovation agenda", OECD Science, Technology and Industry Policy Papers, No. 42, OECD Publishing, Paris. [5]European Commission, Directorate-General for Research and Innovation (2018) Study on mission-oriented r&i on food system microbiomes by A. Malyska,

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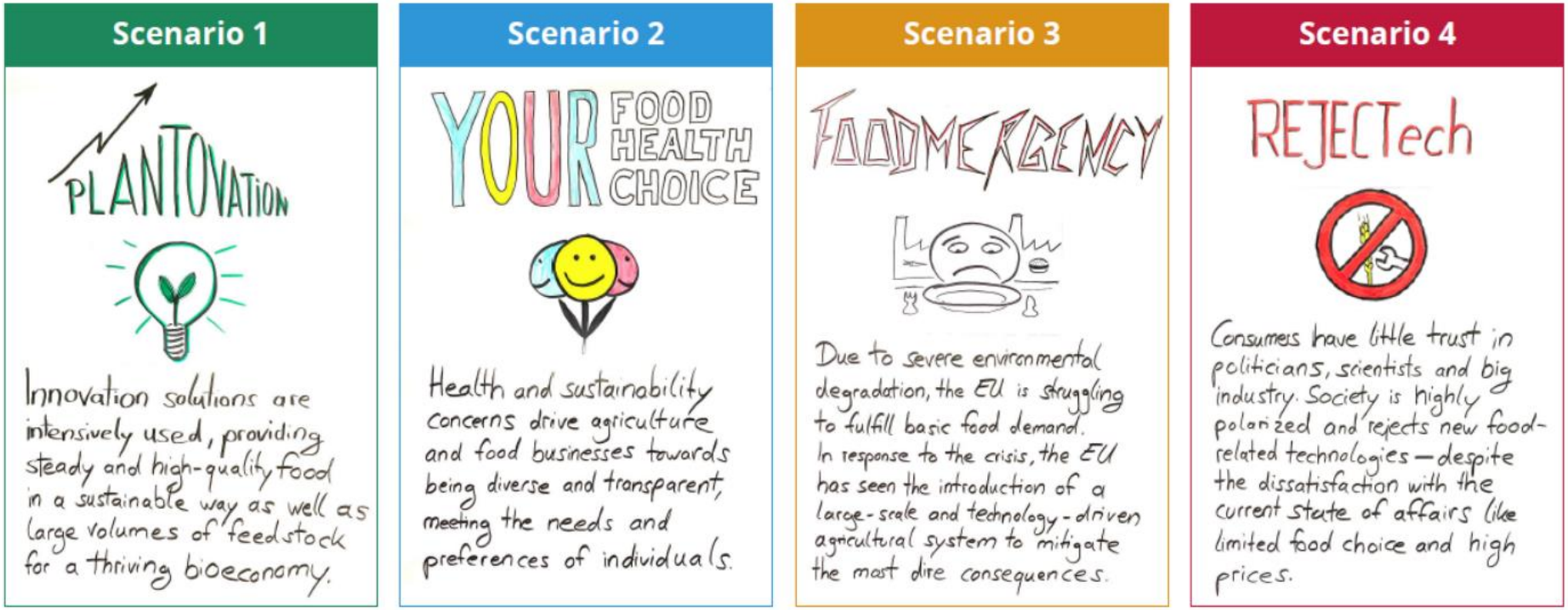
7. Outcome WP1 Task 1.1 – 2-day Scenario Building workshop (Brussels)

Based on the trend card information and proxy variables raising questions regarding crop production in the future, four distinct scenarios were developed:



The four scenarios cover a wide range of outcomes which may affect distinct aspects of Yield, Nutritional quality and Sustainability. Some of the putative impacts of the distinct scenarios on Yield, Nutritional quality and Sustainability are listed below:

Scenario 1 - Plantovation

- Fibres, high value crops
- High value compounds/phytochemicals
- Super-crops pushing the limits of yield/area

Scenario 2 - Your food, your health, your choice

- High value compounds, superfoods
- Alternative plant protein sources
- GM alternatives

Scenario 3 - Foodmergency

- Calories are the most important - Focus on sugars and fats
- Short growing time
- Robust crops
- Concerns on soil quality/nutrient availability

Scenario 4 - Rejectech

- Alternative crops/ancestral cultivation
- Alternative nutrition sources may be required to meet the lack of biomass/yield

8. Assessment and digestion of the outcome and recommendations of the workshop for T1.2

a. Framework for data collection proposed to the participants of the workshop

Traits, processes and pathways WITHIN the scope of CropBooster-P WP1:

- Current trends/state of crops within Europe
- Traits to improve or maintain yield, nutritional quality either under favourable or unfavourable environments
- Traits to improve and optimize crop yield
- Crop nutrient availability
- Breeding technologies relevant for nutrient use efficiency, uptake and metabolism
- Transferable technologies
- Synthetic biology
- Aquatic crops
- Niche/underdeveloped/potentially beneficial crops
- Food and fodder crops
- Specialized metabolites with nutritive scope
- Toxic compounds/anti-nutrients and their accumulation in unfavourable growth conditions

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- Pathways, genes, QTLs, etc. involved in determining yield and their orthologues
- Trade-offs between nutrition and yield and sustainability (contributing to WP1.5)
- Spatial distribution of nutrients and partitioning

Traits, processes and pathways OUTSIDE the scope of CropBooster-P WP1:

- Nutrient trends outside Europe/non-European crops
- Non-heritable traits/traits without genetic basis
- Social/ethical/environmental/physical factors (e.g. GMO debate, global warming, etc.)
- Projections - predicting trends for the future
- Crop management-related traits
- Biotic stress (e.g. pathogens, pests, microorganisms, etc.)
- Organoleptic traits (e.g. taste, smell, mouth feeling, etc.)

b. Feedback from the participants at the scenario building workshop, F2F and teleconferences meetings

✓ **'Toolbox' format** *(cfr. How should the 'toolbox' that is generated in WP1 look like?)*

- Favouring a searchable database as output, which is easy accessible and can continuously be updated as new information/technologies arise.
- Compiling the 'Toolbox' into an encyclopedia format was suggested to be unnecessary as this would easily be out of date.

➔ **Outcome:** 'Toolbox' will not have an encyclopedia- like format, but is likely to comprise short reports capturing the literature and outlining putative trade-offs with other tasks, as well as a searchable spreadsheet that contains the main information for each gene/trait analysed. The spreadsheet will be generated from smaller Surveys. Each Survey will add a line of text/data in the final spreadsheet.

✓ **Crops** *(cfr. Which CROPS should be included in the work that is done in WP1?)*

- The suggested list of priority crops which will be considered in the database should also include vegetable, fruit, fibre producing species and algae examples.
- Niche crops could be considered in a separate category distinct from priority crops, to ensure important information is preserved

➔ **Outcome:** The Survey used for Data collection will include the option to add additional/not predefined e.g. crops, traits, pathways, etc. to not limit the input (free text).

Based on the comments during the 2-day workshop and on the F2F meeting organized in Ghent (7th of May) the list of crops was established (crops in **green, bold and underlined** will be investigated in priority):

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Algae
- Saccharina spp (kelps)
- **Laminaria (kelps)**
- **Porphyra**
- **Ulva**

Forage grasses / fodder
- **Lolium** (rye grass)
- **Alfalfa**
- Clover
- Sugarcane
- Miscanthus

Grain staples
- **Wheat**
- Barley
- Rice
- **Maize**
- Sorghum
- Secale (rye)
- Oats
- Durum wheat
- Millet

N2-fixers
- Field bean
- **Soybean**
- Lupin
- **Pea**
- clover

Oilseed
- **Sunflower**
- Soybean
- **Rapeseed**
- Olive
- maize

Vegetables
- **Tomato**
- Leafy vegetables (spinach)
- **Lettuce**
- Brassica's (broccoli, cabbages)
- Pea
- Carrots
- Parsnip
- Grapes

Fibre & lignocellulose
- Hemp
- **Poplar**
- Willow
- **Miscanthus**
- Switchgrass
- Douglas
- Sitka
- Eucalyptus
- Spruce

Root staples/below-ground part
- **Potato**
- **Sugar beat**
- Onion

Model plants
- **Arabidopsis**
- **Tobacco** (important with regard to plastid transformation – photosynthesis)
- **Rice**
- Spinach (relatively older publications)
- Maize

Fruits
- **Grape**
- **Pome** (apple, pear)
- Citrusses
- Olive trees
- Strawberries
- Raspberries

✓ **Traits** *(cfr. Which TRAITS should be included in the work that is done in WP1?)*

- The major traits pertaining to Sustainability, and considered within the CropBooster-P template for data collection belongs to *Photosynthesis: photochemistry and biochemistry*, *Sink/source activity*, *Resource management* and *Plant growth, architecture and phenology***.** Their relevance will be considered for major crops, niche crops/underutilized crops, and aquatic crops.
- Some literature may correspond to distinct traits, it should be feasible to add this when completing the Survey.
- Though most Yield determining traits are presented in the list shown, some may still be missing.
- There should be a close connection between Task 1.2 (Yield) and Task 1.4 (Sustainability), since for most traits Yield and Sustainability are interlinked.

➔ **Outcome:** Space will be available in the Surveys used for Data collection to add specific traits, stresses and crops as some may not be included in the Survey. Pest, microorganism and

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pathogen interaction-related traits (biotic stress) are out of the main scope of the CropBooster-P project. However, within the Survey it will be possible to mark traits of outstanding interest for which there is a plant genetic basis (free text).

✓ **Technologies** *(cfr. Which TECHNOLOGIES should be included in the work that is done in WP1?)*

- All known technologies will be considered.

➔ **Outcome:** Most technologies are presented/included in the Survey that will be used for Data collection. Nonetheless, space will be made available in the Surveys to add additional technologies (free text).

c. Revised template for data collection

Based on the input of the Stakeholders, results from the WP Task 1.1 Scenario building exercise and several extensive discussions (F2F meetings and teleconferences), a revised framework for Data collection was generated. In Tasks 1.2/3/4 data will be collected in the form of a common Survey, with **(1) a section that is common for Tasks 1.2/3/4** and **(2) a section that is specific for Tasks 1.2 (Yield) and 1.4 (Sustainability)**, detailed in the following paragraphs.

(1) Section common for Tasks 1.2/3/4

Column	Column information	Column 'choices'
Scale (by climate)		**Mediterranean**, humid subtropical, marine, humid **continental**, **subarctic**, **tundra** and **highland, other**
If other, specify		
Relevance to cropbooster	Eg. Increased canopy cover, increases biomass	Free text
Species group type	Eg. Algae, forage grasses	**Algae** **Forage grasses** **Grain staples** **N2 fixers** **Oilseed** **Vegetables** **Fibres and lignocellulose** **Root staples** **Model Plants** **Other**
If other, specify		
Species	(split per species group type? – see earlier)	Fucus, **Laminaria, Porphyra, Ulva** **Ryegrass, Alfafa,** Clover, Sugarcane, Miscanthus **Wheat,** Barley, Rice, **Maize**, Sorghum, Rye, Oats, Durum wheat, Millet, Field bean, **Soybean,** Lupin, **Pea,** Clover **Sunflower**, Soybean, **Rapeseed**, olive, maize **Tomato**, leafy vegetables (spinach), **Lettuce**, Brassicas, Pea, Carrots, Parsnip, Grapes, Hemp, **Poplar,** Willow, **Miscanthus,** Switchgrass, Douglas Sitka, Eucalyptus, Spruce, **Potato, Sugarbeet**, Onion **Arabidopsis, Tobacco,** Rice, Spinach, Maize **Grape, Pome,** Citrus, Olive, Strawberry, Raspberry, other
If other, specify		

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Method summary*	Technologies employed to achieve y/n/s effect	Conventional Breeding Populations/Mapping, Magic, Diversity Sets MAS GWAS Mutant Populations Tagged populations Mutagenesis Epimutation TILLING Transposon Mobilisation Metabolic design Conventional GMO Gene Editing Plastid transformation Synthetic Biology Modelling Phenotyping Speed Breeding other
If other, specify		
Yield benefit**		Yes/ no
Yield benefit- how**		Free text
Nutrition benefit**		Yes/no
Nutrition benefit-how**		Free text
Sustainability benefit**		Yes/no
Sustainability benefit - how**		Free text
Biological process	Eg. respiration	TBD (L1-5, specific for the Task 1.3 and Task 1.2/4)
Genetic pathway (if applicable)		Free text
Genes involved		Free text
Orthologues?		Yes/no
Orthologues in which crops		Free text
Bibliographic reference(s)		Free text
title		Free text
abstract		Free text
uniprot		Free text
PMID		Free text
Transferability potential		Yes/ no
Comments on transferability		Free text
What technology would make this example transferable?	CRISPR, GMO	Free text
General comments		

*This could help build into the technical annexe

**This could allow to determine correlations and trade-offs for WP Task 1.5

The columns for data collection will be used as the basis for a clickable Survey. Based on the features selected in this section, participant will be redirected to the specific Task of which the entry is related to. The data entered will serve as a platform to integrate the final data, as well as identify and link commonalities among Tasks.

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(2) Section specific for Tasks 1.2 (Yield) and 1.4 (Sustainability)

Based on the extensive discussions between Tasks 1.2 (Yield) and Task 1.4 (Sustainability), a template was generated that fits both tasks by structuring the content in five Levels (L1-L5). First of all, partners involved in Task 1.2 and Task 1.4 will be asked to complete the sections from a Yield or Sustainability perspective (L1). Subsequently, the Survey template addresses the following Major Traits (L2):

- *Photosynthesis: photochemistry and biochemistry*
- *Sink/source activity*
- *Resource management*
- *Plant growth, architecture and phenology*

These Major traits (L2) were subsequently further refined in Traits and Sub-Traits (L3-L4). L5 allows to add factors that influence the corresponding Traits. The aim of this data collection strategy is to precisely identify genes and traits that can be improved or targeted to increase Yield or change Sustainability. The data generated by the Surveys will then serve as the basis for the report in Task 1.5.

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The detailed list of Levels (L1-5) that will be used for Data collection in Tasks 1.2 (Yield) and Task 1.4 (Sustainability):

L1	L2	L3	L4	L5 (factors affecting yield)
Yield	Photosynthesis - photochemistry and biochemistry	Photochemistry	Light harvesting Light capture optimisation Pigment composition Light use efficiency (electron transport) Other	Stress - Nutrient deficiency Stress - Nutrient overload/form/quality Stress - Drought Stress - Flood Stress - Heavy metals Stress - Salinity Stress - Heat Stress - Cold/Frost Stress - pH Stress - ozone, UV, oxidative Stress - Light Stress - Photoperiod Stress - Physical constraints (soil compaction, hail, wind, sun…) Stress - High humidity Stress - Soil composition Stress - Bio stimulants Stress - Microbes in the rhizosphere Stress - Toxicity
		Biochemistry – Carbon assimilation	Stomatal aperture Rubisco and other Calvin cycle enzymes Photosynthetic limitations (cofactor, TPU) Chloroplast-cytosol transporters Sucrose - starch balance Photorespiration Dark (mitochondrial) respiration Photosynthetic pathway (C4, C3, CAM, C3-C4 intermediary) Sugar pathways Photoacclimation Photosynthetic induction Other	
		Biochemistry - Photoprotection	NPQ Mehler reaction Repair pathways (Oxidative stress) Photosynthetic by-products Protective molecules Sugars and osmolytes Photosynthetic antioxidants Other	

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Yield	Uptake and spatial management of resources	Water and Nutrient uptake/assimilation vs use	Water and Nutrients uptake (transporter channel regulators…)	
		Primary and secondary metabolism	Osmolytes, Proteins and Metabolic compounds accumulation	
		Nutrient use efficiency (NutUE)	Local Water and Nutrients transport (root, stem and leaf tissues) Long distance Water and Nutrients transport (xylem) Nutrient metabolism Nutrient partitioning Nutrient storage Nutrients recycling Alternative metabolic pathways Ion homeostasis Other	
		Heavy metals and salt	Uptake (transporter channel regulators…) Local and long distance transport metabolism partitioning storage Alternative metabolic pathways Ion homeostasis	
		Other		

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Yield	Sink/source activity	Nutrient metabolism, transport, remobilization and partitioning	Sucrose metabolism (source) Nutrient metabolism (source) Water and nutrients storage Storage compound metabolism (source) Carbon transfer Nutrient transfer Coordination of C and Nutrient assimilation Other micronutrients Other	
		Source sink balance	Sink to source feedback Source to sink feedforward Senescence of source organs Sink/grain development Seed filling Senescence of sink organs Other	
		Other		

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Yield	Plant growth, architecture and phenology	Shoot architecture anatomy and canopy profile	Phyllotaxy Self-shading Compactness Stem anatomy and composition Shoot and canopy hydraulics Vascular tissues anatomy (density, structure) and functioning Organisation of photosynthetic resources Leaf angle (erectness) Leaf morphology/shape Organ length/width/strength Wound healing Other	
		Leaf anatomy and activity	Cuticular thickness Wax/cutin ratio and content Stomatal properties (morphology, densities, distribution, location, aperture and functioning) Mesophyll thickness Mesophyll conductance Mesophyll resistance Mesophyll structure CAM/C3/C4 intermediary structure Vascular tissues anatomy (density, structure) and functioning Leaf hydraulics Stomatal aperture and functioning regulation Organelle properties (density, positioning and movement) Cellular, subcellular and ultrastructural adaptations Wound healing Other	

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		Growth rate	Meristem activity Cell division Growth mechanics Cell expansion Cell wall composition Cell turgor Other	
		Root architecture, anatomy and activity	Root length Root number (lateral, seminal, adventitious) Root growth angle Root density Root plasticity Root competition ability Root hydraulics Cell layer number Cells layer structure Aerenchyma (PCD) Cell division/elongation Cell wall composition Lignification, Suberisation Cellular, subcellular and ultrastructural adaptations Wound healing Storage capacity Respiration Exudation Other	
		Root/shoot coordination	Root/shoot ratio Root/shoot transport and signalling Other	

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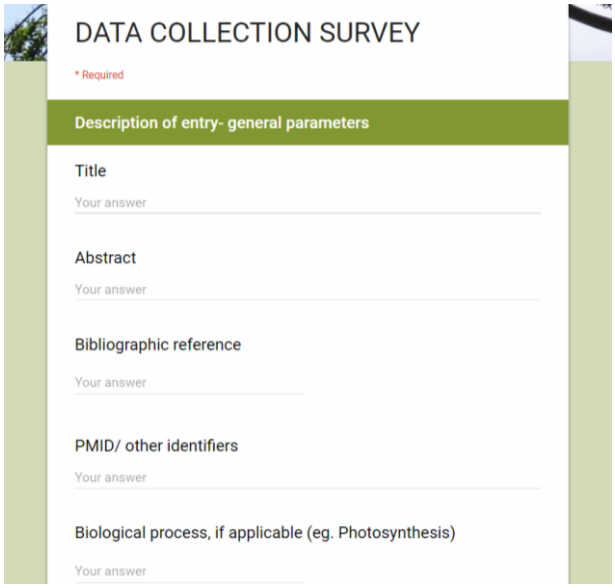
		Phenology	Reproductive switch Flower development/abortion Flowering time Flower number Fertilization and seed set efficiency Seed number/abortion Seed filling rate Inflorescence plasticity Early vigour Ageing/senescence/juvenility Plastid/chloroplast lifetime Stay-green Other	

d. Data collection - Survey construction

Based on the **(1) section that is common for Tasks 1.2/3/4** and the **(2) section that is specific for Tasks 1.2 (Yield) and 1.4 (Sustainability)**, a data collection Survey is currently being designed. Also the input of all partners involved in WP1 was included as much as possible when generating this Survey. A final version of the Survey ready for Data collection within Tasks 1.2, 1.3 and 1.4 is expected to be launched between mid/end of July, 2019.



Extract from the current version of the data collection survey.

9. ExCom meeting

The following points were extensively discussed during the ExCom meeting and/or all other F2F meetings and teleconferences:

1. Bibliographic review should be performed at the TRAIT scale, and when possible, at pathway and gene levels. Some of the key traits will not have clear genes/pathways. Nonetheless, the focus should be on transferable/heritable traits.
2. Traits involved in plant-to-plant interactions: light/nutrient/molecular cues and related pathways used by the plants to detect neighbour plants and adapt their growth/metabolism are currently under-represented in the list of traits considered in T1.2, T1.3 and T1.4.
3. Traits involved in plant/soil micro-organisms interactions, e.g. root exudates are currently under-represented in the list of traits considered in T1.2, T1.3 and T1.4.
4. It was recommended to include the four scenario generated during the 2-day scenario building workshop event in the Survey and thus in the Database.

5. Traits involved in plant-pathogen interactions, including physical/chemical processes linked to plant/tissue chemical and structural composition, from metabolism to architecture are currently under-represented in the list of traits considered in T1.2, T1.3 and T1.4.

➔ Points 1, 2, 3 and 4 were integrated in the template for Data collection, whereas 5 was considered out of the scope of CropBooster-P.

6. The database should contain only a relatively small number of key papers by experts in the field to set the stage for the different traits. In addition, a number of recent publications will be added per trait and sub-trait to capture the current state-of-the-art. Also the stakeholders will get the opportunity to propose entries for the database. The overall feeling is that the database will contain no more than approx. 500 entries.
7. It would be good to develop an 'Ecosystem Services'-based vision in CropBooster-P. The T1.4 group has proposed a reduced and manageable list of services, derived from Costanza et al. 1997, see hereafter) and its interest for WP1. At a later stage, the Ecosystem services could also be used to link WP1 to WP2 & WP3.

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Costanza et al. « The Value of the World's Ecosystem Services and Natural Capital », Nature, 1997

#	ECOSYSTEM SERVICE*	ECOSYSTEM FUNCTIONS	EXAMPLES
1	**Gas regulation**	Regulation of atmospheric chemical composition.	CO_2/O_2 balance, O_3 for UVB protection, and SO_x levels.
2	**Climate regulation**	Regulation of global temperature, precipitation, and other biologically mediated climatic processes at global or local levels.	Green-house gas regulation, DMS production affecting cloud formation.
3	**Disturbance regulation**	Capacitance, damping, and integrity of ecosystem response to environmental fluctuations.	Storm protection, flood control, drought recovery, and other aspects of habitat response to environmental variability mainly controlled by vegetation structure.
4	**Water regulation**	Regulation of hydrological flows.	Provisioning of water for agricultural (e.g., irrigation) or industrial (e.g., milling) processes or transportation.
5	**Water supply**	Storage and retention of water.	Provisioning of water by watersheds, reservoirs, and aquifers.
6	**Erosion control and sediment retention**	Retention of soil within an ecosystem.	Prevention of loss of soil by wind, runoff, or other removal processes, storage of silt in lakes and wetlands.
7	**Soil formation**	Soil formation processes.	Weathering of rock and the accumulation of organic material.
8	**Nutrient cycling**	Storage, internal cycling, processing, and acquisition of nutrients.	Nitrogen fixation, N, P, and other elemental or nutrient cycles.
9	**Waste treatment**	Recovery of mobile nutrients and removal or breakdown of excess or xenic nutrients and compounds.	Waste treatment, pollution control, detoxification.
10	**Pollination**	Movement of floral gametes.	Provisioning of pollinators for the reproduction of plant populations.
11	**Biological control**	Trophic-dynamic regulations of populations.	Keystone predator control of prey species, reduction of herbivory by top predators.
12	**Refugia**	Habitat for resident and transient populations.	Nurseries, habitat for migratory species, regional habitats for locally harvested species, or over wintering grounds.
13	**Food production**	That portion of gross primary production extractable as food.	Production of fish, game, crops, nuts, fruits by hunting, gathering, subsistence farming, or fishing.
14	**Raw materials**	That portion of gross primary production extractable as raw materials.	The production of lumber, fuel, or fodder.
15	**Genetic resources**	Sources of unique biological materials and products.	Medicine, products for materials science, genes for resistance to plant pathogens and crop pests, ornamental species (pets and horticultural varieties of plants).
16	**Recreation**	Providing opportunities for recreational activities.	Eco-tourism, sport fishing, and other outdoor recreational activities.
17	**Cultural**	Providing opportunities for non-commercial uses.	Aesthetic, artistic, educational, spiritual, and/or scientific values of ecosystems.

*We include ecosystem "goods" along with ecosystem services.

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10. Future deliverables

The following deliverables are scheduled for WP1 Task 1.2 and 1.5:

Number	Deliverable Title	Lead beneficiary	Type	Dissemination level	Delivery month
D1.8	Deliver Matrix and Report discussing strategy forward for future plant research in Europe that can be used as input for subsequent WPs – Report of recommendations, gaps, enablers in the identified toolbox	VIB	Report	Public	M12