LIFE Project Number

LIFE17 ENV/IT/000347

Final Report

Covering the project activities from 01/10/2018 to 30/09/2022

Reporting Date

30/12/2022

LIFE PROJECT NAME or Acronym

LIFE SUBSED

Data Project

Project location:	Italy, Spain
Project start date:	01/10/2018
Project end date:	30/09/2022
Total budget:	€ 1,745,524
EU contribution:	€ 1,046,731
(%) of eligible costs:	59.97%

Data Beneficiary

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Package completeness and correctness check	
Obligatory elements	**✓ or N/A**
Technical report	
The correct latest template for the type of project (e.g. traditional) has been followed and all sections have been filled in, in English *In electronic version only*	✓
Index of deliverables with short description annexed, in English *In electronic version only*	✓
Final report: Deliverables not already submitted with the MTR annexed including the Layman's report and after-LIFE plan *In electronic version only*	✓
Financial report	
The reporting period in the financial report (consolidated financial statement **and** financial statement of each Individual Beneficiary) is the same as in the technical report with the exception of any terminated beneficiary for which the end period should be the date of the termination.	✓
Consolidated Financial Statement with all 5 forms duly filled in and signed and dated	✓
Financial Statement(s) of the Coordinating Beneficiary, of each Associated Beneficiary and of each affiliate (if involved), with all forms duly filled in (signed and dated). The Financial Statement(s) of	✓
Amounts, names and other data (e.g. bank account) are correct and consistent with the Grant Agreement / across the different forms (e.g. figures from the individual statements are the same as those reported in the consolidated statement)	✓
Mid-term report (for all projects except IPs): the threshold for the second pre-financing payment has been reached	✓
Beneficiary's certificate for Durable Goods included (if required, i.e. beneficiaries claiming 100% cost for durable goods) *Electronically Q-signed or if paper submission signed and dated originals* and in electronic version (pdfs of signed sheets)*	n/a
Certificate on financial statements (if required, i.e. for beneficiaries with EU contribution ≥750,000 € in the budget) *Electronically Q-signed or if paper submission signed original and in electronic version (pdf)*	n/a
Other checks	
Additional information/clarifications and supporting documents requested in previous letters from the Agency (unless already submitted or not yet due) *In electronic version only*	✓
This table, page 2 of the Final report, is completed - each tick box is filled in *In electronic version only*	✓

**signature by a legal or statutory representative of the beneficiary / affiliate concerned*

1. Table of contents

2. List of keywords and abbreviations

AB: Associated Beneficiary
ANOVA: Analysis of Variance
C> 12: heavy hydrocarbons
CB: Coordinator Beneficiary
CV: cultivar/variety
EoW: End of Waste
KPI: Key Performance Indicator
LCA: Life Cycle Assessment
MtR: Mid-term report
PAHs: polycyclic aromatic hydrocarbons
TA: titratable acidity
TOC: Total Organic Carbon
TSS: Total Solid Soluble

Keywords:
sustainability; dredging; reuse; phytoremediation; substrate; horticulture; floriculture; nursery; end of waste; propagation; contaminants; food safety; circular economy

3. Executive Summary

This report summarizes the activities carried out within the LIFE SUBSED project "Sustainable substrates for agriculture from dredged remediated marine sediments: from ports to pots" (LIFE17 ENV/IT/000347) from its beginning (01/10/2018) to its end (30/09/2022).

The main aim of the SUBSED project is to demonstrate the suitability of a waste (the dredged marine sediment) for producing a commercial substrate through the application of environmentally and economically sustainable techniques.
This project further exploited the results achieved during various previous EU projects (AGRIPORT - ECO/08/239065/S12.532262, CLEANSED – LIFE12 ENV/IT/000652 and HORTISED -LIFE14 ENV/IT/000113), which validated different approaches for sediment reuse and demonstrated the suitability of phytoremediation for remediation of moderately polluted sediments to be used as ingredient for sustainable growing media for ornamental plants and food crops. LIFE SUBSED started from this legacy to confirm and define more in detail the formulation of a sediment-based commercial substrate to be offered to nursery, horticulture and floriculture.

One of the pillars of the LIFE SUBSED project is the review of EU and National regulations on the use of sediments for plant nursery. There is a wide legislation on the management of dredged sediments and on the substrates usable in agriculture, but this is non harmonized at international level and poses relevant barriers to the application of sustainable approaches for the reuse of waste in agriculture. For example, the original SUBSED proposal did not take in consideration the need for an authorization for the demonstration trials, due to the non-hazardous nature of the sediments. Nevertheless the Italian legislation, for each type of waste, requires a specific authorisation even for experimental trials, as stated in D.Lgs. 152/2006 art. 211; the difficulties encountered during the authorisation request caused a one-year delay, demonstrating the rigidities linked to the bureaucracy and the overcomplicated norms. During the last phase of the project, an additional trial has been implemented to validate an End of Waste strategy that allowed – after a proper treatment carried out by an authorised plant – to reclassify the sediments from waste to by-product, allowing their use in agriculture and overcoming the possible legal barriers. At the end of the project, a final and updated review of the legal framework has been carried out.

From the technical point of view, the marine sediments dredged from the Leghorn port and already phytoremediated using AGRIPORT technology have been subjected to three months landfarming process. The landfarming was carried out in the demonstration basin of the previous AGRIPORT project in Leghorn port. This treatment was aimed to: 1. homogenize the substrate, 2. increase the biological activities and, as a consequence, 3. further reduce the organic contamination levels, in order to obtain a substrate suitable for plant growth. The process has been deeply monitored, and sediments were periodically collected and characterized from a chemical, biochemical and toxicological point of view.
After landfarming, sediments were mixed with peat or coconut based commercial substrates to produce SUBSED substrates and start the project cultivation trials; nursery plants (laurel, olive and Citrus), flower plants (calla lily and Protea) and food crops (blueberry, wild strawberry, basil and Citrus) were grown on sediment-based substrates to assess their agronomic performances and validate their use in agriculture production. Citrus trials have been carried out in Spain, at UMH and Caliplant facilities, while the other trials have been carried out in Italy (Pescia and Montecarlo nursery district).
The data monitored and collected during the cultivation trials allowed to achieve the full validation of the use of sediment for the production of sustainable substrates to be used in the

professional agriculture sector.

Through a LCA analysis, the environmental impact of the proposed solutions has been evaluated: the results obtained confirmed that the SUBSED substrates are more environmentally sustainable compared to the traditional ones. To prove the economical sustainability of the proposed solutions, the SUBSED consortium developed a Business Plan that analysed the current context and proved the profitability of the business model proposed.

In order to guarantee the replicability, transferability and sustainability of SUBSED solutions, the consortium organized 4 workshops (open to stakeholders, policy makers and citizens) and 2 technical courses (specifically designed for agronomists and technicians/operators working in the waste and agriculture sectors). Thanks to these events, approx. 400 subjects have been directly involved and engaged in LIFE SUBSED solutions. A manual containing guidelines about sediments, sediment-based growing media and their use in agriculture has been produced and distributed during the project events and through the SUBSED website.

Finally, in order to increase awareness about the environmental problems addressed and the solutions proposed, an extensive dissemination and communication campaign was organized and carried out. Despite the strong and unpredictable impact of the COVID-19 pandemic, the SUBSED beneficiaries participated in more than 45 international events, produced and distributed around 12 500 leaflets and 14 500 branded gadgets, published around 45 scientific and general articles and reached thousands of subjects through the project website and social profiles. Furthermore, various policy makers have been contacted for arise their awareness about the regulatory rigidities currently present, that slow down the transition towards circular economy solutions. Finally, the beneficiaries cooperated with other funded projects and stakeholders relevant to the sectors involved (associations, company representatives, etc.) to build a network for the active exchange of knowledge and experiences and the creation of synergies.

The COVID-19 pandemic has strongly impacted the original plan of the SUBSED project, with slowdowns due to the lockdowns and forced closures of companies and research institutions, and to the restrictions on mobility and live interactions that have greatly hampered dissemination activities. In any case, the SUBSED project – thanks to a 12-months extension – managed to complete all the activities foreseen, even carrying out some additional activities not foreseen but which had a strong added value for the project.

In conclusion, during the 48-month long SUBSED project, the following main objectives have been achieved:

- To demonstrate the suitability of marine sediments to produce sustainable growing media (alternative to the peat-based ones) able to meet market standards and have performances worthy of the professional market.
- To demonstrate the environmental and economic sustainability of the solutions proposed through the LCA analysis and the SUBSED Business Plan.
- To guarantee and encourage the replicability and transferability of the proposed solutions thanks to the workshops and technical courses organized and the guidelines produced and distributed.
- To increase the awareness of general citizenship and specific targets (i.e. policy makers, stakeholders, etc) about the need to solve the environmental problems addressed and to update the regulatory framework to remove the current barriers and facilitate the transition towards eco-sustainable solutions.

4. Introduction

4.1 Environmental problem/issue addressed.

Sediments are dredged periodically from ports, harbours and waterways to guarantee free navigation and docking, prevent flooding and reduce the pollution load of water bodies. In fact, sediments are a sink of inorganic and organic pollutants directly released into waters or reaching water-bodies trough leaching and leakage of contaminated soil. Several International Conventions (e.g. OSPAR) and the EU "Waste Directive" have progressively encouraged the reuse of dredged sediment, but currently there is no specific management for dredged sediments, leading to disposal of dredge spoils to landfill, open water, or nearby the water bodies without any appropriate intervention. The relocation of dredged sediment in sectors of production, such as agriculture, appears problematic due to the possible transfer of contamination to soil, plant and humans. Among the different restoration techniques, phytoremediation and landfarming (Masciandaro et al., 2014; Doni et al., 2015) has been proven to be a sustainable management option for remediate sediments contaminated by inorganic and organic pollutants potentially allowing their productive re-use in important productive sector, according to the principle of the circular economy. Accordingly, dredged remediated sediments have already been successfully used as growing media for producing ornamental and food crops (Mattei et al., 2018; Tozzi et al., 2019). In fact, horticultural and nursery sectors are currently based on the massive use of peat, which have led to the peatland exploitation and consequently to the exploration of other innovative renewable materials, including dredged sediments.

4.2 Hypothesis demonstrated and verified by the project.

LIFE SUBSED demonstrated the suitability of the innovative sediment-based substrates for the production of growing media for the cultivation of both food and non-food crops. Trough demonstration trials (located in Italian and Spanish experimental centre and nurseries), the performances of the sediment-based substrates have been compared to the ones of the commercial peat-based growing media, widely used as standard by the nursery industry. Moreover, LIFE SUBSED explored in detail legislative issue and cultural issues for hindrance in the use of innovative substrates in agriculture and produced guidelines for a safe and sustainable use of sediments as substrate ingredient.

4.3 Description of the technical/methodological solution.

LIFE SUBSED used sediments phytoremediated using AGRIPORT technology and landfarmed according to CLEANSED project. Phytoremediation and landfarming allowed to reduced level of inorganic and organic pollutants and increased the microbiological activity, converting sediment into a valuable substrate able to support growth and production of several plant species as previously demonstrated in HORTISED. During the demonstrative trials carried out, the consortium assessed the performances of sediment-based substrates (mixed in various proportions with peat, coconut fibre and wood fibre) and the use of different irrigation regimes to find the best one for each specific substrate. Substrates have been characterized by several physical, chemical and biochemical properties at the beginning and at the end of the plant cycles. The experimentation focused on the nursery production, aimed at both propagation and production of various plant species for ornamental and food use. In detail, the plants used are *i*) laurel, a typical and very diffuse evergreen ornamental with a very fast plant growing; *ii*) calla lily and king protea, which represent important nursery products for cut flower and potted plant sector; *iii*) citrus, olive, wild strawberry, blueberry and basil, important food crop species well adapted to the Mediterranean countries, but characterized by different growing seasons

and needs. All crops have been monitored according to the production destination, during the various stages of germination, rooting, hardening, vegetative growth, flowering, and fruiting by means of morphological and physiological analyses. The nutritional and nutraceutical characteristics of the edible parts and the eventual presence of contaminants in fruits and other edible parts of plants have also been assessed. Finally, the Life Cycle Assessment and the Business Plan developed confirmed the sustainability of the LIFE SUBSED products from the economic and environmental point of view. The dissemination activities carried out allowed to reach relevant policy makers and stakeholders, professionals, national farmer associations and citizens in Italy and Spain.

4.4 Achieved results and environmental benefits.

- Reuse of approx. 67m^3 of sediment (from Leghorn port and Navicelli canal) as inputs for the LIFE SUBSED trials.
- Substitution of approx. 12 m^3 of peat with sediments and other alternatives to peat during LIFE SUBSED trials.
- Relevant reduction in terms of emissions for the LIFE SUBSED substrates (65% reduction considering the substrate composed by 50% sediment + 30% peat + 20% pumice).
- Validation of sediment-based substrates for the nursery production of food and non-food species (laurel, olive and citrus).
- Validation of sediment-based substrates for production of non-food crops (calla lily, protea and laurel) with commercial quality.
- Validation and characterization of the morphological, biochemical and sensorial point of view of basil, blueberry, and woodland strawberry cultivars grown on sediment-based substrates.
- Improvement of the knowledge on the treated sediment and their influence on plant growth and fruit quality.
- Validation of marketability of sediment-based substrates and assessment of normative and legal issues related to the reuse of sediment in agriculture.
- Increased awareness of the addressed environmental problems and policy makers involvement about the legislation for sediment management and reuse in agriculture.

4.5 Expected longer term results.

SUBSED proposes a solution that in the long term could be replicated in other contexts, perhaps transferring it to other cultivation techniques (e.g. field cultivation), reducing the environmental impact of sediment disposal and peat use.
Despite the presence of non-homogeneous national regulatory frameworks and legal barriers, an End of Waste strategy was validated during the project. This allows the sediment to be classified as a by-product and no longer as waste. Flora Toscana is dealing with the process of formal registration of the substrate recipe in the Minister register, which is mandatory to start the sale of the sediment-based substrates. In the future, the activities of dissemination and promotion of SUBSED solutions will be continued by all beneficiaries, with the objective of encouraging their replication and the use of products grown of LIFE SUBSED substrates.

6. Technical part

6.1. Technical progress, per Action

Action A1: Review on EU and National regulations on the use of sediments for plant nursery and analytical protocol

Foreseen start date: 10/2018 *Actual start date: 10/2018*
Foreseen end date: 06/2021 *Actual end date: 09/2022*
Related deliverable: *Review of legislation on dredged sediment management*
Foreseen date: 12/2018
Date of production: 12/2018 (attached to MtR as Annex 1)
Experimental activities authorization for the use of sediments in Italy
Foreseen date: 12/2018
Date of production: 03/2020 (attached to MtR as Annex 2)
Final national and EU legislation overview with recommendations for future EU legislation of dredged materials
Foreseen date (original): 09/2021
Date of production: 09/2022 (Annex 1 of this report)

A1.1 *Pre-conditioning process for increasing the organic carbon and decreasing the bulk density in order to reach the limit required.*
As already observed in previous projects and confirmed in the analyses carried out in action C1, the sediment after the landfarming process presented bulk density and total organic carbon not in line with Italian legislation on fertilizer (D.Lgs.75/2010). However, the mixing of sediments after landfarming with other organic matrices (peat, coconut, wood) allowed the reaching of required by Italia legislation.
A1.2 *Review of the EU and Italian and Spanish regulations/laws regarding the transport and use of dredged sediment-based substrates for plant nursery being in force at the date of the project beginning.* This action was focused on the review of International and National Legislation regarding the management of dredged sediment and their reuse as growing media for the soilless cultivation of ornamental and food crops. The Italian and Spanish legislation were reviewed from 1992 till 2018. The detailed review was reported in the Deliverable1.A1: "Review of legislation on dredged sediment management". In a second Deliverable (2.A1) "Experimental activities authorization for the use of sediments in Italy", that substitutes the previously programmed document "Authorization of the sediments use in agriculture as agronomic substrate", was reported the proceedings that the consortium had to follow to obtain the authorization by the Italian Institutions for establishing the trials. In fact the Italian legislation, for each type of waste, though non-hazardous, does not include exceptions concerning experimental activities and requires an authorization by the competent Authority, as stated in D.Lgs.152/2006 art. 211. The Italian demonstration trials were carried out in three different places, so the requested authorizations were three, one for each site. In Spain authorizations did not need to carry out the experimental trials
A1.3 *An update of the list of the analyses to be performed on substrates and products*
The list of the analyses to be performed on substrates, plants, and fruits was updated, taking into account the previous task and previous experiences of the beneficiaries. The detailed of the methodologies used were reported in the deliverables of actions B1, C2 and C3.
A1.4 *Defining a common protocol for the analyses.*
Finally, with the collaboration of all the partners, the standard protocols for the analyzes of the sediments, substrates and vegetal matrices were defined to apply homogeneous analytical procedures (i.e. sampling, extraction, quali- and quantification, etc.). The protocols used were reported in in the deliverables of actions B1, C2 and C3.
A1.5 - *On the basis of the final project results the beneficiaries FLORA, CREA and UMH (and*

<u>CNR, even if not written in the proposal</u>) will study and define the final national and EU legislation overview with recommendations for future EU legislation of dredged materials

During the Subsed Project, the management possibilities of the dredging sediment matrix were explored both from an experimental point of view and from an industrial point of view with reference to the Italian legislation. The dredged sediment follows various national regulations according to the place of origin, the geomorphological characteristics and its own chemical-physical characteristics.The Italian legislation is remarkably complex but extremely structured and, from the experiences gathered in the project, it has emerged that it is necessary to intervene at a community level to standardize the legislation on the management of this type of material. At a national level, there is no need for regulatory intervention given the complexity of the legislation itself, but it is necessary to publicize the evolution that biological recovery technologies have undergone in recent years and to encourage their application in plants authorized to treat dredging sediments. Instead, no variations in Spanish legislation were introduced during the project period.

However, during the Italian legislation overview, the possibility of reusing the sediments in agronomic sector as a substrate after a process of END of WASTE was learned.

So, to achieve the END OF WASTE objective, the dredged sediments were subjected to chemical characterization (Release Test according to DM 05 02 98), classified as non-hazardous waste and subsequently subjected to recovery operations in a treatment plant authorized for the management of specific waste classified with CER 17 05 06. The recovery of sediments took place through the placing in reserve (R13) for the production of secondary raw materials through mechanical and technologically interconnected phases of grinding, screening, granulometric selection and separation of the metallic fraction and unwanted fractions to obtain inert fractions at suitable and selected granulometry (R5). The treated sediments, after having satisfied the analyses required by the Release Test, have lost the classification of waste and have been classified as by-products consisting of recycled sand (0-5 mm) defined as “vegetable earth”.

Figure 1 - Sediment during the EoW trial

Then in order to register the product in Italian fertilizer list, the reaching of all the limits required by Italian legislation on fertilizer (D.Lgs.75/2010) is mandatory.

The mixing with other organic matrices (peat, coconut, wood) could allow to the sediment to be in line with this regulation, in particular regarding bulk density and total organic carbon, generally higher and lower, respectively.

For the purposes of the marketability of the product at the Community level, it will be necessary to integrate the legislative requests of decree 1009/2019 which establishes rules relating to the making available on the market of EU fertilizer products which amend the regulations number 1069/2009 and number 1107/2009 and which repeals regulation number 2003/2003. Annex 1 of LD 1009/2019 list the Functional Categories of the Product (PFC) for the fertilizing products;

at point 4 of the lists the requirements relating to the product functional categories for growing substrates are showed. The growing media is defined as a fertilizing product different from soil in situ which has function of growing plants and fungi.
The detailed final review was reported in the Deliverable.A1 “Final National and EU legislation overview with recommendations for future EU legislation of dredged materials” (Annex 1 of this report). This action has been 100% completed.

Action B.1 Phytoremediated sediment treated via landfarming process

Foreseen start date: 10/2018 *Actual start date:10/2018*
Foreseen end date: 03/2019 *Actual end date: 03/2019*
Related deliverable: *Report on the sediment treatment*
Foreseen date: 03/2019
Production date: 03/2019 (attached to MtR as Annex3)
Related milestone: *Sediment treated and characterized*
Foreseen deadline: 03/2019
Status: Completed

Action B.1 started on 01-10-2018 and completed on 31-03-2019 as foreseen in the project. The sediments used in the Subsed project were partially decontaminated in a previous European project (AGRIPORT, ECO/08/239065/S12.532262), using plants (phyto-treatment) and an organic amendment (such as compost) at pilot scale level.
In the Subsed project, with the aim to make the sediment a suitable substrate for plant growth, a landfarming process has been planned as a post-treatment phase. The landfarming was carried out in the demonstration basin of the previous AGRIPORT project (covered with a geo-membrane to avoid the eventual contamination of soil during the process), in Livorno port (43°33'31.78"N, 10°18'29.32"E), allowing to reduce the transportation costs (Figure 2).

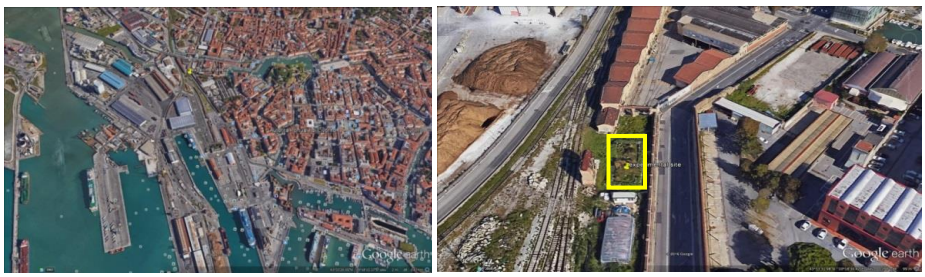

Figure 2 - Port of Livorno and the landfarming basin

In the Subsed project the sediments were submitted to landfarming technology as a post-treatment phase, aimed to: 1. homogenize the substrate, 2. increase the biological activities and, as a consequence, 3. further reduce the organic contamination i n order to obtain a suitable substrate for plant growth. The landfarming process started in November 2019, after the plant removal, and it was completed in February 2019. Three sampling points were selected in the landfarming basin area (about 40 m^3). In an area of about 1 m^3 around each sampling point, 10 sub samples were collected by a shovel, mixed, collected in plastic bags and transported to the CNR-IRET laboratory for the analyses (Figure 3).

Figure 3 - Sediment sampling

The initial sediment properties permitted to plan a sediment treatment process of only 3 months, as already suggested in the proposal, made possible also by the favorable weather conditions. The treatment consisted in the periodically (once a week) mixing and aeration until 60 cm through a little excavator. During the landfarming process the sediments were collected by a shovel (after one, two and three months from the start) and characterized from chemical, biochemical and toxicological point of view.

This action has been completed by 100% and was performed by CNR-IRET. All technical details are given in the Deliverable of Action B1 (Annex 3 of Mid Term Report).

Action B2: Demonstration of the use of remediated sediments as a substrate for nursery production

Foreseen start date: 04/2019 *Actual start date: 04/2020*
Foreseen end date: 03/2021 *Actual end date: 06/2022*
Related deliverable: *Report on nursery production*
Foreseen date (original): 03/21
Date of production: 06/2022 (Annex 2 of this report)

B2.1 Nursery production of ornamentals

*P. laurocera*sus cultivar 'Novìta' was chosen because it is the most common variety in the Tuscan district. Laurel plants were planted at the Azienda Franceschini (Montecarlo, Italy) on 08/06/2020 in a greenhouse. Rooted cuttings were planted in 8.5 L pots (two rooted cuttings for pot). Recirculating drip irrigation was used to control water supply and all plants were irrigated from the same reservoir. Two different line drippers were used to control water supply with one drip emitter per pot at a flow rate of 80 cc min^{-1} and irrigation timing varying from 2.5 to 3.2 min per day. The pH of irrigation water was maintained between 6.0 and 6.5. Two different daily water regimes were chosen to evaluate the performance of the different potting mix: normal (WR1 = 250 cc pot^{-1}) and reduced by 20% (WR2 = 200 cc pot^{-1}). Different proportions (25, 50% *v/v*) of the treated sediment (TS) were mixed with three types of standard substrates, commonly used in Tuscany to obtain six ternary substrate mixes (SM). Standard substrates were based on peat (Pe), coconut fibre (CF) and wood fibre (WF), each one containing 40% of inert pumice (Pu). Growing media prepared using commercial peat-based substrate (LMix 1) was considered as control treatment (Table 1).

Table 1 - Composition of the tested substrate mixes

Substrate mixes	Matrixes (%) *v/v*				
	Peat	Pumice	Coir fibre	Wood fibre	Treated sediment
LMix 1	60	40			0
LMix 2	45	30			25
LMix 3	30	20			50
LMix 4		30	45		25
LMix 5		20	30		50
LMix 6		30		45	25
LMix 7		20		30	50

All pots were fertigated weekly (160 cc/pot) with a soluble fertilizer (Universol 15-7-30) dosed at 4.5 gL^{-1}. Other conventional cultural practices (e.g. weed/pest control) were performed. For each combination SM*WR, 4 pots, each containing 2 rooted cuttings, were prepared, and replicated 3 times for a total of 336 laurel rooted cuttings (Figure 4). The trail was ended in March 2021 achieving 336 one-year old rooted cherry laurel cuttings.

Rep 1	WR1	LMix 7	LMix 4	LMix 5	LMix 2	LMix 1	LMix 6	LMix 3
	WR2	LMix 7	LMix 4	LMix 5	LMix 2	LMix 1	LMix 6	LMix 3
Rep 2	WR1	LMix 6	LMix 1	LMix 3	LMix 7	LMix 5	LMix 4	LMix 2
	WR2	LMix 6	LMix 1	LMix 3	LMix 7	LMix 5	LMix 4	LMix 2
Rep 3	WR1	LMix 5	LMix 3	LMix 2	LMix 6	LMix 4	LMix 7	LMix 1
	WR2	LMix 5	LMix 3	LMix 2	LMix 6	LMix 4	LMix 7	LMix 1

Figure 4 - Laurel experimental design

B.2.2 *Nursery production of olive and citrus*

A total of 150 certified grafted plantlets of olive cv 'Frantoio' were transplanted in 3.4-L squared plastic containers filled with 5 different SM containing sediment and peat-based

substrate at different rate (Table 2).

Table 2 - Composition of substrate mixes used for olive demonstration trial

Substrate mixes	Matrixes (%) *v/v*		
	Treated sediment	**Peat**	**Pumice**
OMix 1	0	60	40
OMix 2	25	45	30
OMix 3	50	30	20
OMix 4	75	15	10
OMix 5	100	0	0

Moreover, two different average daily WR were applied to each substrate mixture: WR1 = 325 cc pot^{-1}; WR2 = 240 cc pot^{-1}. Two 1 mm drip emitters per pot at a flow rate of 40 cc min^{-1} were used to control water supply. Pots were arranged in a randomized block design (Figure 5) with 3 blocks, each consisting of 5 pots per each SM*WR combination, for a total of 150 pots (5 pots x 5 substrate mixtures x 2 water regimes x 3 blocks). The trial ended in Spring 2021, when plants reached the marketable height of 150 cm, which is the standard for market.

Rep 1	**WR1**	**OMix 3**	**OMix 4**	**OMix 2**	**OMix 5**	**OMix 1**
	WR2	**OMix 3**	**OMix 4**	**OMix 2**	**OMix 5**	**OMix 1**
Rep 2	**WR1**	**OMix 4**	**OMix 5**	**OMix 3**	**OMix 1**	**OMix 2**
	WR2	**OMix 4**	**OMix 5**	**OMix 3**	**OMix 1**	**OMix 2**
Rep 3	**WR1**	**OMix 1**	**OMix 2**	**OMix 4**	**OMix 3**	**OMix 5**
	WR2	**OMix 1**	**OMix 2**	**OMix 4**	**OMix 3**	**OMix 5**

Figure 5 - Olive experimental design (left); demonstration trials on olive propagation (right)

The demonstration trail regarding the production of *Citrus* commercial seedlings to be used as rootstocks was started on 22 May 2020 at Caliplant nursery facility (Murcia, Spain). Five different SM combining different proportions of the treated sediment (TS) with cocopeat substrate (CP) were tested: i) CMix 1 = 100% CP, control; ii) CMix 2 = 75% CP + 25% TS; iii) CMix 3 = 50% CP + 50% TS; iv) CMix 4 = 25% CP + 75% TS; v) CMix 5 = 100% TS. Seedlings of three species most employed for rootstocks creation were used as plant material: *Citrus macrophylla*, *Citrus aurantium* and Forner alcaide nº5. Totally, 375 lemon trees (25 plants x 5 SM x 3 rootstocks x 3 blocks) were grown in 2.5-L polypropylene pots (Figure 6 - left). Seedlings were cultivated until they reached and fulfilled the standard commercial requirements, that is 60-70 cm height of 1-year-old citrus rootstock.

Once the seedlings reached the optimal commercial rootstock requirements (22 October 2022), they were used as rootstocks to produce grafted plants of *C. limon* cv 'Fino' (Figure 6 - right). This cultivar was used as the scion since it is the most common cultivar in Spain. The studied parameters were trunk size, height development and drainage composition over time compared to the control treatment. The trial ended in September 2022 with the achievement of 375 two-year-old grafted lemon seedlings.

Figure 6 - Production of lemon rootstocks seedlings in pots (left). One-year-old Forner alcaide n°5 rootstocks grown on TS100, TS75, TS50, TS25, TS0 (right).

This action has been 100% completed. All technical details are presented in the specific Deliverable (Annex 2 of this Report).

Action B3: Demonstration of the use of remediated sediments as a substrate for non-food crops cultivation nursery production (from plantlets to final production: flowers/ornamentals)

Foreseen start date: 04/2019 *Actual start date: 04/2020*

Foreseen end date: 03/2021 *Actual end date: 06/2022*

Related deliverable: *Report on the use of remediated sediment as substrate for non food crops production (flowers and ornamentals)*

Foreseen date (original): 03/2021

Date of production: 06/2022 (Annex 3 of this report)

Prunus laurocerasus (evergreen ornamental)

The demonstrative trial was intended to evaluate if sediment enriched substrates allowed nursery grown *P. laurocerasus* potted plants to meet high-quality standards. Thus, rooted cuttings of cherry laurel were grown indoors to market size in 8.5-L containers. Soilless cultivation was performed using one-year-old rooted cherry laurel plants from the previous trial on cutting propagation. Plants were not transplanted, thus the same growing media and irrigation scheduling described for nursery production in Deliverable action B2.1 were used. Moreover, each pot was considered to contain a single well-established plant, although being obtained by two initial cuttings. The growth trial started in April 2021 with three replications of each treatment, and three cherry laurel plants in each replication. Thus, a total of fourteen treatments (7 SM*2WR) were evaluated, with nine cherry laurel plants grown per treatment. All pots were fertigated weekly (160 cc/pot) with a soluble fertilizer (Universol 15-7-30) dosed at 10.5 gL-1. The trail was ended in March 2022 with the physical and chemical characterization of the growing media and the destructive analyses of the plant material.

Zantedeschia aethiopica (cut flower production)

Calla lily was chosen for cut flower production thanks to the beauty of its flowers and economic importance worldwide. Rhizomes were planted in greenhouse in late summer (12 September 2020), as usually done for this species, and cultivation was finished in May 2022, at the end of the second flower flush. Three different SM, combining different proportions (0, 25, 50%) of the TS with a standard peat-based substrate composed by 60% Pe and 40% Pu (*v/v*), were tested (Table 3Table 6). Totally 378 rhizomes were planted in 30-L containers placed on three raised benches served by different water regimes (WR) by a drip irrigation system: i) WR1, high water regime=WR2+30% (1220 cc day^{-1} of water per pot on average); ii) WR2, normal water regime (930 cc day^{-1} of water per pot on average); iii) WR3, low water regime=WR2-30% (650 cc day-

[1] of water per pot on average). Three different line drippers were used to control water supply with 4 drip emitters per pot at a flow rate of 100 cc min^{-1}, 2 drip emitters per pot at a flow rate of 100 cc min^{-1}, and 4 drip emitters per pot at a flow rate of 80 cc min^{-1}. Containers were arranged in three blocks, each consisting of 7 pots per SM*WR treatment, for a total of 189 pots each holding 2 rhizomes (14 rhizomes x 9 treatments x 3 blocks = 378 rhizomes) (Figure 7). Before planting, rhizomes were soaked in a solution of copper oxychloride 0.5 % to prevent *Pectobacterium carotovorum* attacks. Plants were fed with a nutrient solution commonly adopted for the cultivation of soilless calla. The total amount of nutrients per pot was: 245 g of Peters Excel CalMag Finisher (13-5-20 + 7 CaO + 2 MgO) and 8 g of Farben H50 (EDDHA Iron chelate 6%). Other cultural practices, such as weed and pest control, were performed as typically done in the area of production (Tuscany).

WR1	CMix 3	CMix 2	CMix 1	CMix 3	CMix 1	CMix 2	CMix 3	CMix 2	CMix 1
	Rep 1	Rep 1	Rep 1	Rep 2	Rep 2	Rep 2	Rep 3	Rep 3	Rep 3
WR3	CMix 3	CMix 2	CMix 1	CMix 3	CMix 2	CMix 1	CMix 3	CMix 1	CMix 2
	Rep 1	Rep 1	Rep 1	Rep 2	Rep 2	Rep 2	Rep 3	Rep 3	Rep 3
WR2	CMix 2	CMix 1	CMix 3	CMix 1	CMix 2	CMix 3	CMix 2	CMix 1	CMix 3
	Rep 1	Rep 1	Rep 1	Rep 2	Rep 2	Rep 2	Rep 3	Rep 3	Rep 3

Figure 7 - Calla experimental design

Protea cynaroides (potted flowering plant)

Protea dwarf 'Little Prince' was chosen as candidate species for potted flowering plant production. Totally 630 rooted cuttings were planted indoor at the Azienda Vivai Simoncini, (Pescia, Italy) in 2-L pots on 01/06/2020 (Figure 8, right). The treated sediment (TS) was used as a partial substitute of standard substrates, commonly used for flowering crop cultivation in Tuscany. In addition to sphagnum peat, coconut coir and bark, were employed as organic materials, while pumice was added as inorganic matrix in all mixtures. These matrixes were mixed separately to create ternary media containing 25 or 50% by volume of TS (Table 3).

Table 3 - Composition of the tested substrate mixes

Substrate mixes	Matrixes (%) *v/v*				
	Peat	Pumice	Coir fibre	Coir pith	Treated sediment
PMix 1	60	40			0
PMix 2	45	30			25
PMix 3	30	20			50
PMix 4		18	34.2	22.8	25
PMix 5		12	22.8	15.2	50
PMix 6		18	17.1	39.9	25
PMix 7		12	11.4	26.6	50

Plants were supplied with 3 different daily water volumes: normal (WR1 = 180 cc day^{-1} of water per pot on average); low, reduced by 17% (WR2 = 150 cc day^{-1} of water per pot on average); very low, reduced by 33.5% (WR3 = 120 cc day^{-1} of water per pot on average). The pH of irrigation water was maintained at 5.8 by acidification with sulfuric acid. Pots were arranged according to a complete randomized block design: 10 pots for each substrate x water regime combination (each consisting in 1 plantlet), replicated 3 times (Figure 8, left).

In November 2020, one third of the protea plants, namely those irrigated with the lowest water regime WR3 and showing major visible stress symptoms regardless of growing media, were replaced with new plantlets (totally 210 rooted cuttings) and subjected to water regime WR2 (150 cc day-1 of water per pot on average) (Figure 8, left). This adjustment eliminated the non-performing treatment while allowing the additional comparison between two growing seasons, characterized by summer and autumn planting. Plants were fertilized during 2021 as described above. All proteas were cultivated until full blooming (May 2022).

First experimental design

	06/2020	06/2020	06/2020
	WR3	WR1	WR2
Rep 3	PMix 2	PMix 5	PMix 6
	PMix 6	PMix 6	PMix 3
	PMix 1	PMix 4	PMix 2
	PMix 4	PMix 1	PMix 4
	PMix 3	PMix 7	PMix 7
	PMix 7	PMix 3	PMix 1
	PMix 5	PMix 2	PMix 5
Rep 2	PMix 2	PMix 7	PMix 3
	PMix 3	PMix 2	PMix 2
	PMix 5	PMix 1	PMix 5
	PMix 7	PMix 6	PMix 4
	PMix 4	PMix 3	PMix 6
	PMix 6	PMix 5	PMix 1
	PMix 1	PMix 4	PMix 7
Rep 1	PMix 7	PMix 5	PMix 3
	PMix 3	PMix 6	PMix 6
	PMix 2	PMix 3	PMix 5
	PMix 4	PMix 2	PMix 2
	PMix 1	PMix 4	PMix 4
	PMix 6	PMix 1	PMix 7
	PMix 5	PMix 7	PMix 1

Adjusted experimental design

	11/2020	06/2020	06/2020
	WR2	WR1	WR2
Rep 3	PMix 2	PMix 5	PMix 6
	PMix 6	PMix 6	PMix 3
	PMix 1	PMix 4	PMix 2
	PMix 4	PMix 1	PMix 4
	PMix 3	PMix 7	PMix 7
	PMix 7	PMix 3	PMix 1
	PMix 5	PMix 2	PMix 5
Rep 2	PMix 2	PMix 7	PMix 3
	PMix 3	PMix 2	PMix 2
	PMix 5	PMix 1	PMix 5
	PMix 7	PMix 6	PMix 4
	PMix 4	PMix 3	PMix 6
	PMix 6	PMix 5	PMix 1
	PMix 1	PMix 4	PMix 7
Rep 1	PMix 7	PMix 5	PMix 3
	PMix 3	PMix 6	PMix 6
	PMix 2	PMix 3	PMix 5
	PMix 4	PMix 2	PMix 2
	PMix 1	PMix 4	PMix 4
	PMix 6	PMix 1	PMix 7
	PMix 5	PMix 7	PMix 1

Figure 8 - Protea experimental design (left); site preparatory works (right)

This action has been 100% completed. All technical details are given in the specific Deliverable (Annex 3 of this Report).

Action B4: Demonstration of the use of remediated sediments as a substrate for food crops production

Foreseen start date: 04/2019 *Actual start date: 04/2020*
Foreseen end date: 03/2021 *Actual end date: 06/2022*
Related deliverable: *Report on the use of remediated sediment as substrate for food crops production (basil, blueberry, wild strawberry, citrus)*
Foreseen date (original): 03/2021
Date of production: 06/2022 (Annex 4 of this report)

The demonstration sites were set up both in Italy, in the nurseries of Azienda Agricola Franceschini (blueberry and wild strawberry) and Vivai Simoncini (basil), and in Spain, at the Miguel Hernandez University. The cultivated food crop species were basil, blueberry, wild strawberry and lemon. The partners involved were CREA, Carbonsink, Flora Toscana, UMH.

B4.1 *Basil cultivation*

Two cultivars of basil were chosen: 'Genovese' and 'Valentino'. The demonstration trials were prepared at Vivai Simoncini (Pescia, Italy) and were split into two separate tests. The first one was performed in Autumn 2020 (04/09/2020) by testing the pure peat (Pe) and the TS in the following ratios: BMix 1 = 100% Pe (*v/v*), considered as control treatment; BMix 2 = 50% Pe and 50% TS (*v/v*); BMix 3 = 100% TS (*v/v*). Totally 7,452 seeds (3,726 for each cv) were sown manually in 0.75-L plastic square pots. The second trial was started in Spring 2021 (12/05/2021) reducing by half the percentages of TS used in the first test: BMix 4 = 87.5% Pe and 12.5% TS (*v/v*); BMix 5 = 75% Pe and 25% TS (*v/v*) compared to the control of pure Pe (BMix 1). Totally 7,452 seeds (3,726 for each cv) were sown manually in 1-L pots.

During both trials, water was applied by subirrigation below the soil surface to raise the watertable into or near the plant root zone. The subirrigation system consisted of three raised benches, each one receiving different amounts of water: normal (WR1 = 3.6 L day^{-1}); low, reduced by 25% (WR 2 = 2.7 L day^{-1}); very low, reduced by 37.8% (WR3 = 2.25 L day^{-1}). For each cultivar, containers were arranged in three blocks, each consisting of 6 pots (each containing 23 seeds) per SM*WR treatment, for a total of 162 pots per cultivar (Figure 9).

	Rep 1	Rep 2	Rep 3
WR3	BMix 2	BMix 3	BMix 1
	BMix 1	BMix 2	BMix 3
	BMix 3	BMix 1	BMix 2
WR2	BMix 1	BMix 3	BMix 2
	BMix 3	BMix 2	BMix 1
	BMix 2	BMix 1	BMix 3
WR1	BMix 1	BMix 3	BMix 2
	BMix 2	BMix 1	BMix 3
	BMix 3	BMix 2	BMix 1

Figure 9 - Basil experimental design (left); site preparatory works (right)

B4.2 – Blueberry cultivation

Figure 10 - Blueberry demonstration trial

Certified two-year-old blueberry plantlets cvs 'Duke' and 'Bluecrop' were planted at Franceschini facility (Montecarlo, LU, Italy) in 35-L plastic pots on 8 June 2020 and grown under greenhouse conditions (Figure 10). Three different SM, combining different proportions of the TS with a standard peat-based substrate (Pe 60%, Pu 40% *v/v*), were tested: i) MMix 1 = 100% standard peat-based substrate; ii) MMix 2 = 50% peat-based substrate + 50% TS; MMix 3 = 100% TS. Two different daily WR were applied in order to evaluate their effect on plant growth and productivity in relation to the SM tested: normal = 480 cc pot^{-1} (WR1); reduced by 25% = 360 cc pot^{-1} (WR2). Two drip emitters per pot at a flow rate of 40 cc min^{-1} were used to control water supply. Pots were arranged in three blocks, each consisting of 3 pots per GM* WR*CV, for a total of 108 pots (3 pots x 3 SM x 2 WR x 2 cultivars x 3 blocks). The trial was ended in May 2022, when plants were cut for disruptive analysis and the evaluation of organic and inorganic contaminants on different plant parts was performed.

B4.3 – Wild strawberry cultivation

Figure 11 - Wild strawberry plants in rectangular (80 x cm) pot

A total of 90 certified micropropagated plantlets of strawberry cultivar 'Regina delle Valli' were transplanted in 50-L (80 x 50 cm) plastic plant-boxes on 8 June 2020 and were grown under greenhouse conditions at the Franceschini facility in Montecarlo, Lucca (Italy) (Figure 11). Three subsrates mixes were tested: i) FMix 1 = 100% peat-based substrate; ii) FMix 2 = 50% peat-based substrate + 50% TS; iii) FMix 3 = 100% TS. Two daily WR were applied: normal = 960 cc pot^{-1} (WR1); reduced by 45% = 540 cc pot^{-1} (WR2). Each SM*WR combination was replicated in 3 blocks (1 block per plant-box, consisting of 5 replicates) according to a randomized block design. The demonstration trial was ended in May 2022 with plant collection for disruptive analyses.

B4.4 Citrus cultivation

On 04/05/2020 the sediment was received at the UMH. On 14/05/2020 the preparation, mixing, and filling the pots with the sediment and universal substrate were carried out and on 20/05/2020, the citrus plants were planted. A total of 99 citrus plants of *C. lemon* cv 'Verna 51' grafted on three different rootstocks (*C. macrophylla*, *C. aurantium* and Bitter orange/Sweet orange) were used for the experimental test. For their cultivation, 40-L volume plastic pots filled with three mixtures of the sediment and universal substrate (25%, 50%, and 75%) were used, aiming to determine the viability and suitability of the sediment for citrus cultivation. Five replication blocks were established for each variety*rootstocks*substrate combination,

each with 2 pots (10 pots x 1 cultivar x 3 substrates x 3 rootstocks). Plants were cultivated adopting monitored practices (irrigation, fertilization, protection).

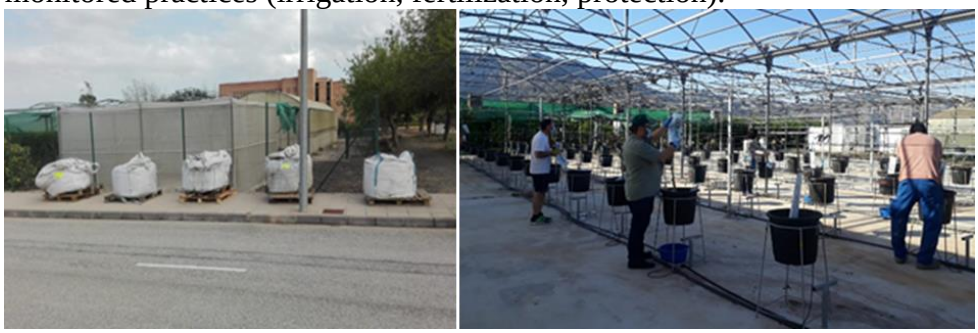

Figure 12 - Arrival of the sediment at UMH (left) and preparatory of the demonstration trial (right)

This action has been 100% completed. All technical details are given in the specific Deliverable (Annex 4 of this Report).

Action B.5 Training courses, workshops and guidelines for project replicability and transferability

Foreseen start date: 10/2020 *Actual start date: 04/2021*
Foreseen end date: 09/2021 *Actual end date: 09/2022*
Related deliverable: *SUBSED replicability and transferability plan*
Foreseen date (original): 09/2021
Date of production: 09/2022 (Annex 5 of this report)
Report on training courses
Foreseen date (original): 09/2021
Date of production: 09/2022 (Annex 6 of this report)
Report on workshops
Foreseen date (original): 09/2021
Date of production: 09/2022 (Annex 7 of this report)
Manual with guidelines on use of sed-based substrates for plant growing
Foreseen date (original): 09/2021
Date of production: 09/2022 (Annex 8 of this report)
Related milestone: *2 Technical training courses*
Foreseen date (original): 09/2021
Achieved on 09/2022
4 project workshops
Foreseen date (original): 09/2021
Achieved on 09/2022
Technical guidelines
Foreseen date (original): 09/2021
Achieved on 09/2022

This action aimed to maximize the sustainability, replicability and transferability of the SUBSED project. To this end, a series of actions have been set up, which have proved to be extremely effective and able to involve numerous subjects.

Training courses → the consortium organised 2 technical courses designed for technicians, professionals, worker, students, and future professionals of the concerned sectors:

- Spanish technical course (live, 15th October 2021 ~ 9 participants)
- Italian technical course (bimodal event, 3rd March 2022 ~ 65 participants)

All courses included a theoretical session and a practical session, for an effective transfer of knowledge and project experiences.

Workshops → the consortium organized 4 workshops, designed for stakeholders, policy makers, citizens and a wider audience compared to technical courses. In particular:

- First Italian Workshop (8th July 2021, online ~ 100 participants)
- First Spanish Workshop (29th November 2021, hybrid ~ 110 participants)
- Second Spanish Workshop (24th May 2022, live ~ 57 participants)
- Second Italian Workshop (15th September 2022, live ~ 50 participants)

The contents of the workshops were less technical, but nevertheless made it possible to increase the awareness of the participants about the environmental issues dealt with, the solutions proposed and the challenges still open.

Guidelines → The consortium prepared 1 technical guideline regarding the use of sediment-based substrates for plant growing. The guidelines have been distributed in digital format through the project website and in paper during the last project events.

These activities have been strongly impacted by the COVID-19 pandemic: restrictions on mobility and live interactions have forced the consortium to **reorganize the planned activities**. In order to mitigate the impact, the consortium has opted in some cases for the **organization of online/hybrid events** (with an excellent response from the public).

The action was 100% completed. All details are given in the deliverables of action B.5.

Action B.6 SUBSED Business Plan

Foreseen start date: 01/2021 *Actual start date: 07/2021*
Foreseen end date: 09/2021 *Actual end date: 09/2022*
Related deliverable: SUBSED Business Plan
Foreseen date (original): 09/2021
Date of production: 09/2022 (Annex 9 of this report)

The LIFE SUBSED project collects the legacy of several projects that have validated and optimized technologies for sediment recovery. In addition to the technical validation, SUBSED aimed to demonstrate the economic sustainability of the proposed solution. The pilot trial carried out during the last phase of the project has been fundamental to validate a process capable of overcoming the legal barriers that over the years threatened the commercial exploitation of sediment-derived product.

Flora Toscana considers the commercial exploitation of the substrate interesting, and for this reason developed a business plan to assess the launch of a new sediment-based product. The market context is currently favourable, and companies are looking for new alternatives to peat and coco. Economic and financial sustainability of the new business area were assessed, and forecasts confirm sustainability of the business in the medium period. The action was 100% completed. All details are given in the "SUBSED Business Plan" attached to this report as Annex 9.

Action C.1 Monitoring and validation of treated sediments

Foreseen start date: 01/2019 *Actual start date: 01/2019*
Foreseen end date: 06/2019 *Actual end date: 06/2019*
Related deliverable: Report on the characterization of treated sediments
Foreseen date (original): 06/2019
Date of production: 06/2019 (attached to MtR as Annex 4)
Related milestone: Sampling, analysis and characterization of treated sediments
Foreseen date: 06/2019
Status: Completed

Action C.1 started on 01-01-2019 and it has been completed on 30-06-2019 as planned.

To evaluate the evolution of sediment characteristics during the three months of landfarming, three sampling points, consisting of 10 sub samples each, were collected and characterized from physical, chemical, biochemical, toxicological and hydrological point of view.
The sediment sampling has been carried out as following:

- start of the landfarming process (end of November 2018), **Ti**
- middle of the landfarming process (middle of January 2019), **Tm**
- end of the landfarming process (end of February 2019), **Tf**

The results of the analysed samples suggested that three months landfarming process was effective in homogenizing the substrate and further reducing organic contamination, and in reaching physical and chemical characteristics in accordance with the Italian regulation for agronomic substrates (D.lgs. 75/2010) with the only exception of organic carbon content and bulk density value. The bulk density was, in fact, slightly higher than the maximum limit, while the organic carbon was lower. Nevertheless, in order to reach the C concentration and bulk density required by Italian legislation, it would be sufficient to mix the sediments with a source of organic matter rich in carbon and with low bulk density such as peat, sludge or coconut fiber. Regarding the inorganic contaminants (heavy metals), normed by D.lgs. 75/2010, all the heavy metals in the sediments at the end of the landfarming process showed a concentration considerably lower than the legal limits. On the contrary, heavy hydrocarbons (C> 12), normed by D.lgs 152/2006, were still higher than the legal limit for civil reuse, even if much lower than the limit for industrial reuse. On the other hand, polycyclic aromatic hydrocarbons (PAHs) were notably reduced during the landfarming process (about 80%), reaching concentration also lower than the limits for civil reuse. However, this residual contamination seemed to not compromise the reuse of the sediments in horticulture, since the toxicological tests showed no phyto toxicity of the sediments.
This action has been completed by 100% and was performed by CNR-IRET.

Action C2: Monitoring and validation of the use of remediated sediments as a substrate for plant nursery and cultivation: non food crops production

Foreseen start date: 01/07/2019 *Actual start date: 05/2020*
Foreseen end date: 01/06/2021 *Actual end date: 09/2022*
Related deliverable: *Monitoring activity on non food crops*
Foreseen date (original): 06/2021
Date of production: 09/2022 (Annex 10 of this report)

C2.1 *Laurel nursery production*

Vegetative growth of cherry laurel cuttings was monitored from June 2020 to March 2021, except for the months of vegetative rest (December-February) in terms of base stem diameter, maximum plant height, number of vegetative shoots, length of primary vegetative shoot, and number of fully expanded leaves on primary vegetative shoot. At the end of the growing season plant biomass was recorded. Physiological analyses included leaf colour, membrane lipid peroxidation by measuring malondialdehyde (MDA) content, leaf macro and micronutrients, chlorophyll, and carotenoid contents.
All growing parameters were significantly affected by the SM while no statistically significant WR and SM*WR interaction effects were found. Plant development was strongly reduced when cultivated on WF-based substrate mixed with TS (Table 5). Differences were particularly evident in the first few months of growth, but these differences almost disappeared over time. Also as regards leaf blade colour, significant differences were found after 60-days growth, with leaves of cherry laurel cuttings showing a significant yellowing compared to the control when grown on sediment-based mixtures, regardless of the sediment percentage used, with the only exception of growing medium composed of peat and 25% TS (LMix 2). In October, the alteration in the colour of leaves appeared to be mitigated and a significant negative effect on

Chroma was exerted only by LMix 6 and LMix 7, both containing WF. According to destructive plant analyses, the substrate mixture had a clear effect on dry weight of the main vegetative organs and total leaf area, measured at the end of the growing season. In fact, these parameters exhibited a substantial decrease (even up to 40%) when WF was included in the growth substrate.

Table 4 - Effect of substrate mix on growth parameters

SM	BSD	MPH	NVS	LVS	NEL
LMix 1	16.6 a	42.3 a	5.6 a	20.0 a	14.1 a
LMix 2	15.9 ab	40.2 ab	4.8 b	17.1 b	13.8 a
LMix 3	15.5 ab	36.9 bc	4.2 cd	15.7 bc	12.6 ab
LMix 4	15.5 ab	40.1 ab	4.4 bcd	16.9 b	13.6 a
LMix 5	14.6 b	34.3 c	3.9 d	14.5 c	11.6 bc
LMix 6	14.2 bc	29.6 d	4.5 bc	12.4 d	11.0 c
LMix 7	13.6 c	28.2 d	3.5 e	11.4 d	10.5 c

Legend. BSD base stem diameter (mm), MPH maximum plant height (cm), NVS number of vegetative sprouts, LVS length of vegetative sprouts (cm), NEL number of fully expanded leaves on vegetative sprouts. Mean values within each column followed by the same letter are not significantly different ($p < 0.01$) according to Duncan's multiple range test.

At the end of the first vegetative cycle, total chlorophyll concentration and MDA in leaves, used as sensitive indicators of the cellular metabolic state (plant stress) did not show significant differences. Values of total organic N and C (1.1 – 1.4% and 42.7 – 47.7%, respectively) were found within the normal range reported for structural carbon and nitrogen in adult plants. These results highlighted that sediment can be used as a partial substitute for standard raw materials, especially peat and CF, in container production of cherry laurel.

C2.2 *Cultivation of non-food crops: cherry laurel, calla lily, and protea*

This sub-action was under the supervision of CREA. Growth and flower production of these flowers and ornamental plants were monitored by assessing different morphological and physiological parameters.

Cherry laurel. The SM had a clear effect on plant height, shoot number, trunk diameter, and final plant biomass production of cherry laurel, while WR was without effect on all areal traits, and SM*WR significantly influenced only some growth parameters of cherry laurel during the harsh growing season (July-August). More specifically, plant height and vegetative shoots increased over time when plants were grown on Pe:TS media. Growth parameters increased linearly, but slower with CF:TS, while plants grown on WF:TS mixes had a more compact shape and significantly lower dry weight biomass compared to the control plants. Interestingly, a SM*WR interaction was noted immediately after the extremely hot-dry summer growth period, resulting WR2 detrimental for plant growth only when applied on Pe alone or Pe in combination with TS. In this regard, it should be noted that the higher water holding capacity of TS might have compensate for the greater hydrophobicity in peat-based mixes under restrictive irrigation. The net CO_2 assimilation rate and transpiration rate decreased in response to the increasing TS concentration in the SM with detrimental effects more pronounced for WF:TS treatments (LMix 6 and LMix 7). The colour of the leaves showed highest Chroma values in WF:TSs and were mainly associated to the b* component more shifted towards yellow. Small variations in chlorophylls (Chls) and carotenoids were observed among all sediment-based SM, while in control plants Chl values were found to be higher and carotenoid content was lower. Results of oxidative stress by MDA analysis confirmed this trend. Tissue nutrient concentrations were found to be extremely variable, with P, K, Ca, and Mg being the predominant leaf macronutrients. Concerning microelements, higher Cu, Fe and Zn were measured in plants cultivated on the TS-based growing media blended with WF. Despite the differences found in the tested SM, *P. laurocerasus* development grown in blends containing Pe as well as CF and WF, were consistent with 2-year-old nursery grown cherry laurel quality standards reported for marketing category of 7-L pot grown plants (60-80 cm plant height).

Calla lily. The treated sediment had a clear positive effect on calla lily plant development,

which became evident immediately after planting during the first year of cultivation. Indeed, mean leaf length showed increasing values as the content of the TS in the mixture increased. Regarding water supply, a 30% water increase enhanced leaf development being the total leaf length on average 9 % greater than that obtained under normal water supply. The number of flowers showed increasing values as the content of the TS in the mixture increased. Regarding water supply, a 30% water reduction diminished calla blooming, being the number of flowers per plant on average 21% smaller than that obtained under normal WR (Figure 13). Plants cultivated on CMix 3 produced a consistently higher number of quality flowers reaching 80, 90 and 100 cm of final length compared to the control. Thus, the selling value averaged over the entire harvest season was found to be greater for flowers obtained on CMix 3 consisting of 50% TS (Table 5, Figure 14). Regarding petal senescence, inferior cut flower performance during vase life was observed when flowers were cultivated on CMix 1 and CMix 2 with reduced irrigation.

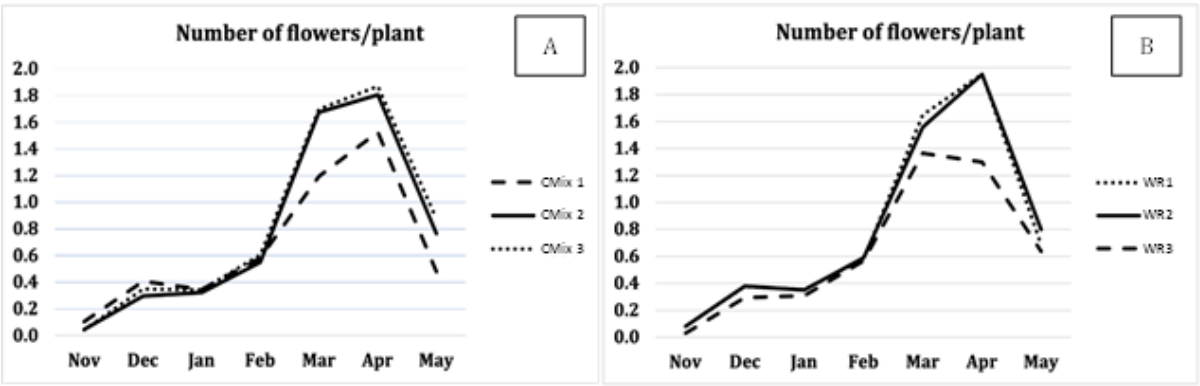

Figure 13 - Flower production of calla lily grown on CMix 1, CMIx 2 and CMix 3 substrates; B) Flower production of calla lily grown with different water regimes (WR1, WR2 and WR3)

Table 5 - Effect of SM and WR on the number of flowers and their selling value

Factor	Flowers/plant (n)	Selling value/flower (€)
SM		
CMix 1	4.6 b	1.8 b
CMix 2	5.5 a	2.6 a
CMix 3	5.8 a	2.8 a
WR		
WR1	5.7 a	2.9 a
WR2	5.7 a	2.6 a
WR3	4.5 b	1.6 b

Mean values within each factor followed by different letters are significantly different at p ≤0.01.

Figure 14 - Calla lily harvested flowers

In general, it appears evident that the plant photosynthetic activity was good, regardless of growth conditions, that is substrate composition and water availability, while results of oxidative stress by MDA analysis confirmed the negative effect of reduced WR3 and the positive impact of TS-based substrates (CMix 1 and CMix 3) on plant performance. Thus, the treated sediment was successfully used as a matrix of substrate mixture in the portion up to 50% as an alternative to classic soilless growing media for calla lily cut flower production.

Protea. All proteas suffered from a delayed planting in late Spring showing initial growth efforts and reduced successful plant establishment, particularly evident in the hottest summer

months of the first growing season and in the presence of 50% of treated sediment. Proteas planted in early summer and raised under reduced water availability (WR3) showed a high mortality. In most cases, once the winter period was over, at the vegetative restart of the second year of cultivation, plants showed a considerable enhancement of plant growth activity, although protea growth parameters were significantly affected by the SM. In particular, protea grown on the control (PMix 1) exhibited significant higher average values of stem number and length, along with an anticipated flower induction and development compared to plants grown on TS-based media. The incorporation of 50% *v/v* TS in the growing media drastically reduced plant growth and flower production in all tested mixes (Figure 15A). On the other hand, protea grown on mixes containing 25% *v/v* TS had a more
compact shape, but developed a good number of flowers, except for PMix 6 containing a higher percentage of coir pith. In this regard, it should be noted that a compact behaviour might represent a valuable feature for this species, when cultivated as a flowering pot.
Selling prices of potted flowering proteas were in line with the values expressed by plant vegetative and reproductive behaviour under the different tested soilless conditions (Figure 15B). Once flowers opened, they were similar in terms of size (Table 6, Figure 16), except for flower length which was smaller in PMix 5, PMix 6 and PMix 7 essentially related to the lesser flower development at the time of data collection. In general, control flowers were deep pink, while those grown on sed-based substrates had brighter tones and tended to purple.

Figure 15 - Bloomed plants (A) and selling value (B) of P. cynaroides at marketing stage. Mean separation among bars by Duncan's multiple range test. Means followed by different letters are significantly different (p < 0.01).

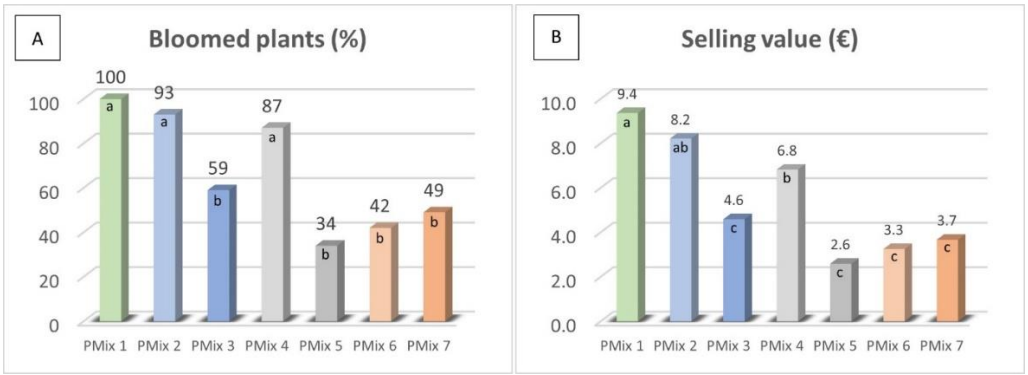

Table 6 - Effect of substrate mix (SM) on protea flower size and colour

SM	Flower size			Chroma
	Length (mm)[a]	Width (mm)[a]	Diameter (mm)[b]	
PMix 1	97.3 a	38.7 abc	22.5 ns	32.7 a
PMix 2	97.3 a	38.4 abc	22.3 ns	30.0 abc
PMix 3	97.9 a	39.3 abc	21.4 ns	28.3 bc
PMix 4	97.8 a	40.3 a	23.1 ns	32.2 a
PMix 5	81.0 ab	32.9 c	22.7 ns	27.5 c
PMix 6	74.7 b	38.6 abc	22.3 ns	30.9 ab
PMix 7	81.6 ab	33.9 bc	22.0 ns	28.9 bc

[a]measured with closed flower (March 2022);
[b]measured with fully open flower (May 2022)

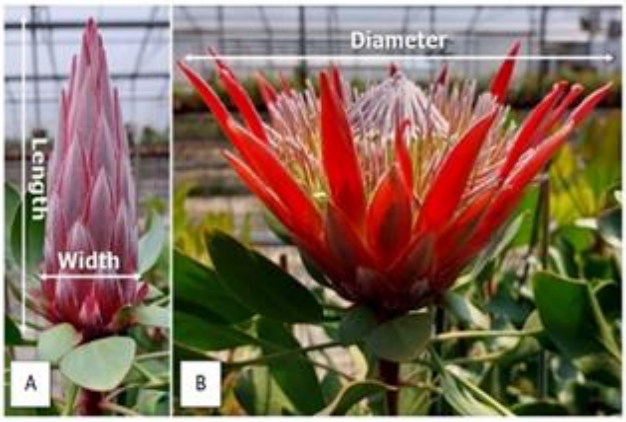

Figure 16 - Size measurement on protea flower. Lenght and width (A); diameter (B)

C2.3 Physical, chemical and biochemical properties of the growing media

CNR-IRET was involved in this action for the physical, chemical and biochemical characterization of the growing media. In particular, the following analysis were carried out on all substrates both at the time of preparation and at the end of the vegetative plant cycles.

- Physical: Bulk density
- Chemical: pH, Electrical Conductivity, organic matter, Nutrients Total content and Availability
- Biochemical: Hydrolytic and Oxidoreductase enzymes

Other analysis such as water retention curve, phytotest, cation exchange capacity, etc. were carried out for scientific interest and with the aim of publishing in high-ranking scientific journals. The results showed that the mixing of sediments after landfarming with other organic matrices (peat, coconut, wood) allow the reaching of values required by Italia legislation for agronomic substrates for all parameters (D.Lgs 75/2010). All the substrates were suitable for the growth of the selected plants, and in particular those with a concentration of sediments less than or equal to 50% showed better growth and better physiological characteristics of the plants. In addition, a different influence of various plants on physical, chemical and biochemical characteristics of the substrates were generally observed.

This action has been 100% completed. All technical details are given in the specific Deliverable (Annex 10 of this Report).

Action C.3: Monitoring and validation of the use of remediated sediments as a substrate for nursing and cultivation: food crops production

Foreseen start date: 07/2019 *Actual start date: 05/2020*
Foreseen end date: 06/2021 *Actual end date: 09/2022*
Related deliverable: Monitoring activity on food crops production
Foreseen date (original): 06/2021
Date of production: 09/2022 (Annex 11 of this report)

Action C.3 started on July 2020. The beneficiaries involved were: CREA, Carbonsink, UMH and CNR. In the frame of this action, each demonstration item was monitored, to validate the use of remediated sediments as a substrate for nursing and cultivating food crops.

C3.1 *Olive nursing production*

Olive saplings growth was evaluated every two months, even if a visual evaluation of the whole plant was done every fifteen days, in order to evaluate general plant health status and promptly detect symptoms of abiotic stress. The following parameters were considered: plant mortality, stem diameter, plant height, leaf blade colour. Stem diameter was significantly influenced by the growing media, with higher values for OMix 2 (18.1 mm) and OMix 1 and OMix 3 (17.4 mm; 17.5 mm, respectively), characterized by a low to medium/high concentration of TS (Table 7). Also, WR influenced this parameter. In fact, plants irrigated with WR2 had bigger diameter compared to plants irrigated with WR1. As for plant height significant differences were found both for WR and SM. WR2 enhanced the growing rate of the olive trees, while medium to high content of marine sediment in the SM increase the growth of plants, with best result obtained on OMix 3. SM did not influence the values of leaf blade colour; on the other side, we found significant differences between WR and the SM*WR interaction. Analysis of SPAD index did not reveal significant differences between SM and WR, indicating no influences of these two factors on chlorophyll content in olive leaves. Results showed an increment of leaf area with increasing concentration of TS, with high values until a percentage of 75%. Disruptive analysis did not show significant differences in plant biomass production (Figure 17), although plant leaf area was slightly reduced in plants grown on OMix 5 under reduced water availability.

Figure 17 - Olive trees at the end of the demonstration trial

Table 7 - Effect of SM and WR on stem diameter and plant height

Factor	Stem diameter (mm)	Plant height (cm)
SM		
OMix 1	17.43 ab	138.60 ab
OMix 2	18.10 a	135.20 ab
OMix 3	17.56 ab	139.01 a
OMix 4	16.46 b	138.50 ab
OMix 5	16.66 b	133.97 b
WR		
WR1	16.66 b	132.53 b
WR2	17.82 a	141.57 a

Means separation by Duncan's multiple range test ($p < 0.05$)

C3.2 *Basil, wild strawberry, blueberry and citrus cultivation*

The monitoring of basil seed cultivation started soon after seed sowing and for each demonstration trial, germination rate, plant biomass, physiological parameters and the transfer of nutrients and toxic metals to the leaves were analysed. Basil production was significantly influenced by the growing media, being total FW and leaf area significantly reduced in plants obtained on growing media containing high amounts (≥ 50%) of TS. On the other hand, the TS was successfully and safely used in the proportion from 12.5 to 25% (*v/v*) with peat to produce fresh basil herb pots with spring sowing. Under these growing conditions, plants did not show any visible

Figure 18 - Basil cvs 'Genova' and 'Valentino' cultivated in Spring 2021

phytotoxic symptoms or damages. In our test, high water availability always positively affected plant biomass production. In general, cv 'Valentino' showed a better development compared to 'Genovese'.
Strawberries and blueberries were monitored at monthly intervals. Plant growth and physiological parameters were recorded, and fruit yield was determined as total production of marketable fruits over the whole plant growth. For each treatment, 30 fresh berries were randomly selected and used for pomological characterization. At the end of the second growing season the aerial and root plant fresh and dry weight were measured on randomly selected plants of each treatment. Nutrients, heavy metals and organic micropollutants, and nutraceutical properties were analysed by an external accredited laboratory.
Wild strawberries grown on FMix 2 and FMix 3 substrate mixes exhibited significant higher average values of crown diameter (34.9 and 36.9 vs 22.1 mm) and shoot development (24.2 and 23.6 vs 21.2 cm) compared to plants grown in control Pe-based substrate. Conversely, leaf area was considerably reduced in plants grown on TS-based media (21.8 and 21.7 vs 23.9 mm2, respectively for FMix 3, FMix 2 and FMix 1). No noticeable differences were detected in the number of leaves, leaf chlorophyll content (SPAD index) and chroma index among the three tested SM. The highest average total production was obtained in control plants with greater water availability (Table 8), but when the WR was reduced by 30% fruit production obtained on FMix 1 dropped dramatically. Productive yields of plants grown on FMix 2 and FMix 3 were lower compared to the control, but the reduction of water volumes resulted of much less importance on fruit production probably due to the greater water retention capacity of the sediment matrix compared to peat. The WR had a significant effect on fruit weight, chroma index and soluble solids content, which exhibited higher values with WR1. The strawberry fruit colour is an important characteristic feature for consumer product acceptance and preferences, however, berries obtained on the tested growing media did not show any significant changes in fruit skin colour. The nutraceutical quality of fruits was similar in FMix 1 and FMix 2, while decrease in FMix 3 compared to the control, indicating a good quality and marketability of fruits obtained on SM containing up to 50% of TS (Figure 19).

*Table 8 - Effect of SM*WR on F. vesca total production*

SM	WR1	WR2
FMix 1	273.9 a	87.1 c
FMix 2	244.4 ab	193.4 b
FMix 3	208.4 ab	105.1 bc

Means followed by different letters are significantly different ($p < 0.01$).

Figure 19 - Wild strawberry plant grown on FMix2: inflorescenxe and fruit bearing shoot

Results concerning blueberry soilless cultivation showed that all growing parameters very significant affected by the SM regardless of the tested cultivar (**Errore. L'origine riferimento non è stata trovata.**). Even though all the plants suffered during the summer period from the unfavourable environmental conditions imposed by the crop protection, blueberry plants grown on MMix 1 exhibited increased stem diameter, plant height, number of sprouts and fruit production compared to TS-based substrate mixes. These data indicate that the remediated marine sediment is not suitable for the cultivation of this species, due to its high pH and bulk density as well as low TOC percentage (Figure 20 left). Fruits of cv 'Bluecrop' displayed better morphological and physiological patterns than 'Duke'. Water supply did not affect plant development, flower differentiation and fruit set (**Errore. L'origine riferimento non è stata trovata.**0 right).

Figure 20 - Undeveloped root system of 'Duke' blueberry grown in MMix 3-WR1 (left); inflorescence of 'Bluecrop' plant grown in MMix 2 – WR2 (right)

The analyses of inorganic and organic contaminants in the different plant parts evidenced that heavy metals, PAHs and HhC10-C40 are sequestered in the roots and stems of this shrub species.

Citrus limon cv 'Verna' grafted on 3 different rootstocks was monitored during two growing season (Spring 2020-Spring 2022). Growth parameters, fruit production, fruit quality (morphological, chemical and nutraceutical), soil microbiome (bacterial and fungi communities), and sensitive indicators of the cellular metabolic state (leaf gas exchange measurements and metabolomic analysis) were assessed. In general, all the lemon trees showed adequate vegetative growth and production patterns, although lemon trees grown on TS75 showed a reduced development in terms of both trunk diameter and leaf size. Moreover, lemon trees grown on TS50 and TS75 required less water than those cultivated on TS25, that is, the amount of irrigation water applied was lower as the content of TS was higher. This is due to the physical-chemical characteristics of the treated sediment that retains a more significant amount of water in the growing media.

Trees cultivated on SM composed by 50%TS and 50% Pe exhibited the highest fruit production (both in number of fruits and in weight) (Table 90), while few significant differences in lemon fruit morphological characteristics were found among the considered treatments (Figure 21). The lemons obtained from the 9 studied substrate*rootstock combinations had appropriate characteristics for their categorization as commercial product. The nutritional value of the 'Verna' lemon juices was homogeneous among all treatments.

Table 90 - Effect of the growing media and rootstock on 'Verna' lemon production

Factor	Fruits/tree (n°)	Yield (kg tree^{-1})	Fruits (total n°)	Total yield (kg)
Growing medium				
TS25	9.63 c	1.68 a	289 c	50.51 b
TS50	19.66 a	3.12 b	590 b	90.53 a
TS75	4.13 b	0.58 c	124 a	17.28 c
Rootstock				
C. macrophylla	14.83 a	2.35 a	445 b	70.78 b
C. aurantium	3.03 b	0.65 b	91 a	18.86 a
C. aurantium/C. sinensis	15.56 a	2.28 a	467 c	68.67 c

Mean values within each factor followed by different letters are significantly different at $P \leq 0.01$.

Figure 20 - Production of grafted lemon plants in pots

In conclusion, the amount of sediment that can be successfully replaced with peat for soilless cultivation fluctuated according to the considered species and its soil and nutritional requirements. In particular, the sediment was not a suitable substrate component for blueberry,

a very demanding species especially in terms of organic matter and pH. On the other hand, the treated sediment was successfully used in low percentages for the cultivation of basil and in higher rates (up to 50%) for the production of strawberries and lemons.

C3.3 *Physical, chemical and biochemical properties of the growing media*

CNR-IRET was involved in this action for the physical, chemical and biochemical characterization of the growing media. In particular, the following analysis were carried out on all substrates both at the time of preparation and at the end of the vegetative plant cycles.

- Physical: Bulk density
- Chemical: pH, Electrical Conductivity, organic matter, Nutrients Total content and Availability
- Biochemical: Hydrolytic and Oxidoreductase enzymes

Other analysis such as water retention curve, phytotest, cation exchange capacity, etc. were carried out for scientific interest and with the aim of publishing in high-ranking scientific journals. The results showed that the mixing of sediments after landfarming with other organic matrices (peat, coconut, wood) allow the reaching of values required by Italia legislation for agronomic substrates for all parameters (D.Lgs 75/2010). All the substrates were suitable for the growth of the selected plants, and in particular those with a concentration of sediments less than or equal to 50% showed better growth and better physiological characteristics of the plants. In addition, a different influence of various plants on physical, chemical and biochemical characteristics of the substrates were generally observed.

This action has been 100% completed. All technical details are given in the specific Deliverable (Annex 11 of this Report).

Action C.4: Monitoring of socio-economic impact of the project and LCA

Foreseen start date: 10/2020 *Actual start date: 02/2019*
Foreseen end date: 09/2021 *Actual end date: 09/2022*
Related deliverable: *Report on the socio-economic impact of the project*
Foreseen date (original): 09/2021
Date of production: 09/2022 (Annex 12 of this report)
SUBSED LCA
Foreseen date (original): 09/2021
Date of production: 09/2022 (Annex 13 of this report)

One of the main objectives of this action was to analyse and comprehend the socio-economic context in which the SUBSED project operated. This activity was fundamental to understand the sensitivity of society towards the environmental issues addressed and the impact that the SUBSED project had on their awareness. For this reason, the consortium developed 2 questionnaires (in Italian and Spanish) that were distributed during the events and via the project website. At the end of the project, 214 responses (110 IT + 204 ES) were collected and analysed. The main conclusions can be summarised as follows:

- SUBSED contributed to raising awareness about the environmental problems addressed, especially about sediments and coconut products.
- Interviewees strongly request the offer of new sustainable alternatives and more information about the problems deriving from traditional solutions.
- Interviewees are willing to use sediment-based substrates and to pay higher prices to purchase substrates or products grown on them.
- Interviewees requires a regulatory support for the diffusion and growth of new circular and sustainable solutions.
- A part of the interviewees proved to be wary of consuming food products grown on sediment-based substrates, and therefore an increasing information and communication activity is needed in this sense.

In general, therefore, the new eco-sustainable model proposed by SUBSED could find fertile ground from a social point of view and could lead to an effective social impact.
Full details about questionnaire and data elaboration are given in the Deliverable attached to this report as Annex 12.
The other main outcome of Action C.4 is the Life Cycle Assessment (LCA) of the proposed solution, carried out with the scope to prove that the use of dredged sediment instead of the standard substrate is a benefit in absolute terms on all categories of environmental impact.

Italian LCA Analysis

The Italian LCA analysed seven different cultivations summarized in the following three plant families: nursery plants (Olive tree and Laurel); ornamental plants (Calla and Protea); edible plants (Strawberry, Blueberry, Basil). The coltivations are located at 'Flora Toscana'and grown under controlled experimental conditions using different proportions of port sediment. The study has been divided into the folowing phases:

- Definition of the objective and scope. The main goal of this study is to assess the environmental impacts deriving from the "from-cradle-to-gate" life cycle of a functional unit consisting in a pot of nursery plants / ornamental plants / edible plants. The scope of the analysis in this study is to prove that the use of dredged sediment instead of the standard substrate is a benefit in absolute terms on 16 categories of environmental impact.
- Inventory analysis. The inventory data have been obtained from the monitoring carried out at Flora Toscana Soc. Agr. Coop. (Cooperative Agricultural Company), where the sediment has been tested. For each functional unit (pot of nursery plants / ornamental plants / edible plants) the system boundaries considered in this study includes: Substrate production; Water supply and Wastewater management; Electricity supply; Fertilizer production; Pesticides production; Transportation of the materials and products

Impact evaluation. The sediments-based substrate life cycle (including extraction of the dredged sediment, end-of-waste process and transportation) has a much lower environmental impact in absolute terms than the production of peat (including extraction, elaboration and transportation). The major impact of the peat life cycle is given by transport. In fact, the study compares peat imported from the Latvian supplier with dredged sediment from the Italian coast. Life-cycle impact of 1 kg of sediment is 90-96% lower than the life-cycle impact 1 kg of peat in terms of Climate Change (kg CO_2 equivalent); Freshwater ecotoxicity (CTUe); Human toxicity, non-cancer effects (CTUh); Ionizing radiation HH (kBq U235equivalente); Ionizing radiation E (CTUequivalent); Terrestrial eutrophication (molc N equivalent); Land use (kg C deficit) and Mineral, fossil & ren resource depletion (kg Sb equivalent).
When the overall cultivation life cycle is evaluated (including substrates, water, fertilizers and pestices consumption) the impact using the sediments-based substrate is lower in absolute terms for quite all the environmental impact categories (for at least 10 out of 16 categories up to 16 out of 16 categories).
The analized system, so called "functional unit", was chosen at the beginning of the project with the aim of obtaining a representative object of study for each crop (eg. 1 pot containing 1 olive tree). This unit did not allow the productivity of each crop to be assessed (e.g. the quantity of olives obtained from 1 pot of olive tree). For this reason, each functional unit was linked to a characteristic unit useful to create intensity indicators and enriching the analysis with new elements to evaluate the results. So, the results obtained by verifying the yield of each product demonstrate that an increase in productivity is obtained for Olives, Lauro, Calla and Strawberry when these crops are grown on a substrate composed of 50% dredged sediments. Protea and Blueberry, on the other hand, prove to be less suitable for this type of substrate, recording lower yields.
Interpretation. In conclusion, the alternatives prove to be valid substitutes for peat for quite all the crops (below the best substrate composition for each crop):

- Olive: 50% ST (dredged sediments) and 50% SBT (peat-based substrate)
- Laurel: 25% ST (dredged sediments) and 75% SBT (peat-based substrate) but also 25% ST (dredged sediments) and 75% SBFC (substrate based on coconut fiber)
- Calla: 50% ST (dredged sediments) and 50% SBT (peat-based substrate)
- Protea: 25% ST (dredged sediments) and 75% SBT (peat-based substrate) but also 100% SBT (peat-based substrate)
- Strawberry: 50% ST (dredged sediments) and 50% SBT (peat-based substrate)
- Blueberry: 100% SBT (peat-based substrate)
- Basil: 100% ST (dredged sediments)

Notes: SBT (peat-based substrate) is composed by 60% peat and 40% pumice; SBFC (substrate based on coconut fibre) is composed by 60% coco fibre and 40% pumice.

Spanish LCA Analysis

The Spanish focused on lemon production (*Citrus limon* L. Burm) of the 'Verna' cultivar, grown under controlled experimental conditions using different proportions of port sediment.

The international standard used has been ISO 14040:2006; it has been divided into 4 phases:

- **Definition of the objective and scope.** For the study three different culture media mixes were studied (v:v); i) 25% sediment + 75% peat (S25); ii) 50% sediment and peat (S50); and iii) 75% sediment + 25% peat (S75). The product system of this LCA is shown in Figure 21. The extraction and phytoremediation process of the dredged port sediment has been left out of the product system since it is of no interest in terms of the objectives of this study. The functional unit or reference unit used to measure the performance of the inputs and outputs of the product system corresponded to 1 kg of Verna lemons. The limits of the system have been established from the cradle to the door of the experimental farm (*cradle-to-gate*).

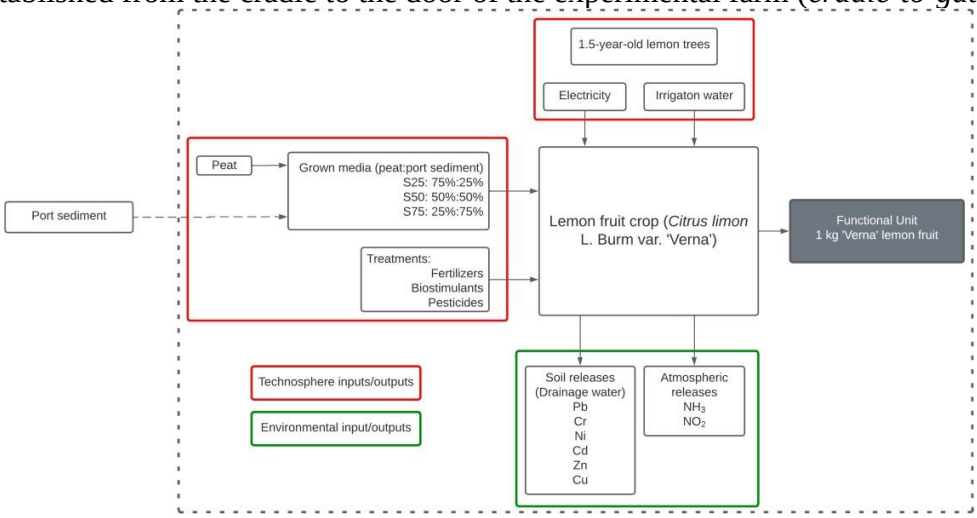

Figure 21 - Scheme of the product system defined for the study

- **Inventory analysis.** The inventory data have been obtained from the monitoring carried out on the experimental farm between May 2020 and January 2022. A smaller amount of data (the so-called secondary data) have had to be calculated through estimates.
- **Impact evaluation.** The results confirmed that S50 (a mixture of 50% peat and 50% port sediment) provided the highest production of lemons (90.5 kg), followed by S25 (50.7 kg) and, S75 (17.3 kg). The water demand, referenced to the functional unit (1 kg of lemons), was higher in the case of S75 (1698 kg water/kg lemons). This is because, despite the fact that, in absolute terms, the amount of irrigation water supplied was similar for all the culture media, the production was lower in the case of S75. On the contrary, S50 presented the lowest water consumption per kg of lemons produced, with a consumption of 329 kg water/kg lemons, mainly due to both the higher production obtained in the trees grown with

this substrate and the greater water retention caused by the characteristics of the port sediment, which has a more clayey structure, improving water retention and reducing its demand. Regarding drainage water, the largest volume of leachate in absolute terms was collected for S25 (6.9 m^3), followed by S50 (4.2 m^3), and S75 (3.4 m^3). This would be reasonable since crops with higher sediment contents present greater compaction, so they would better retain water and, therefore, generate less leachate. However, if we express the volume of drainage water per kg of lemons produced, S50 presents a lower ratio (0.05 m^3/kg lemons), followed by S25 (0.14 m^3/kg lemons), and S75 (0.20 m^3/kg lemons). Consequently, S50 deposited a lower amount of metal emissions into the soil per kg of lemons obtained. For atmospheric emissions, estimated from the amount of nitrogen applied in the form of fertilizer, both NH_3 and NO_2 emissions per kg of lemons were lower in case of S50 (0.440 g/kg for NH_3 and 0.352 g/kg for NO_2), followed by S25 (0.896 g/kg for NO_2). NH_3 and 0.717 g/kg for NO_2) were < (2.27 g/kg for NH_3 and 1.82 g/kg for NO_2)

- **Interpretation**. The results indicate that S75 was the sample with the greatest impact for all the categories included in the methodology. So, the impacts associated with S50 were approximately 80% lower than those associated with S75 for all impact categories, except in terms of the ecotoxicity of the terrestrial environment, which was somewhat lower (71% lower). In summary, the lower production obtained in S75 translated into higher environmental impacts per kg of lemons.

The results of the study confirmed that the environmental footprint of the use of port sediment for the cultivation of 'Verna' lemon trees increases as its percentage in the culture medium increases. This is mainly due to its effect on lemon yields. In this way, the lower yields of lemons obtained from lemon trees grown in the substrate with port sediment (S75) translated into greater environmental impacts per kilo of fruit. In this context, and based on the results, the potential for the use of port sediments mixed with other substrates was confirmed, employing media mixes that do not exceed 50% port sediment.

Action C.5: Performance indicators monitoring

Foreseen start date: 10/2018 *Actual start date: 10/2018*
Foreseen end date: 09/2021 *Actual end date: 09/2022*
Related milestone: *KPI Webtool at Mid-term report*
Foreseen date (original): 03/2020
Status: Achieved
KPI Webtool at Progress report
Foreseen date (original): 03/2021
Status: Achieved
KPI Webtool at Final report
Foreseen date (original): 09/2021
Status: Achieved

At the beginning of the project Flora Toscana implemented the KPI webtool as indicated in the original proposal. During the project, in addition to the continuous monitoring of these KPIs, the consortium cooperated several times to review the KPI webtool with the support of the external monitor and the project advisor. At the end of the project there are no major unexpected and unjustifiable deviations. More details are provided in Chapter 7 of this report.

Action D.1: Project dissemination plan: web-site, material, articles, Layman's report and video

Foreseen start date: 10/2018 *Actual start date: 10/2018*
Foreseen end date: 09/2021 *Actual end date: 09/2022*
Related deliverable: SUBSED Communication plan

Foreseen date (original): 12/2018
Production date: 12/2018 (attached to MtR as Annex 5)
SUBSED dissemination material at mid-term period
Foreseen date (original): 03/2020
Production date: 03/2020 (attached to MtR as Annex 6)
SUBSED dissemination material at project end
Foreseen date (original): 09/2021
Date of production: 09/2022 (Annex 14 of this report)

Related milestone: *SUBSED website*
Foreseen date (original): 12/2018
Status: Achieved

D1.1 Project website and social profiles → The lifesubsed.com website has been published during October 2018. Flora Toscana is responsible for the creation and maintenance of this project website and contributes together with the other beneficiaries to updating the contents.
The website has been created with a simple and functional interface, considering the heterogeneity of the target audience. Each content is available in the 3 project languages: English, Italian and Spanish. The original structure has been modified and improved during the project to be user-friendly and to quickly deliver the most important contents.
The associated G-Analytics profile reports the following main indicators (01/10/18-30/09/22):

- n. of users → 4,971;
- n. of sessions → 6,222;
- 91% new visitor vs 9% returning visitor

The website contains also links to the SUBSED social pages:
- **Facebook profile**: 260 followers at 30/09/22, with just over 21,000 people reached.
- **Twitter profile**: 34 followers at 30/09/22, with 2,374 impressions and 1.483 profile visits.

D1.2 Dissemination material → the following dissemination materials have been produced:
- 1 project logo.
- 12 notice boards, displayed in visible spots and public places at the partners' premises.
- 15 posters.
- ~ 12,500 brochures (2 versions: one for illustrating the SUBSED general contents, one for summarising the activities carried out and the results achieved at the end of the project);
- ~ 14,500 branded items;
- 3 roll-ups illustrating SUBSED contents;
- 12 SUBSED banners for fairs and events.

All the partners cooperate in the development of these materials and in the distribution of them during events, fairs, daily activities, project workshops and technical events. All the materials contained SUBSES acronym and other references to project and LIFE programme.
D1.3 SUBSED publications, articles and press releases → during the project life, the consortium produced and published 25 general articles and 22 scientific articles.
D1.4 Layman's report → during the last phase of the project, the consortium cooperated to develop the SUBSED Layman's report, that has been translated in Italian, Spanish and English. This report has been designed to quickly and easily provide the reader with information on project objectives, activities, results and impact obtained. Some paper copies have been produced and distributed during the last project events, while the PDF version is available on the project website and can be quickly downloaded directly from the homepage.
D1.4 SUBSED video → in addition to some secondary videos produced and published online during the project life, a specific SUBSED video has been produced. The video contains both external material and original material, shot in different moments of the project. The video was produced in English, Italian and Spanish and broadcasted during the final events. The video is available on the SUBSED website and has been shared via social networks.

As scheduled, this action was 100% completed. Full details on all these activities are given in the deliverables already attached to the Mid-term report and in the deliverable "SUBSED dissemination material at project end" attached to this report as Annex 14.

Action D2: Project dissemination plan: events, networking and contacts with Institutions and policy makers

Foreseen start date: 10/2018 *Actual start date: 10/2018*
Foreseen end date: 09/2021 *Actual end date: 09/2022*
Related deliverable: SUBSED dissemination events at mid-term period
Foreseen date (original): 03/2020
Production date: 03/2020 (attached to MtR as Annex 7)
SUBSED dissemination events at project end
Foreseen date (original): 09/2021
Date of production: 09/2022 (Annex 15 of this report)

D2.1 SUBSED participation in events → This dissemination activity has been strongly impacted by the COVID-19 pandemic: however, the SUBSED beneficiaries participated in more than 45 national and international events (the proposal plans at least 10 events), achieving an effective dissemination of the project objectives, activities and achieved results.

D2.2 Networking → all the project beneficiaries have been involved in networking activities with other projects, both from LIFE programme and other kinds of programmes. In particular, during the project there have been active exchanges in experiences and knowledge with 17 projects (the proposal plans at least 10 projects involved in active networking). This networking activities will continue beyond the project end.

D2.3 Dissemination to Institution and Policy makers → This activity was also heavily impacted by the restrictions linked to the COVID-19 pandemic, which have greatly reduced the opportunities for meeting with these subjects. However, the consortium had contacts with 26 policy makers (the proposal plans at least 10 representatives of institution and policy makers during the project lifetime). This number do not consider the various members of the Tuscany authorisation committee (composed by representants from the Tuscany Region administration and ARPAT) and the 45 members of the INNOAGENTS network of the Valencian Innovation System. In addition, more than 45 **stakeholders** (e.g. trade associations, professional associations, waste and water managers, companies, etc.) have been contacted and involved in the project activities, and much positive feedbacks have been collected. The consortium will cooperate with them for the future exploitation of project outcomes.

As scheduled, this action was 100% completed. Full details on all these activities are given in the deliverables already attached to the Mid-term report and in the deliverable "SUBSED dissemination events at project end" attached to this report as Annex 15.

Action E1: Project management by FLORA

Foreseen start date: 10/2018 *Actual start date: 10/2018*
Foreseen end date: 09/2021 *Actual end date: 09/2022*
Related deliverable: SUBSED Mid-term report
Foreseen date (original): 03/2020 Production date: 09/2020
SUBSED final report
Foreseen date (original): 12/2021 Date of production: 12/2022

All the beneficiaries strictly collaborated during all the phases of the project, in order to achieve the objectives foreseen and perform a proper project management. Management activities are almost daily, and meetings (physical and mainly virtual after the COVID emergency) are held to guarantee the correct management activities. Actions carried out were:

1. Grant and Partnership agreements: preparation, discussion, signing
2. Coordination and monitoring meetings:
   - Kick-off meeting at Flora Toscana's headquarter (5th October 2018, Pescia, Italy)
   - Monitoring meeting during the 6M Coordination meeting (21st March 2019, Flora Toscana's headquarter, Pescia)
   - Monitoring meeting during the 18M Coordination meeting (27th March 2020, online)
   - 24M Coordination meeting (15th September 2020, online);
   - Monitoring meeting during the 30M Coordination meeting (22nd April 2021, online + 26th April 2021 live at trial sites)
   - 36M Coordination Meeting (28th September 2021, online)
   - Monitoring Meeting during the 42M Coordination Meeting (17th May 2022, Flora Toscana's headquarter, Pescia)
   - 48M Coordination Meeting (15th September 2022, CREA-OF headquarter, Pescia)
3. General contacts between beneficiaries: continue contacts via phone, mail, online calls and meetings for planning and monitoring of project technical activities
4. Management of the financial aspects and periodical collection of documents from ABs
5. Periodical reporting to the LIFE external team monitor: collection of contributes and predisposition of the reports on the project progress
6. Submission of progress reports (31/03/2020, 31/03/2021, 31/03/2022)
7. Submission of Mid-term report (30/09/2022)
8. Amendment requests (a first one for administrative changes in the status of two Abs, a second one for request of project prolongment)
9. General actions and activities for the coordination of the project

All beneficiaries contributed to project management activities, keeping in smooth contact with the project coordinator. All beneficiaries actively attended the project meetings and collaborated with Flora Toscana in the preparation of this Final Report.

Action E2: SUBSED audit

Foreseen start date: 07/2021 *Actual start date: -*
Foreseen end date: 09/2021 *Actual end date: -*

Contrary to what was originally foreseen in the proposal, none of the beneficiaries has to produce a certificate on the financial statements because the EC total contribution in the form of reimbursement of actual costs is always less than €750,000 (Art. II.23.2 (d) of the GA).

Action E3: SUBSED After-LIFE plan

Foreseen start date: 07/2021 *Actual start date: 07/2022*
Foreseen end date: 09/2021 *Actual end date: 09/2022*
Related deliverable: *SUBSED After-LIFE plan report*
Foreseen deadline: 09/2021
Status: Completed on 09/2022 (Annex 16 of this report)
Related milestone: n/a

During the last months of the LIFE SUBSED project, the beneficiaries collaborated to define the possible paths for the future exploitation of the project outcomes.

Communication and Dissemination activities will be continued by all partners with their own resources. These activities include:

1. maintenance and updating of the website and socials for 5 years after the project end;
2. distribution of dissemination material produced before and after project end;
3. participation in national and international conferences and fairs and promotion of the results of the SUBSED project;
4. production of scientific and general articles related to the SUBSED project;

5. networking activities with other projects (LIFE and other programmes);
6. contacts and cooperation with relevant stakeholders and policy makers;

The **exploitation** of the results of SUBSED will be pursued on several levels:

- **R&D level** → SUBSED results will be the basis for new research activities, both for public and private entities. CNR, CREA and UMH are already including the experience gained during the SUBSED project in new R&D activities. The consortium will look for new funded project for bringing the SUBSED solution at higher TRL.
- **Commercial level** → The pilot trial carried out in collaboration with AREA srl validates an effective alternative for completing the EoW procedure for sediments and obtaining materials which – being no longer classified as waste – can be used as an ingredient for substrates. In addition, the changes introduced by the new European regulation (implemented in Italy in the last months, and for which some regulatory adaptations are still undergoing) have opened up new prospects for the commercial exploitation of sed-based products. Flora Toscana considers the use sediment from the EoW trial interesting for substrate production.

As scheduled, this action was 100% completed. Full details are given in the deliverable "SUBSED After-LIFE plan report" attached to this report as Annex 16.

6.3. Evaluation of Project Implementation

The following table compares through quantitative and qualitative information the results achieved at the end of the SUBSED project:

Action	**Sub-action**	**Foreseen in the revised proposal**	**Achieved**	**Evaluation**
A.1 Review of the EU and national regulations on the use of sediments for plant nursery and analytical protocols	A.1.1 Preconditioning process for increasing the organic carbon and decreasing the bulk density in order to reach the limit required	Objectives: To produce a sediment which can be used as agronomic substrate Expected results: Bulk density 0.9-0.95 TOC 4-6%	To reach the characteristic requested by D.Lgs.75/2010 in the final commercial sediment-based substrate, the sediments have be mixed with materials able to reach the legal limits	In line
	A.1.2 Review of the EU and Italian and Spanish law/ regulations regarding the transport and use of dredged sed-based substrates for plant nursery being in force at project beginning	Objectives: To describe the legal framework on reuse of dredged sediments Expected results: Starting SUBSED project based on the existing regulations	Report on the Review of legislation on dredged sediment management (Deliverable 1 A.1) Report on Experimental activities authorization for the use of sediments in Italy (Deliverable 2 A.1) This action is 100% completed	The issue of Authorisation for Italian trials took longer than expected. In Spring 2020 the Authorisation was obtained.
	A.1.3 An update of the list of the analyses to be performed on substrates and products	Objectives: To update the analyses on sediments and plants Expected results: To define a standardised list of analyses	A commonly agreed analytical protocols has been designed. This action is 100% completed.	No relevant problems occurred.
	A.1.4 Defining a common analytical protocol	Objectives: To define common protocols Expected results: Homogeneity of analytical procedures	Obtain a common standard protocol and useful toolkits for all partners. This action is 100% completed.	No relevant problems occurred.
	A.1.5 Final national and EU legislation overview with recommendation for future legislation	Objectives: To describe the legal framework on reuse of dredged sediments at project end and to give recommendation on future improvement Expected results: To have a final	The analysis of the legal framework has been performed including updates. The related deliverable includes details on the EoW trial and recommendations for future	No relevant problems occurred.

		updated overview of the legal framework and to give recommendation based on the experience gained during the project	improvement of legal framework.	
B.1 Phytoremediated sediment treated via landfarming process		Objectives: to homogenise the substrate, increase the biological activity and reduce organic contamination. Expected results: Sediments homogenized and ready to use.	The landfarming methodology was effective in the decontamination and transformation of sediments. The related deliverable has been submitted with MtR. This action is 100% completed.	This action began 1 month in advance and was completed in 3 months.
B.2 Demonstration of the use of remediated sediments as a substrate for nursery production	B.2.1 Nursery production of ornamentals B.2.2 Nursery production of olive and citrus	Objectives: Establishment of nursery plants using sed-based substrates Expected results: To obtain marketable nursery plants comparable to those grown in a standard peat-based substrate	The foreseen trials have been carried out. The substrates proved to be suitable for nursery production. The related deliverable is attached as Annex 2. This action is 100% completed.	This action has been 12 months delayed depending on the authorization issue by Tuscany Region. The project prolongment allowed to complete the action as planned and achieve the substrate validation.
B.3 Demonstration of the use of remediated sediment as a substrate for non food crop cultivation		Objectives: Establishment of flowers/ornamental crops using sediment-based substrates Expected results: To obtain marketable nursery plants comparable to those grown in a standard peat-based substrate	The foreseen trials have been carried out. The substrates proved to be suitable for nursery production. The related deliverable is attached as Annex 3. This action is 100% completed.	This action has been 12 months delayed depending on the authorization issue by Tuscany Region. The project prolongment allowed to complete the action as planned and achieve the substrate validation.
B.4 Demonstration of the use of remediated sediment as a	B.4.1 Basil cultivation B.4.2 Blueberry cultivation B.4.3 Wild strawberry cultivation	Objectives: Establishment of flowers/ornamental crops using sediment-based substrates Expected results: To obtain marketable nursery plants	The foreseen trials have been carried out. The substrates proved to be suitable for nursery production. The related deliverable is attached as Annex	This action has been 12 months delayed depending on the authorization issue by Tuscany Region. The project prolongment

substrate for food crop production	B.4.4 Citrus cultivation	comparable to those grown in a standard peat-based substrate	4. This action is 100% completed.	allowed to complete the action as planned and achieve the substrate validation.
B.5 Training courses, workshop and guidelines	B.5.1 – Training courses	Objectives: To train operators involved in plant nursery and agriculture about the developed solutions. Expected results: To plan and perform 2 training courses.	2 training courses organised (1 in Italy, 1 in Spain). This action is 100% completed.	Despite the COVID-19 pandemic restrictions, the consortium involved ~ 75 people in these courses.
	B.5.2 – Workshops	Objectives: To disseminate SUBSED progress and results to specialised workers, general audience, policy makers and stakeholders. Expected results: To organise and perform 4 workshops.	4 workshops organised (2 in Italy, 2 in Spain). This action is 100% completed.	Despite the COVID-19 pandemic restrictions, the consortium involved ~ 320 people in these courses.
	B.5.3 - Guidelines	Objectives: To develop and distribute guidelines to enhance replicability and transferability of the SUBSED solutions. Expected results: To develop and distribute1 Manual with guidelines for use of sediment-based substrates.	The Manual has been produced and distributed (online and in paper format). This action is 100% completed.	The guidelines were distributed to participants in project events and relevant stakeholders. They are available in PDF on the project website.
B.6 SUBSED business plan		Objectives: To assess the target markets and analyse the economic viability of the proposed solution Expected results: To validate the economic sustainability of the proposed solution	The SUBSED business plan has been developed. This action is 100% completed.	The assessment carried out during the BP development validated the sustainability of commercial exploitation of SUBSED outcomes.
C.1 Monitoring and validation of treated sediment		Objectives: Chemical, physical, biological characterisation and analyses of dredged sediments Expected results: General recommendations for the use of the	Treated sediments have been analysed from chemical, physical and biological point of view. Action completed 100%	The treated sediments appear suitable for use in cultivation trials. The related deliverable has been submitted with MtR. An additional document

		treated sediments in horticulture and nursery production.		containing recommendations of future sediment use has been produced.
C.2 Monitoring and validation of the use of remediated sediment as a substrate for plant nursery and cultivation: non food crops	C.2.1 Laurel nursery production C.2.2 Cultivation of non food crops C.2.3 Physical, chemical and biochemical properties of the growing media	Objectives: To verify the suitability of remediated sediments as a component of a substrate for non food crops Expected results: Validation of the substrate use and assessment of growing performances.	The cultivation trials allowed to fully validate the use of sediment-based substrates for plant nursing compared to traditional media. Full details are available in the related deliverable (Annex 10). This action is 100% completed.	This action has been 12 months delayed depending on the authorization issue by Tuscany Region. The project prolongment allowed to complete the action as planned and achieve the substrate validation.
C.3 Monitoring and validation of the use of remediated sediment as a substrate for plant nursery and cultivation: food crops	C.3.1 Olive nursery production C.3.2 Basil, wild strawberry, blueberry and citrus cultivation C.3.3 Physical, chemical and biochemical properties of the growing media	Objectives: To verify the suitability of remediated sediments as a component of a substrate for non food crops Expected results: Validation of the substrate use and assessment of growing performances.	The cultivation trials allowed to fully validate the use of sediment-based substrates for plant nursing compared to traditional media. Full details are available in the related deliverable (Annex 11). This action is 100% completed.	This action has been 12 months delayed depending on the authorization issue by Tuscany Region. The project prolongment allowed to complete the action as planned and achieve the substrate validation.
C.4 Monitoring of socio-economic impact of the project and LCA		Objectives: To evaluate the social and environmental impacts of the proposed solution. Expected results: Proof of socioeconomic impact achieved and benefits deriving from the project; LCA document for environmental assessment of the project solutions.	A survey has been carried out to understand the baseline and the impact of SUBSED on the perception of the environmental issues addressed. Two LCA analysis (1 for Italian trials and 1 for Spanish trials) have been performed to assess the environmental sustainability. This action is 100% completed.	214 responses have been collected: the elaborated data confirm that SUBSED contributed to raise awareness about the addressed environmental issues and the LIFE programme. LCA analysis demonstrated the sustainability of the SUBSED solutions compared to the traditional ones.

C.5 Performances indicators monitoring		Objectives: To monitor project progress and performances. Expected results: Punctual project progress monitoring and evaluation.	Updated of the KPI webtool and continuous monitoring of the progress. This action is 100% completed.	No major deviation to be reported.
D.1 Project dissemination plan (web-site, material, articles, Layman's report and video)	D.1.1 web-site	Project website and Facebook page implementation and updating	Project website, Facebook page and Twitter profile implemented and regularly updated	The Twitter profile was not originally planned, but it helped for a wider visibility.
	D.1.2 dissemination material	Logo - 12 notice boards - 12 posters - 10,000 brochures - 2,500 gadgets - 1 roll-up	- Logo produced - 12 notice board produced - 15 posters produced - ~ 12,500 brochures produced (2 version in 3 languages) - ~ 14,500 branded gadgets produced - 3 roll-ups produced - 12 banners produced	More than planned.
	D.1.3 Articles	- 15 technical and general articles	- 25 technical publications - 22 general articles	More than planned.
	D.1.4 Layman's report	- 1 SUBSED Layman's report	- 1 SUBSED Layman's report (3 version in EN+IT+ES)	Paper copies distributed during events. PDF version available on the project website
	D.1.5 Video	- 1 project video	- 1 project video (IT+EN+ES) - various minor videos during project life	More than planned.
D.2 Project dissemination plan (events, networking and contacts with Institutions and policy makers)	D.2.1 – Fairs and international events	- participation in at least 10 national and international events	- participated in > 45 national and international events	More than planned (despite the impact of COVID-19!)
	D.2.2 – Networking	- networking with at least 10 projects	- networking with 17 projects	More than planned.
	D.2.3 – Dissemination to institutions and policy makers	- 10 people from institutions and policy makers	- >26 policy makers reached	More than planned.
E.1 Project		Management of project activities	Contacts between beneficiaries	Effective collaboration of all

management			and periodic meetings	beneficiaries
E.2 Audit		-	-	Not necessary.
E.3 SUBSED After-LIFE plan		After-LIFE plan	- SUBSED After-LIFE plan produced	The plan defines dissemination and exploitation activities for the next 5 years.

The following table presents the results achieved compared to the general expected results (from the proposal).

Result expected	Result achieved	Note
The 100% evaluation of the suitability of the sediments for the nursery production of food/non food species (laurel, olive and citrus)	The trials and related monitoring activities carried out allowed the full validation of the use of sediments as component of substrates for the nursery production of food/non-food species.	The treated sediment was successfully used as growth medium constituent in the proportion up to 50%. Indeed, cherry laurel rooted cuttings, grafted olive trees and *Citrus* seedling rootstocks cultivated in blends containing 25-50% treated sediment in combination with peat or coconut coir showed a similar agronomical behaviour in terms of plant development compared to the control treatment.
The 100% evaluation of growth and commercial quality of non food crops (calla lily, protea and laurel)	The trials and related monitoring activities carried out allowed the assessment of the quality of non-food crops grown using sediments-based substrates. The products obtained meet the target commercial quality.	The treated sediment allowed plant development and flowering in all tested substrate blends tested. Recommended for calla cut flower production (up to 50%), the TS can be also used successfully for potted cherry laurel and protea cultivation if properly combined in the correct proportions (up to a maximum of 50% and 25%, respectively) with other organic matrixes, such as peat and coir. Especially for protea, the induced compact behaviour might represent a valuable feature for this species, when cultivated as a flowering pot.
The 100% characterisation from the morphological, biochemical and sensorial point of view of 1 basil, 2 blueberry and 1 woodland strawberry cultivars grown in container on treated sediment-based substrates	The trials and related monitoring activities carried out allowed the characterisation of these products.	The amount of sediment that can be successfully replaced with peat differed according to the considered species and its soil and nutritional requirements. The sediment was not a suitable substrate component for blueberry, a very demanding species especially in terms of organic matter and pH, while was successfully used in low percentages for the cultivation of basil and in higher rates (up to 50%) to produce strawberries and lemons. The nutraceutical values of the products confirmed qualities in line with commercial standards.
The 100% evaluation of the suitability of food crops in relation to heavy	Full evaluation of the sustainability of food crops in relation to pollutants contained in sediments.	The analysis carried out during the project on sediments, plants and fruit allowed to assess the levels of pollutants and the consequence on products. The substrates proved to be suitable for the use in these

metals and other pollutants also of organic origin		productions. More details are contained in the related deliverables, annexed to this Report.
The 100% improvement of the knowledge on the treated sediments and their influence on plant growth and fruit quality	Improvement of the knowledge on the treatment and use of sediments for producing growing media.	The trials and the data elaborated during the SUBSED project allowed to increase the knowledge about treatment and use of sediments in agriculture. The achieved results have been disseminated to the scientific community and professionals working in the nursery/agriculture sector and in the field of sediment/waste management. This information is also included in the SUBSED Manual produced during the project and distributed (it can be downloaded for free from the project website).
The 100% evaluation of the suitability of treated sediments to be converted into a marketable product and also face the normative and legal issues related to the use of dredged remediated sediment as substrate in agriculture	The analysis and trials carried out confirmed the suitability of treated sediments for the production of marketable substrates. During the project, a new possible path based on the current legislation has been identified and validated through a trial that allowed to reach the EoW for sediments.	The EoW pilot trial allowed to recover a first batch of sediments that have been reclassified from waste to by-products that can be used in agronomic contexts. During the project, the consortium carried out a specific communication activity aimed at reaching relevant policy makers and stakeholders, in order to present the current rigidities related to bureaucracy and difficult legal procedures.
Substitution of peat with treated sediments (approx. 10-20% substitution is expected)	This result has been fully achieved.	During the cultivation trials carried out within the SUBSED project we had a 39% substitution of peat with sediments and a general 63% substitution of peat with sediments and other alternative matrixes.
Reduction of CO_2 emission (kg) due to the substitution of peat by treated sediments (expected to be about 80-90% less) – Expected result from original proposal	In the answer to the issues raised in the EC letter of 24/05/2019 (attached to MtR), we reformulated the expected result as "Reduction of peat content in the substrate with at least 10-20% of remediated sediment and a consequent CO_2 emission reduction". Relevant decrease in emission has been highlighted during LCA.	The quantification of the emission reduction depends on the basic assumptions and the type of substrate and configuration considered (full details can be found in Annex 13). For example, 1 kg of peat produces 202 kgCO2eq, while 1 kg of SUBSED substrate composed by 50% sediment + 30% peat + 20% pumice produces 69.90 kgCO2eq. So, in this case, we reached a -65% reduction in emissions per kg of substrate.
A marketable product	The SUBSED substrates proved to be suitable for professional use in nursery and agricultural production, with performances able to meet the needs of the demand.	The EoW pilot trial represented a great opportunity for validate a strategy for overcoming the current regulatory rigidities. However, the normative framework is evolving, and that could result in more support for the transition to circular economy models.

Project progress was periodically monitored by the leaders of the related actions. During the coordination meetings, the consortium meets and discusses the results achieved in the previous months and plans the actions for the following (at least) 6 months. Any deviations or threats were discussed together and, subsequently, the corrective actions to be taken were decided. Thanks to the extension approved by the EC and to the efforts of all beneficiaries, the consortium was able to recover the initial delay without compromising the significance of the results obtained, but rather by increasing the value of demonstration with additional and not originally planned activities.

6.4 Analysis of benefits

Environmental benefits

The SUBSED project faced environmental and sustainability aspects in the sectors of the management of dredged sediments, food crop production and plant nursing. Previous projects provided demonstration on the possibility to develop a sustainable management for dredged contaminated sediments, turning them into a marketable clean raw material with a 65%-80% cost save compared to traditional decontamination costs. SUBSED took a step forward and validate the possibility to apply the "clean sediment" for production of an innovative and sustainable substrate, alternative to the peat-based ones, suitable in common agricultural practices for plants (ornamentals and food crops) propagation and cultivation. In this way, the SUBSED solution contributes:

- to reduce the impact of dredging activity → during the project 67 m^3 (equal to approx. 100 ton) of sediments have been treated and reused for producing sustainable growing media;
- to reduce the impact of peat as ingredient for agricultural substrates → thank to the SUBSED cultivation trials, approx. 12 m^3 of peat have been substituted with sediments and other alternatives to peat.

In terms of emissions, the LCA analysis highlighted a relevant reduction: 1 kg of peat produces 202 kgCO2eq; 1 kg of SUBSED substrate composed by 50% sediment + 30% peat + 20% pumice produces 69.90 kgCO2eq (-65%).

Economic benefits

In terms of direct benefits obtained, the companies involved in SUBSED have created new additional direct jobs (5.47 FTEs), have been created for highly qualified personnel, while - currently - no FTEs have been created for unqualified personnel. Other indirect jobs have been created considering the work required to external companies whose services are needed in the project implementation.

In terms of indirect economic benefit, the participating SMEs had benefits from the visibility of the SUBSED project (dissemination activities, participation in fairs and events, networking with new entities and new business relationships) and the better image deriving from the participation in an eco-friendly initiatives. Environmental ethics is a growing theme among all the people, but also specifically among nursery operators: nursery companies are aware that a reduction of inputs commonly used in their production cycle (these inputs are generally highly impacting on the environment - e.g. peat, water, etc.) is necessary in a long-term perspective. Final users (and in turns companies) are increasingly oriented towards conscious purchase choices, and the transition of the production chain towards a more ecological model is certainly necessary for companies to maintain economic competitiveness.

Social benefit

Society can benefit from several direct and indirect effects: the environmental benefits deriving from SUBSED expected results (i.e. recycling of waste, lower emissions, lower impact on the environment) have positive effects on the environment which is a good for the community; the economic impacts (creation of jobs and nursery sector transition to new, more eco-sustainable and commonly appreciated business models) allow to offer new job opportunities (both in terms of number of jobs and also of new qualification and skill required) and improvement of economic and social conditions of the involved districts; increasing awareness of environmental issues allows to achieve the long-term consolidation of the previous benefits.

Despite the impact of COVID-19 pandemic, SUBSED worked hard for capillary disseminating and communicating the project purposes and the themes addressed. Increasing the knowledge and awareness of the general public in a long-term perspective is one of the most important social benefits pursued in the project (perhaps the most important). SUBSED's awareness raising activity is not intended only destined to the general audience, but also to companies and

policy makers. If consumers change their purchase orientation, companies must be able to provide eco-sustainable solutions. If citizens change their behaviours, also policy makers must change their orientations to facilitate the transition to new lifestyles and business models. Policy makers must certainly encourage consumers to make more conscious and eco-sustainable choices, but at the same time they must provide companies with the tools to complete the transition to sustainable business models. By acting on all these levels, the transition to a more sustainable future is truly possible, and SUBSED consortium worked for maximising the result obtainable at the end of the project and, overall, beyond the project end.

Replicability, transferability and cooperation

From a technical point of view, the proposed solutions proved to be replicable in different climatic and geographical contexts. The analysis of the substrates' performances on different species, in different geographical contexts and with the application of different water regimes allowed to have a global assessment of the possibilities of application and transfer of the proposed solution to other contexts/sectors.

From a commercial point of view, all markets are evolving and in search of new eco-sustainable solutions, and the nursery and agricultural ones are in line with this trend. The growing awareness of citizens about environmental issues and the pressures of the customers for ever more sustainable products require companies to look for products that are not only sustainable in economic terms, but also in environmental terms. The BP developed confirms the economic and financial sustainability at micro-economic level of the proposed model.

The possibility of reusing waste whose management is not very profitable or even very expensive (the disposal of polluted sediments costs about 150-170 €/m^3, the disposal of unpolluted sediments costs about 80-90 €/m^3) arouses a lot of interest for replicability. However, there are still some regulatory barriers (especially in Italy) to the use of sediments in agriculture, due to a non-harmonized and not totally clear legislation. The technical potential of the proposed solution therefore contrasts with the regulatory criticalities, strictly dependent on the framework in force in the individual country. The implementation of the EoW pilot trial validated a strategy exploitable in Italy for overcoming these barriers.

For the future exploitation of SUBSED outcomes, the Consortium developed a replicability and transferability plan (Annex 5), summarising: i) the possible paths for the replicability and transferability (e.g. trying to use different sediments as inputs) of the proposed solutions; ii) all actions carried out during the project and the material developed and distributed (e.g. guidelines); iii) the future activities for supporting the replication of the solutions validated (e.g. online support, organisation of specific courses/events for workers and professionals).

Finally, from the communication and dissemination point of view, the project reached different targets through direct dissemination (more than 12,500 brochures and 14,500 branded gadgets produced and distributed), participation in over 45 international and national events, networking activities with other 17 project, associations and other relevant stakeholders (around 26 direct contacts with their representant), online communication and production of videos. Various expressions of interest have been collected: some beneficiaries are already cooperating for the future exploitation of the SUBSED results, mainly for the its replication but also for the transfer (even partial) of the knowledge, experience and solutions developed. More details can be found in the afterLIFE plan attached.

Best practice lesson

The environmental, economic and social advantages of the SUBSED project make the proposed solutions very interesting. LIFE SUBSED benefited greatly from the experience inherited from past LIFE projects that dealt with sediments and with their reuse and is still collaborating with projects still in progress for the development of synergies and partnerships. The networking and comparison sessions with other projects are very useful and constructive to achieve an effective and synergistic exchange of the knowledge developed and experiences gained. During

its life, SUBSED validated the use of sediment-based substrates in the nursery production: the consortium, in addition to directly continuing the development of these solutions with future projects (funded or not), will actively work to transfer and share the knowledge, data and experiences gained in favour of other subjects wishing to optimize the validated processes and products or develop new solutions based on SUBSED good practices. A unitary strategic vision shared between different subjects allows to achieve a greater impact at technical, environmental and regulatory level.

Innovation and demonstration value.

The LIFE SUBSED project validated an innovative approach for turning marine port dredged sediments into valuable materials to be used as substrate for plant nursing and crop production. The derived advantages are: i) a sustainable management of dredged sediments, turned from waste into a resource; ii) soil conservation through a sustainable alternative for nurseries instead of peat; iii) public cost reduction due to a smarter utilization of sediments.

The exploitation of SUBSED solution will have a positive impact on environment, not only in the area where are localized the trials (Toscana and Murcia), but wherever there are areas with agricultural production in pot and bodies of water that need to be regularly dredged. The LCA analysis demonstrated that sediment-based substrates and products grown on these growing media have a reduced impact on the environment, and this result is in line with the emerging concerning about emissions and climate change and changing purchase behaviour and lifestyle of citizens and companies. Full details on technical, economical and environmental validation can be found in the related deliverables attached to this report.

Policy implications

The regulatory framework about treatment and reuse of sediments is really rigid and complicated. The non-harmonization at the European level, with significant regulatory differences between the single countries, limits the replication of solutions like the SUBSED ones in other geographical contexts. Evidence of the presence of legislative problems occurred during the action A.1 progress, where regulatory barriers emerged at Italian level. Although SUBSED was intended on a pre-industrial scale, the complex and uncoordinated Italian legislation required a lot of additional work for obtaining the Authorisation for trials (just imagine the difficulties in applying for an authorization at industrial level). The presence of these regulatory barriers and the absence of an effectively viably path of authorization for valorisation and re-use (free of incomprehensible bureaucratic delays and barriers of various kinds) represent a serious obstacle to the diffusion of circular economy solutions. This experience underlined the importance of acting at institutional level, to involve policy makers and authorities on these critical issues, the only subjects who can change the context. During the project, the beneficiaries encountered various stakeholders and policy makers with the aim of increase their sensitivity about these problems.

Even if the EoW trial validated a possible strategy for overcoming these barriers, the presence of these regulatory barriers represents a great obstacle to general transition to more sustainable business models and circular economy solutions. A lot of work still must be done for encouraging policy makers and institution to act for an improvement of the regulatory apparatus.

7. Key Project-level Indicators

At the project beginning, Flora Toscana entered the key indicators on the KPI webtool, collaborating with the whole consortium. During the weeks before the monitoring meeting held on March 2020, a review phase of the SUBSED KPI webtool started. During the KPI revision on the one hand some values had to be reformulated to make the indicators coherent with the edit guides and with the updated descriptors and units, on the other hand some additional comments about the basic assumptions and the calculation hypotheses have been included, in order to make the significance of the estimates more perceptible.
At the end of the project, the KPI webtool has been updated with the final values calculated for the final KPI snapshot.

In some cases, during the project lifetime, it was also necessary to change the baseline values indicated during the first KPI snapshot at mid-term period, due to some changes in project activities or new and more accurate estimations. In other cases, after consultation with the monitor, the consortium opted for deleting indicators that did not adhere to the actual reality and to the activities carried out during the project.

The following tables present the evolution of the indicators and the comparison between the expected results entered in the KPI webtool during the first snapshot and the results actually achieved at the end of the project. In addition, we also tried to make a comparison with the indicators initially estimated during the proposal submission: in some cases, these indicators cannot be included in the KPI platform because no suitable descriptors or units were found. In other cases, some indicators have been recalculated and adapted to the KPIs included in the webtool during the first data snapshot.

# KPI	First level descriptor	Start value	Target value	Actual end value	% of target achieved	Beyond end value	Unit
1.5	Project area/length	0	0.76	0.76	100%	20.00	ha
The estimated start and end values of the first snapshot have been confirmed. The areas indicated represents the actual area where the actions are taking place. The end value refers to the area connected to the LIFE SUBSED trials (mainly dredging area and cultivating area). This value does not include the area used for the additional EoW trial carried out in collaboration with AREA srl. The value beyond 3 years has been confirmed. It has been estimated considering specific areas where the less impactant SUBSED solutions could be adopted. This estimation considers the areas of inland waterbodies (rivers, basins, lakes), the adjacent areas (where, currently, the non-revalorized sediments are stored) and the areas for nursery production using SUBSED substrates. * With reference to the indicator table from the original proposal, during the first data snapshot the value at the end of the project (0.76 ha) was confirmed. However, the value after 3 years (56 ha) was reduced because, by checking the assumptions of the calculation, it appeared overestimated.							

# KPI	First level descriptor	Start value	Target value	Actual end value	% of target achieved	Beyond end value	Unit

1.6	Humans (to be) influenced by the project	0	12,000	12,000	100%	50,000	n.

The estimated values of the first snapshot have been confirmed.
The estimates of these values consider the number of people who has been and will be influenced by the project results and benefit of changes in their opinion and awareness.
Categories targeted by the project are citizens, workers, and professionals of the involved sectors (plant nursery, sediments management and waste managers); students and researchers; representatives of trade associations and other stakeholders relevant for the promotion of SUBSED contents.
The great participation of beneficiaries to fairs and events and the great number of contacts with several people and stakeholders permitted to reach the target set out for the end of the project during the review of the first snapshot. The "Beyond end value" has been estimated taking into consideration on the one hand the future "word of mouth effect" of people engaged during the project, on the other hand the effects of the planned AfterLIFE activities.

* With reference to the indicator table from the original proposal, there are 2 indicators linkable to this one from the KPI webtool:

- Number of entities/individuals reached/made aware: the end value proposed was 25,000 people, the beyond end value was 25,000.
- Number of entities/individuals changing behaviour: the end value proposed was 20,000 people, the beyond end value was 100,000.

During the first data snapshot, we "merged" and revised both the values, reducing the estimations entered in the KPI webtool because they seem overestimated and, in any case, difficult to be proved via objective data. In any case, in the light of the great participation in national and international events and the numerous direct contacts, we could consider the target of 25,000 people reached at the end of the project (although, as indicated above, we conservatively confirm the estimate of 12,000 people). The beyond end value of 100,000 people has been reduced because we considered reasonable to consider it achievable in at least 5 years after the end of the project and not in 3 years.

# KPI	First level descriptor / Second level descriptor	Start value	Target value	Actual end value	% of target achieved	Beyond end value	Unit
3.1	Waste management - 17 05 06 dredging spoil / Mass reduction due to recycling	0	15	100.5	670%	200	Ton/y

The estimated values of the first snapshot have been exceeded.
These values have been estimated converting the m^3 of sediments treated during the whole life of the SUBSED project in tons.

- Leghorn sediment treated with landfarming: $25m^3*1.5$ ton/m^3= 37.5ton
- Navicelli sediment treated during the EoW trial: $42m^3*1.5$ ton/m^3= 63 ton

The "Beyond end value" has been estimated considering the afterLIFE activities and the exploitation of SUBSED results by beneficiaries.

* With reference to the indicator table from the original proposal, the values estimated for the "Waste Reduction" indicator were 9 ton/y, while the beyond end value was 1780 ton/y. During the first data snapshot, we recalculated these values based on the project evolution

and of the KPI webtool guide instructions. The end value has been increased and has been exceeded during the project. The beyond end value has been recalculated considering the recovery of sediments focusing only on the context of the SUBSED project, and not considering the general sector at European/global level.

# KPI	First level descriptor	Start value	Target value	Actual end value	% of target achieved	Beyond end value	Unit
4.3	Resource efficiency – soil Soil erosion	37.3	14	13.6	169%	0	m^2

As already reporting with the first snapshot, we could not find, among the available ones in the KPI webtool guide, a descriptor capable to closely describe the decrease of pressure on peatland, as a consequence of the adoption of the SUBSED technology. Therefore, we have chosen "soil erosion" as a proxy of it. The estimated values are about the peatland area (considering an average 50 cm of depth for peat extraction) which is dug due to peat extraction for the production of traditional nursery substrates. During the first data snapshot, the Consortium estimated 28 m^2 as the begin value (the peatland area which would be affected by using only peat for the cultivation trials) and 14 m^2 as the final value (the peatland area which would be affected after substitution of average 50% peat during the cultivation trials).
The begin value has been recalculated considering the amount of peat necessary for carrying out the SUBSED cultivation trials using only peat (in this case 18.65 m^3 of peat would be used, which corresponds to 37.3 m^2). The actual end value refers to peat actually used for carrying out the SUBSED trials (11.82 m^3 of peat was replaced with other materials, and only 6.83 m^3 of peat was used during the SUBSED project, which correspond to 13.6m^2 of peatland area).
The % target has been calculated using the differences between start and end values of first snapshot (28m^2-14m^2=14m^2) and the actual ones (37.3m^2-13.6m^2=23.7m^2).

* With reference to the indicator table from the original proposal, there are 2 indicators linkable to this one from the KPI webtool:

- Reduced resource consumption – Raw materials: the end value proposed was 7 ton/y, while the beyond end value was 700 ton/y.
- Habitats - Areas progressing towards improvement or restoration or in a favourable conservation status: the end value proposed was 0.002 ha, while the beyond end value was 0.147 ha.

During the first data snapshot, we adapted these values to the scheme of KPI webtool, reducing the beyond end values because they appeared to be overestimated (they considered the macro-context, and not the specific context of the SUBSED project). The peat substitution obtained at the end of the project meets the target values indicated during the proposal submission.

# KPI	First level descriptor	Start value	Target value	Actual end value	% of target achieved	Beyond end value	Unit
4.3	Resource efficiency – Circular economy Number of entities where green circular	0	n/a	6	n/a	13	n. of entities

	economy practices are implemented						

These values represent the number of entities involved in the demonstration trials based on sediment recycling (Flora Toscana, its 3 subcontractors involved in cultivation trials, UMH, Caliplant). The number of entities interested in using sediment-based products after the end of the project may be higher, but we prefer to be more cautious while waiting to evaluate the uptake by the market.

* With reference to the indicator table from the original proposal, the table included the indicator "N. of replication/Transfer", which reported 1 replication at the end of the project and 13 replications after 3 years beyond project end were estimated. This indicator is a little bit different from the one available in the KPI webtool, but similar. The values indicated during the proposal submission can be confirmed, considering the replication carried out in Spain during the project and the possible replication of SUBSED solutions in other contexts in the coming years.

# KPI	First level descriptor	Start value	Target value	Actual end value	% of target achieved	Beyond end value	Unit
4.3	Resource efficiency – Circular economy Mass of input of actually recycled or reused waste per unit produced	0	n/a	0.75	n/a	0.75	Kg/kg unit produced

During the project, sediment was used as new alternative ingredient for the production of nursery growing media. We can consider as reference a substrate containing the 50% by volume of sediment as input material, which is equivalent to about 75% by weight of input materials (assumption for volume-weight conversion: sediment = 1500 kg/m3; peat/pumice= 500kg/m3).

# KPI	First level descriptor	Start value	Target value	Actual end value	% of target achieved	Beyond end value	Unit
4.3	Resource efficiency – Circular economy Mass of output of waste per unit produced	1	n/a	0	n/a	0	Kg/kg unit produced

At the beginning, the output of waste is total (100%). Then, due to the project's activity, at the end of project the output of waste is zeroed because all the sediment is integrated in the substrate. In other terms, there is no output of waste at the end of project nor beyond 3 years.

# KPI	First level descriptor	Start value	Target value	Actual end value	% of target achieved	Beyond end value	Unit
4.3	Resource efficiency – Circular economy Number of units produced/year	0	n/a	134	n/a	267	units

The units considered are the tons of growing media/substrate produced using sediments. These values have been calculated on the basis of values indicated in the KPI 3.1, considering the use of 75% in weight of sediment as ingredient.

# KPI	First level descriptor	Start value	Target value	Actual end value	% of target achieved	Beyond end value	Unit
8.1.1	CO_2	202	-	69.90	n/a	69.90	Kg CO_2eq/kg produced
		627,895.27	-	301,431.41	n/a	301,431.41	Kg CO_2eq/y

All the values of this KPI have been reformulated due to more accurate data obtained from LCA analysis. The values indicated during the proposal submission phase were already recalculated during the first data snapshot, but these values were still based on the available literature and previous experiences. The LCA carried out during the project allowed to obtain more accurate data.

Regarding the indicator with Kg CO_2/kg produced unit, the values have been recalculated as below:

- Start value: 202 kgCO_2eq/kg produced unit (instead of 53 kgCO_2eq/kg produced unit estimated at mid-term period). The produced unit considered is a 100% peat substrate. The value indicated is the one calculated during LCA analysis for peat from Latvia (the one used during the project);
- End value: 69.90 kgCO_2eq/kg produced unit (instead of 23 kgCO_2eq/kg produced unit estimated at mid-term period). In this case, the produced unit is the SUBSED substrate composed by 50% sediment + 30% peat + 20% pumice. The emission calculated for substrate considers all the transport activities and even the activities related to the EoW trial.

Regarding the indicator with Kg CO_2eq/y, the values have been recalculated as below:

- Start value: 627,895.27 Kg CO2eq/y. This value was calculated considering only the use of peat for carrying out the SUBSED cultivation trials. In total, 18.65 m^3 of peat would have been used. The unitary climatic change impact of peat is 101,001.92 kg CO_2eq/m^3. The total climate change would therefore be 1,883,685.81 kg CO_2eq which, divided by the 3 years of the test, corresponds to 627,895.27 kg CO_2eq/y.
- Final value: 301,431.41 Kg CO_2eq/y. This value was calculated considering all the ingredients used during the SUBSED trials (both peat and alternative materials). The calculation for each individual component is reported in the table below.

		SEDIMENT	PEAT	PUMICE	WOOD FIBER	COCONUT FIBER
Total quantity [m^3]	m^3	7,31	6,83	3,40	0,15	0,96
Climate change [kg CO_2eq/ m^3]	kg CO_2eq/ m^3	7.719,40	101.001,92	15.144,28	4.656,94	110.242,94
Climate change [kg CO_2eq]	kg CO_2eq	56.428,81	689.843,11	51.490,55	698,54	105.833,22
Total impact [kg CO_2eq]	kg CO_2eq	904.294,24				
Annual impact of the project [kg CO_2eq/y]	**kg CO_2eq/y**	**301.431,41**				

The total value of 904,294.24 kg CO_2eq, divided by the 3 years of testing, corresponds to 301,431.41 kg CO_2eq/y.

Due to the recalculation of all the values on the basis of the final SUBSED LCA, it is not possible to directly compare actual values with estimations done during proposal submission and at mid-term period.

# KPI	First level descriptor	Start value	Target value	Actual end value	% of target achieved	Beyond end value	Unit
10.2	Involvement of non-governmental organisations (NGOs) and other stakeholders in project activities	0	500	500	100%	1100	n.

The estimated values of the first snapshot have been confirmed.
During the project we had several contacts with staff and representatives of regional/national/international authorities (e.g. from ARPAT and other environmental authorities of Tuscany; the port Authorities in Spain, etc); from trade associations from all the involved sectors (e.g CEO of Navicelli, Presidents of the Order of Agronomists and Foresters, Director of Coldiretti Pistoia, etc), local/regional/national policy makers and representants of political entities (Minister of water, agriculture, livestock, fishing and the environment of the Region of Murcia; President of the Region of Murcia; Councillors for Agriculture of Murcia and Tuscany Regions; the former Italian Minister of Education, University and Research and currently President of Italian Council for Research (CNR); etc). These stakeholders have been targeted by specific project's dissemination and consultation actions: we reached around 100 people by face-to-face meetings, and we had other several virtual and indirect contacts with other stakeholders interested in the future of SUBSED solutions.

# KPI	First level descriptor	Start value	Target value	Actual end value	% of target achieved	Beyond end value	Unit
11.1	Website	0	25,000	9,800*	40%	50000	n. of unique visits

The estimated values of the first snapshot have been confirmed.
We deem that, in 2022, considering only the performances of the project website to evaluate online engagement could be too limiting. So, for the estimations, we considered the visits to the project website + the visits to the social profiles of the project:

- Website: 6,222 sessions
- Twitter: 1,483 profile visits
- Facebook: 2,100 logged-in page views (this info is not more available after FB updates in Insights, but we estimated it as 10% of people reached by SUBSED posts)

TOTAL = 9,805 visits

NB: For assessing the communication effectiveness of the social project's profiles, it's common to consider COVERAGE (the number of people reached by contents) and IMPRESSIONS (the number of times any content from the page or about the page entered a person's screen) as best indicators. In this case, the total amounts increase:

- Website: 6,222 sessions
- Twitter: 2,374 impressions
- Facebook: 21,048 people reached (coverage)

TOTAL = 29,644 visits

In this way, we would have a 119% achievement compared to initial estimation. However, being more cautious, we used as KPI the number calculated with the first method.

* With reference to the indicator table from the original proposal, during the first data snapshot the values originally estimated were recalculated. During the proposal submission a conceptual error was made, since the number of site visits was considered as the number of page views. A counter is still present on website, which exceeds 340,000 views. But this number is not representative of the subjects who actually visited the page, but only of their page views.

# KPI	First level descriptor	Start value	Target value	Actual end value	% of target achieved	Beyond end value	Unit
11.2	Number of events/exhibitions organised	0	6	6	100%	14	n.

The value "at the end" considers the 2 technical courses and the 4 workshops organised during the SUBSED project. The value "beyond 3 years" considers other 8 similar events that will be carried out after the project end.

The organisation of this kind of events is foreseen in the SUBSED Replicability and Transferability plan and in the SUBSED AfterLIFE plan. These activities could be carried out by organising stand-alone events or by contributing to other external events related to the same topics.

Please note that, considering all the events organised/attended (e.g. conferences, fairs, etc), the SUBSED consortium took part in >45 events (the proposal foreseen participation in at least 10 events).

* With reference to the indicator table from the original proposal, the following indicators were defined:

- **Workshops - Number and individuals involved** → 4 workshops for involving at least 250 people were expected at the end of the project, while 4 courses for involving at least 500 peoples were estimated after 3 years beyond project end. During the project 4 workshops were held, reaching about 320 people. The organisation of this kind of events is foreseen in the SUBSED Replicability and Transferability plan and in the SUBSED AfterLIFE plan. These activities could be carried out by organising stand-alone events or by contributing to other external events related to the same topics.
- **Technical informative course - number and individuals involved** → 2 courses for involving at least 50 people were expected at the end of the project, while 4 courses for involving at least 200 peoples were estimated 3 years after project end. During the project, 2 technical courses were held, reaching about 75 people. The organisation of this kind of events is foreseen in the SUBSED Replicability and Transferability plan and in the SUBSED AfterLIFE plan. These activities could be carried out by organising stand-alone events or by contributing to other external events related to the same topics.

# KPI	First level descriptor	Start value	Target value	Actual end value	% of target achieved	Beyond end value	Unit
11.2	Number of different publications made (Journal/conference)	0	15	25	167%	33	n.
The value "at the end" considers the technical articles published during the SUBSED project, while the value "beyond 3 years" considers the future publication of articles resulting from the future exploitation of the SUBSED results. The proposal foreseen the publication of 15 technical and general articles. The actual value considers only the technical articles.							
# KPI	First level descriptor	Start value	Target value	Actual end value	% of target achieved	Beyond end value	Unit
11.2	Number of different displayed information created	0	24	39	162%	50	n.
The value "at the end" considers the following materials produced during the SUBSED project - 12 notice boards (the proposal foreseen the production of 12 notice boards) - 15 posters (the proposal foreseen the production of 12 posters) - 12 informative banners (the proposal didn't foresee the production of banners) The value "beyond 3 years" considers the future production of similar materials, which will be used during the future dissemination of the project, as foreseen by the SUBSED AfterLIFE plan.							
# KPI	First level descriptor	Start value	Target value	Actual end value	% of target achieved	Beyond end value	Unit
11.2	Number of articles in print media	0	10				n.
The value "at the end" considers the general articles/interviews published during the SUBSED project, while the value "beyond 3 years" considers the future publication of articles resulting from the future exploitation of the SUBSED results. The proposal foreseen the publication of 15 technical and general articles. The actual value considers only the general articles.							

# KPI	First level descriptor	Start value	Target value	Actual end value	% of target achieved	Beyond end value	Unit
11.3	Surveys carried out regarding awareness of the environmental/climate problem addressed	0	n/a	214	n/a	214	n. of people surveyed
These values consider the number of respondents reached by the survey carried out during the project for assessing the SUBSED socio-economic impact. In particular, we obtained: - 110 responses from Italy; - 204 responses from Spain.							

The proposal didn’t originally foresee this activity, so no comparison is possible.

# KPI	First level descriptor	Start value	Target value	Actual end value	% of target achieved	Beyond end value	Unit
12.1	Networking - Members of interest groups / lobby organisations	0	10	190	1900%	350	n.

The estimated values of the first snapshot have been largely exceeded.
The number of members from interest groups/lobby organisations that we indicate at the end of the project is composed by: i) relevant scientists or researchers and coordinators from other environmental projects at European level (at least 50 scientists through direct networking with other 18 projects + other 30 researchers met during other events); ii) representatives of trade associations of the involved sectors (at least 80 stakeholders from trade and sector associations and other actors of the production chain); iii) representatives of national and international organisations involved in environmental protection (at least 30 policy makers and representants of local and national environmental agencies/authorities). During the after-LIFE, networking activities from the project's partners will continue and expand, as foreseen by the after-LIFE Plan.

# KPI	First level descriptor	Start value	Target value	Actual end value	% of target achieved	Beyond end value	Unit
13	Jobs	0	4.86	5.47	113%	12	FTE

Due to a misunderstanding, during the mid-term review we wrongly indicated 31 FTEs instead of 4.86 FTEs, which are the correct ones recalculated considering only additional staff budgeted by Public Bodies (Flora Toscana erroneously indicated some additional staff during the proposal submission phase, but it was not neither voluntary nor required being a private entity).
The comparison is done referring to this last value.

The number of FTEs at the end of the project has been calculated considering the actual hours reported for additional staff at the end of the project (9,631 h) divided by 1760 h/FTE as indicated by the guide.
The number of FTEs 3y after the project end has been estimated considering the after-LIFE activities (e.g. continuation of dissemination and awareness raising activities, continuation of training courses and online support to professionals, production of SUBSED substrates, searching for other fundings, etc). The value after 3 years considers both additional and permanent staff, not being currently able to assess the future work structure and organisation.

* With reference to the indicator table from the original proposal, during the first data snapshot the values originally estimated were recalculated. During the proposal submission a conceptual error was made, considering direct and indirect jobs that could derive from the project activities (so not only new jobs from beneficiaries, but also from other external companies supplying services and products). The values have been recalculated considering the KPI webtool guide instructions.

# KPI	First level descriptor	Start value	Target value	Actual end value	Beyond end value	Unit
14.1	Running cost/operating costs during the project and expected in case of continuation/replication/ transfer after the project period	0	1,745,524	1,756,815	2,095,524	€
The value at the end of the project refers to the actual cost reported. The value 3 years beyond project end has been estimated on the basis of the data entered in KPI 14.3, considering both expected beneficiaries' contribution for the afterLIFE activities and the possibility to apply for and success in other funding programmes.						

# KPI	First level descriptor	Beyond end value	Unit
14.3	Future funding – Beneficiary own contribution	200,000	€
	Future funding – Beneficiary own contribution	150,000	€
These values have been estimated considering additional external funds (e.g. funding grants from new future proposal for the transfer or scale up of SUBSED technologies) and the co-financing from the beneficiaries for the afterLIFE activities (i.e. personnel and other costs related to dissemination and enhancement of the technology)			

In addition to these indicators, some indicators specified during the proposal submission have not been included in the KPI webtool during the first snapshot. Following an analysis of them:

- **Reduction/substitution of dangerous substances** → during the submission phase, a 30% reduction in Zn levels was estimated, from 300 mg/kg to 210 mg/kg.
  These values were initially included in the KPI webtool as indicator *5.1.1 Chemical released*. However, this indicator appeared to be not really appropriate for monitoring the expected impact of SUBSED project, because i) the indicator seems to refer to a chemical "strictly intended", a substance used/generated during a production process, while SUBSED aims to impact specifically on a pollutant substance (Zn); ii) the indicator refers to a reduction in chemical released, but in SUBSED there is no release of contaminant and beneficiaries will work to obtain a reduction of Zn level in the sediment. So, this indicator has been cancelled during the first review of the KPI.
  Even if this indicator cannot be included in the KPI webtool, during the SUBSED project Zn levels were reduced by 33.8%, from 151 mg/kg of sediments before landfarming to 100 mg/kg at the end of cultivation trials. It is reasonable to expect a further 5% reduction in Zn content over the next 3 years considering continuing to grow the plants on the same substrate.
- **Market uptake – Expected revenues** → during the submission phase, €17,180 of revenue at the end of the project and €128,850 after 3 years beyond project end were estimated. No direct revenues were obtained from sale of SUBSED substrates during the project; however, an increase in revenues could be derived from the improvement of the image of business partners. At this stage, the value after 3 years could be confirmed, considering the commercialisation of SUBSED substrates (Flora Toscana is currently working to start their sale).

- **Guideline/manual - Number and individuals involved →** this indicator envisaged the production of 1 manual to reach at least 300 people at the end of the project and 1,000 people 3 years after project end. During the project, 1 manual was produced and distributed live in paper format and online in PDF (the manual will be downloadable for free from project website). The values estimated during the submission of the proposal can be confirmed.

In conclusion, the monitoring of indicators can be summarised for each category of KPI:

- *technical indicators* can be considered as confirmed.
- *economic indicators* can be considered as confirmed (new jobs have been created and financial resources have been used as planned).
- *communication indicators* can be considered as confirmed despite the impact of the COVID-19 pandemic (the dissemination activity has brought positive effects, permitting to reach a large number of subjects both through online publications/posts and through direct contacts during fairs and events. The intensification of technical updates and results and the workshops and technical courses organised allowed to engage various visitors and followers).