LIFE AGROWETLANDS II

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LIFE AGROWETLANDS II
LIFE15 ENV/IT/000423

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Deliverable 5 of the Action C.1

Complete LCA on positive and negative environmental impacts of LIFE AGROWETLANDS II System for water and soil salinity management

The present document summarises the Environmental Sustainability Assessment performed to evaluate the smart solution proposed, applying an integrated Life Cycle Thinking approach.

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LIFE Agrowetlands II

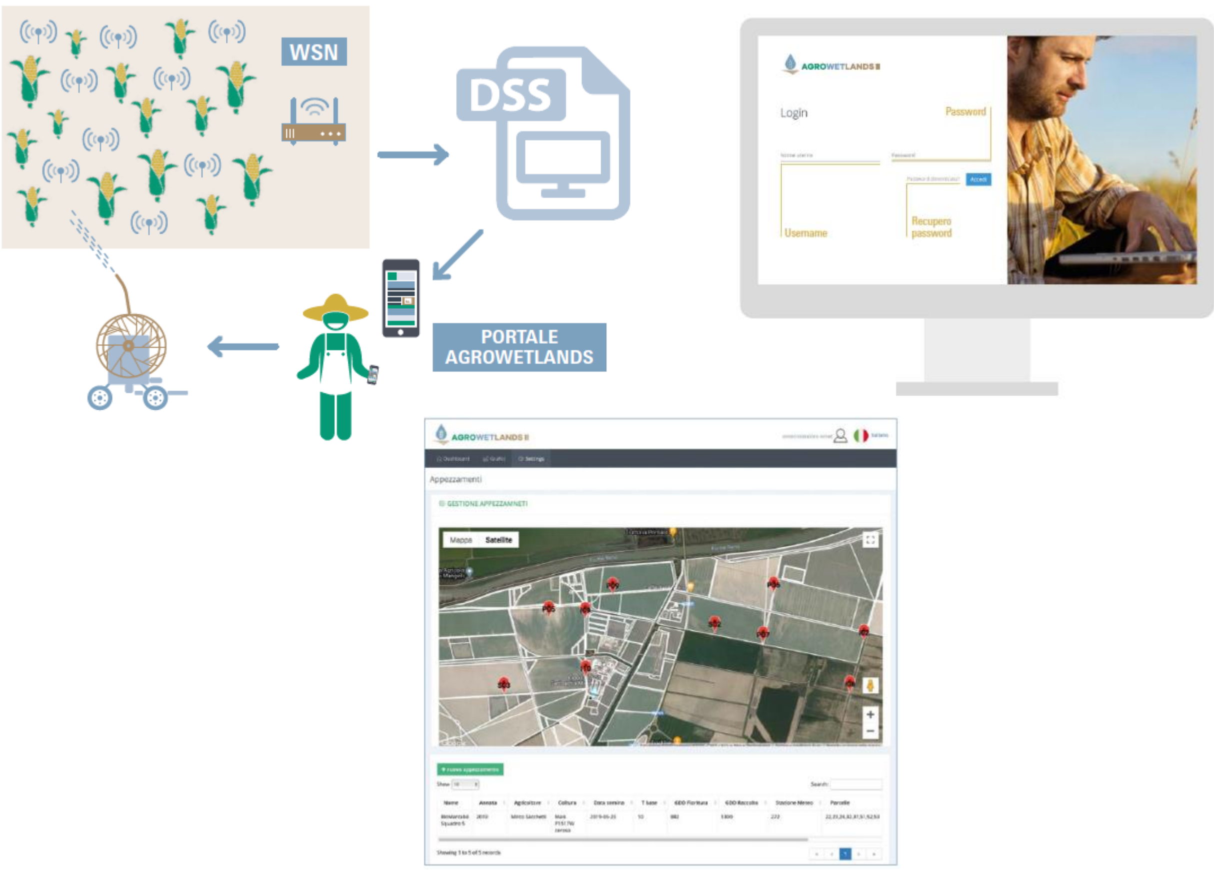
COMPLETE LCA ON POSITIVE AND NEGATIVE ENVIRONMENTAL IMPACTS OF LIFE AGROWETLANDS II SYSTEM FOR WATER AND SOIL SALINITY MANAGEMENT

OUTLINE OF THE PROJECT

Life Agrowetlands II – *Smart water and soil salinity management in agro-wetlands* (LIFE15/ENV/IT000423) is funded by LIFE Programme 2014-2020 and it is devoted to the monitoring of environmental parameters in agricultural land subject to salinity issues, to feed a decision support software able to return the optimal irrigation configuration for the areas.

A Wireless Sensor Network (WSN) performs monitoring of environmental parameters (Cipolla et al. 2019; Speranza et al., 2020). The WSN LIFE AGROWETLANDS covers an area of about 30 km^2 (figure 1), on which n.23 receivers and transmitters are distributed (router nodes of the network); each router is equipped with one or more types of sensors, which perform measurements continuously. The network Agrowetlands presents n.7 gateways, that coordinate 2 to 5 routers each, and it is designed in a modular structure, allowing a customised scale-up.

Figure 1 – WSN Life Agrowetlands project outline (Speranza, 2020)



The network includes sensors able to measure:

- physical parameters of the soil (relative humidity, water potential, temperature, electrical conductivity)

- physical parameters of surface waters (temperature, level, conductivity)

- physical parameters of groundwater (temperature, level, conductivity)

- meteorological parameters (temperature and air humidity, precipitation, solar radiation, direction and speed of the wind).

Data collected are retrievable in Excel format and elaborated by a decision support software based on AquaCrop by FAO (Steduto et al., 2009).

METHODOLOGY

Definition of the conceptual model

A simplified Life Cycle Assessment (LCA) approach has been used, with the aim of evaluating the environmental consequences of the innovative elements in the system. LCA is a method for the quantification of impacts of a product, a process or a service in terms of effects on environmental matrices, i.e. soil, water and air, and damage generated, in terms of resource depletion, effects on climate change, human health and biodiversity. The methodology is based on a solid scientific structure and it is standardised at the international level (Wolf et al., 2012). Considering the object of the project, a comparative LCA has been outlined, and reiterated, to compare the sustainability performance of the smart solution designed within the LIFE project, with the traditional irrigation system already in place. The overall impact has been assessed considering:

- The network of sensors
- The communication apparatus for data transmission
- The data storage and elaboration
- The net energy consumption

The items composing the network have been included into the inventory and the availability of Environmental Product Declarations have been investigated, as detailed information about the impact generated by the specific production of electronic components used would have provided a solid basis for the LCA of the network. In absence of such information, a simplified model per each device composing the network has been realised, based on processes available on referenced libraries.

As quantitative results about the possible water savings are currently not available and the benefit derived from the improved management of environmental resources will emerge in the longer period, the analysis has been limited to the assessment of the environmental burden generated. This in order to identify hotspot of impact and outline measures applicable for the improvement of the environmental performance of the system.

Table 1 – Conceptual model development

Item	Details	Inventory	Modeling

Item	Details	Inventory	Modeling
Sensors	2 weather kits (anemometer, rain gauge, air temperature and humidity, solar radiation), 9 groundwater piezometers (monitor level / temperature / conductivity), 12 soil moisture / temperature / conductivity sensors, 11 hydrometers to always monitor level / temperature / conductivity along the canals of the area.	n.2 anemometer, n.2 rain gauge, n.2 air temperature and humidity, n. 2 solar radiation, n. 9 groundwater piezometers, n.2 soil moisture / temperature / conductivity sensors n. 11 hydrometers	The specificity of the sensors cannot be modelled in detail in the standard LCA approach. Therefore, a simplified module was required to model the items.
Connections			The cable infrastructure has been included into the model, estimating its entity.
Transmission module	The monitoring stations communicate with each other through the IEEE 802.15.4 2.4Ghz protocol dedicated to wireless sensor networks and some of these, i.e. the advanced nodes, collect the information and send them to a web server via GPRS.	n.23 basic nodes n.7 advanced nodes	The data transmission module has been modelled as a communication platform for the basic nodes of the network and internet access points have been modelled for the advanced nodes.
Hardware infrastructure	The functions of data storage and information platform are accomplished by mySql database installed on a dedicated server.	n.1 desktop computer acting as server	Considering the present stage of development of the network, a single server has been included in the analysis. In the perspective of scaling-up, the data storage element should be sized in proportion to the amount of data to be stored and elaborated.
Software	"AquaCrop is a crop growth model developed by the Land and Water Division of FAO to address food security and to assess the effect of environment and management on crop production. AquaCrop simulates yield response to water of herbaceous crops, and is particularly suited to address conditions where water is a key limiting factor in crop production… AquaCrop uses only a relatively small number of explicit parameters and mostly-intuitive input-variables requiring simple methods for their determination."	-	As the software is currently hosted on an international infrastructure, provided by FAO, the contribution of the project to the overall computational effort was considered negligible and, therefore, it was excluded from the analysis.
Energy supply	The estimated consumption per each connection device is about 100mW in transmission for 2-300milliseconds, 30mW for 4-5 seconds of data acquisition, processing and for the remaining part of the time about 1mW. The coordinator devices, i.e. the advanced nodes of the network, can develop an additional consumption for	n.28 6V 5Ah batteries (BE 06005) connected to 2.5W solar cell for each monitoring station, no connection to the mains.	Each monitoring and data transmission station is energetically autonomous, thanks to photovoltaic cells and storage batteries, therefore these elements have been included into the analysis. In addition, energy consumption from the national network has been considered for the centralised infrastructure for data storage.

Item	Details	Inventory	Modeling
	sending data to the web server of 0.7W.		

Model development: LCA application

For the assessment of the impact along the Life Cycle of the technological elements of the smart system proposed, literature data has been used, derived from Ecoinvent 3.0 database. The database is regarded as it is among the most comprehensive international Life Cycle Inventory (LCI) databases, providing information about thousands of LCI datasets in the areas of agriculture, energy supply, transport, biofuels and biomaterials, bulk and specialty chemicals, construction materials, packaging materials, basic and precious metals, metals processing, ICT and electronics as well as waste treatment, classified by region, economic sector and product type (Frischknecht and Rebitzer, 2005). A peer review process for the revision of the dataset is applied and LCA professionals are responsible for the feeding procedure into the database (Swiss Centre For Life Cycle Inventories, 2007). Each data available is previously assessed in terms of uncertainty and representativeness (Pascual-González et al., 2016).

The calculation has been carried out with the application of Simapro 8.0 software. SimaPro is product system modelling and assessment software released for the first time in 1990, distributed worldwide by the developers, i.e. PRé Consultants, based in the Netherlands.

The LCA calculation method selected was “ILCD 2011+ Midpoint + V1.10 / EC-JRC Global, equal weighting”. ILCD is the acronym for International Reference Life Cycle Data System and is the result of a project conducted by the Joint Research Centre (JRC) of the European Commission which analysed different life cycle impact assessment methodologies to reach consensus on the recommended method for each environmental issue, both at the midpoint (impact assessment) and the final one (damage assessment). The method selected is, therefore, intrinsically compliant with the International Reference Life Cycle Data System (ILCD) Handbook, by Joint Research Centre (JRC) of the European Commission (Wolf et al., 2012), specifying the broader provisions of the international guidelines on LCA (ISO 14040 and 14044).

The characterization factors (CFs), as well as Normalization factors included into the impact assessment method "ILCD 2011 v1.0.10" are based on the list provided by the JRC and they are evaluated based on the reference literature for each impact category (e.g. climate change CFs are based on the IPCC report (2007)).

Table 2 - Simapro processes applied

<table>
<tr><th>Item</th><th>Simapro Process</th><th>Modeling</th></tr>
<tr><td>Sensors</td><td>For CTD-10, GS3, ECH2O GS3, Anemometer, Air temperature and humidity sensor, Sentek probe, Solar radiation sensor and Anecone rain collector: Electronic component, passive, unspecified {GLO}| market for | APOS, U (of project Ecoinvent 3 - allocation at point of substitution - unit)</td><td>As the Simapro processes are mass-based, the weight of each device has been considered.
<table>
<tr><th></th><th>n.</th><th>Weight (kg)</th><th>Total Weight (kg)</th></tr>
<tr><td>CTD-10</td><td>20</td><td>1</td><td>20</td></tr>
<tr><td>ECH2O GS3 Volumetric Water Content (VWC), Electrical Conductivity (EC), and Temperature sensor from METER Group</td><td>11</td><td>0,45</td><td>4,95</td></tr>
</table></td></tr>
</table>

<table>
<tr><th>Item</th><th>Simapro Process</th><th>Modeling</th></tr>
<tr><td></td><td></td><td>
<table>
<tr><td>Anecone rain collector</td><td>2</td><td>1,5</td><td>3</td></tr>
<tr><td>Anemometer</td><td>2</td><td>1,332</td><td>2,664</td></tr>
<tr><td>Air temperature and humidity sensor</td><td>2</td><td>1,6</td><td>3,2</td></tr>
<tr><td>Sentek probe</td><td>1</td><td>2</td><td>2</td></tr>
<tr><td>Solar radiation sensor</td><td>2</td><td>0,226</td><td>0,452</td></tr>
<tr><td>Total</td><td></td><td></td><td>36,266</td></tr>
</table>
</td></tr>
<tr><td>Connections</td><td>1. Cable, three-conductor cable {GLO}| market for | APOS, U
2. Cable, data cable in infrastructure {GLO}| market for | APOS, U</td><td>For each monitoring station, 1 m of data cable and 10 m of generic cable for electricity supply have been included</td></tr>
<tr><td>Energy supply</td><td>1. For the monitoring platforms:
a) Battery cell, Li-ion {GLO}| market for | APOS, U (of project Ecoinvent 3 - allocation at point of substitution - unit)
b) Photovoltaic cell, single-Si wafer {GLO}| market for | APOS, U (of project Ecoinvent 3 - allocation at point of substitution - unit)
2. For the data storage: Electricity, low voltage {IT}| market for | APOS, U (of project Ecoinvent 3 - allocation at point of substitution - unit)</td><td>1. Monitoring platform
a) N. 23 Batteries, weighting 0,8 kg each
b) N. 23 Photovoltaic cells, 0,02 m2 wide each

2. Server supply: for the data storage infrastructure electricity supply from the national grid, quantified in 0.4 kWh/day considering 2 hours/day as working time. Accounting, then, a 5-year lifespan for the entire infrastructure,</td></tr>
<tr><td>Data transmission module</td><td>Internet access equipment {GLO}| market for | APOS, U (of project Ecoinvent 3 - allocation at point of substitution - unit)</td><td>n. 23 basic nodes + n. 7 GPRS modules.
As the Ecoinvent library do not discriminate between Wifi communication and Internet access, the same process was used to model both.</td></tr>
<tr><td>Server for data storage</td><td>Computer, desktop, without screen {GLO}| market for | APOS, U</td><td>n.1 computer working as server has been modelled</td></tr>
<tr><td>Maintenance</td><td>1. For the travels of the personnel: Transport, passenger car, small size, petrol, EURO 5 {RER}| transport, passenger car, small size, petrol, EURO 4 | APOS, U (of project Ecoinvent 3 – allocation at point of substitution – unit)
2. For the spare parts: the respective processes, already included for the start-up of the infrastructure, have been applied</td><td>1. The travels for planned maintenance have been considered in the number of 4 per year. It has been also considered an additional travel per year to fix unexpected failures possibly occurring. Thus, the total number of travels for the 5-year lifespan considered is 25. The travelling distance has been set in 100 km, considering the distance Cesena/Ravenna and smaller travels among the nodes.
2. In order to account for the spare parts possibly necessary, a coefficient has been applied to the total amount of each sensible device, i.e.:
o Batteries: the failure of 25% of the batteries per each of the five years has been accounted, taking the total mass of batteries to 225% of the initial simulation
o Sensors: the failure of 10% of the sensors per each of the five years has been accounted, taking the total mass of sensors to 150% of the initial simulation
o Data transmission modules: the failure of 10% of the sensors per each of the five years has been accounted, taking the total mass of communication modules to</td></tr>
</table>

<table>
<tr><th>Item</th><th>Simapro Process</th><th>Modeling</th></tr>
<tr><td></td><td></td><td>150% of the initial simulation
Cables: the failure of 10% of the total cables has been accounted on the total lifespan of the project, taking the total to the 110% of the initial simulation</td></tr>
<tr><td>Technological infrastructure – disposal scenario</td><td>Waste electric and electronic equipment {GLO}| market for | APOS, U</td><td>The End-of-life disposal scenario has been modelled based on the overall weight of the infrastructure. In particular, the following quantities have been considered:
<table>
<tr><th>Item</th><th>kg start-up</th><th>kg spare parts</th><th>kg tot</th></tr>
<tr><td>photovoltaic</td><td>14,421</td><td></td><td>14,421</td></tr>
<tr><td>batteries</td><td>18,4</td><td>23</td><td>41,4</td></tr>
<tr><td>communication modules</td><td>6</td><td>3</td><td>9</td></tr>
<tr><td>cables</td><td>50,6</td><td>5,06</td><td>55,66</td></tr>
<tr><td>sensors</td><td>36,266</td><td>18,133</td><td>54,399</td></tr>
<tr><td>server</td><td>3</td><td></td><td>3</td></tr>
<tr><td>TOTAL</td><td>128,687</td><td>49,193</td><td>177,88</td></tr>
</table></td></tr>
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RESULTS OBTAINED

Considering the limitations in the application of LCA models, the results are limited to the assessment of the technological apparatus developed within the framework of the project.

In the following Table 3, impact calculated are detailed, by sub-process and impact category. In particular, impacts are reported for the processes outlined and presented in the above Table 3, i.e.:

- For the monitoring platforms:
  - Battery cells Li-ion and Photovoltaic cells single-Si wafer for energy supply;
  - Communication devices and Internet access equipment for data transmission;
  - Data cable and Electricity cable for infrastructure;
  - Sensors for monitoring the environmental parameters;
- For the data storage and elaboration infrastructure:
  - Computer Desktop – Server;
  - Electricity from grid for the supply of the server;
- For the maintenance operations:
  - Travels from the headquarter of the projects to the network location;
  - Spare parts supply;
- For the End-of-Life of the entire network and infrastructure:
  - End-of-Life scenario for Waste Electrical & Electronic Equipment (WEEE).

The Life Cycle outlined for the network, including its implementation, maintenance, and final disposal, generates 6743 kg CO_2 equivalent. The major contributions are developed by:

- the production and delivery of the sensors for the first implementation of the network results the most impactful item, generating about 2300 kg CO_2 equivalent, representing about 34% of the total
- the maintenance operations, including spare parts supply and travels, generating about 2105 kg CO_2 equivalent, representing about 31% of the total

Results obtained have, then, been visualised in Figure 2, to visually appreciate the processes affecting the different impact categories. As evident from the visualisation, the sensing infrastructure, i.e. sensors and cable, together with maintenance operations represent the major contributors per each impact category analysed. A clear singularity is represented by the Water resource depletion category, which appears to be positively impacted by the system implementation. This is apparently contrary to expectations and it would require a deeper investigation to evaluate the initial processes' primary data and elaboration procedure. As an alternative, a dedicated model could be developed, in cooperation with the manufacturers of the sensors.

A drill-down visualisation has been prepared and reported in Figure 3 on the Global Warming Potential category, evaluated in terms of kg CO2 equivalent, i.e. considering all greenhouse gases emissions related to the processes and converting them into a common unit of measure, based on their global warming potential., to better highlight the contribution of each sub-process to the specific impact category. This impact category is particularly relevant, considering the urgency posed at the international level on the global challenge to limit the emission of greenhouse gases and to mitigate the effects of the climate change.

The overall impact in terms of global warming potential has been evaluated in correspondence to the one generated by a car to improve the understanding of the dimension of the environmental burden carried by the project. In particular, the overall impact result equivalent to a passenger's car, small size, petrol, EURO 5, travelling about 24700 km, i.e. about 450 days of average use, typically set at 20000 km (Figure 4).

The impacts calculated have, then, been normalised, based on the specific calculation method, to appreciate the impact categories mostly affected by the implementation of the project. As evident from Figure 5, the three main impact categories result Human toxicity, both for cancer and non-cancer effects, and freshwater ecotoxicity. These categories are strongly affected by the mineral components included into electronic components, which are typically related to rare minerals depletion (as demonstrated by the mineral resources impact, the fourth in order of importance) and release of chemicals into the environment necessary to their extraction.

Table 3 – Calculated impacts, by process and impact category (ILCD 2011+)

Impact category	Unit	Battery cells	Photovoltaic cells	Communication devices	Internet access equipment	Data cable	Electricity cable	Sensors	Server_production	Server_Electricity consumption	Maintenance_travels	Maintenance_spare parts	End-of-Life	TOTAL
Climate change	kg CO2 eq	130.8111015	116.3711116	178.7919202	54.41493223	6.299123609	1281.666697	2299.686454	240.0884074	318.4709014	546.9809288	1558.757112	1.03E+01	6742.615364
Ozone depletion	kg CFC-11 eq	2.74497E-05	1.2217E-05	2.50496E-05	7.62379E-06	2.22197E-06	0.000665381	0.000232224	2.49322E-05	3.58212E-05	8.61954E-05	0.000233521	5.59E-07	0.001353197
Human toxicity, non-cancer effects	CTUh	0.000625073	4.84404E-05	0.000986063	0.000300106	5.87116E-05	0.018376954	0.016901657	0.000902469	6.6769E-05	0.000161676	0.01171882	7.96E-06	0.050154695
Human toxicity, cancer effects	CTUh	3.5371E-05	8.39726E-06	5.31391E-05	1.61728E-05	2.29136E-06	0.000688793	0.000745222	6.51751E-05	1.32599E-05	3.59633E-05	0.000520589	7.06E-07	0.002185079
Particulate matter	kg PM2.5 eq	0.204602922	0.102118095	0.188757711	0.057447999	0.013178186	3.67808571	2.714109845	0.233580033	0.118273151	0.275441676	2.105037821	9.47E-03	9.700098404
Ionizing radiation HH	kBq U235 eq	14.72271477	12.48113331	21.2241449	6.459522361	0.988822765	264.5710482	241.3349098	25.10890911	54.11553138	43.04023606	179.4686691	1.34E+00	864.8597924
Ionizing radiation E (interim)	CTUe	3.81887E-05	4.17724E-05	6.87553E-05	2.09255E-05	2.27483E-06	0.000557456	0.00083538	8.46365E-05	0.000137123	0.000230279	0.00056624	4.46E-06	0.002587486
Photochemical ozone formation	kg NMVOC eq	0.62571444	0.371963801	0.716347252	0.218018729	0.045758963	11.37278401	15.42857842	0.938261975	0.661506938	1.30432784	10.10546955	2.76E-02	41.81636565
Acidification	molc H+ eq	2.321591449	0.591257253	1.674312402	0.50957334	0.185488633	54.20418556	26.61900687	1.81443491	1.890207653	1.804395873	22.74240303	5.93E-02	114.416202
Terrestrial eutrophication	molc N eq	2.143355664	1.035103797	2.676551541	0.814602643	0.156490215	40.1477558	43.54747598	3.206156861	3.405119765	2.882240437	30.22893426	1.07E-01	130.3508529
Freshwater eutrophication	kg P eq	0.355489704	0.061155404	0.624075775	0.189936105	0.031353922	9.77003499	10.55616524	0.584166982	0.099728204	0.103355244	7.109589579	5.57E-03	29.49061674
Marine eutrophication	kg N eq	0.23744905	0.113421198	0.278951963	0.084898424	0.017394674	4.62724557	4.298396327	0.325036153	0.237435705	0.270229906	3.092398694	1.01E-02	13.59298467
Freshwater ecotoxicity	CTUe	14652.81046	1039.474623	24114.1037	7339.07504	1272.297647	399007.1763	405069.3042	24744.03109	7316.568571	16100.84782	276605.2019	1.06E+02	1177367.36
Land use	kg C deficit	205.1316131	92.1915789	254.5450501	77.47023265	12.99167477	3479.878658	6336.655283	372.5599765	696.5379821	1461.212215	3940.036833	1.50E+01	16944.24473
Water resource depletion	m3 water eq	-0.288293219	1.409674328	-0.158243189	-0.048160971	0.001721887	1.65665504	-2.084718031	-0.267178492	3.852757412	0.041461705	-1.340089927	-1.53E-02	2.760331553
Mineral, fossil & ren resource depletion	kg Sb eq	0.055118856	0.020157618	0.077253961	0.023512075	0.003547871	1.08235539	16.91106168	0.40674367	0.009466112	0.132078892	8.683402756	7.93E-04	27.40549152

Figure 2 – Impact characterisation, by process

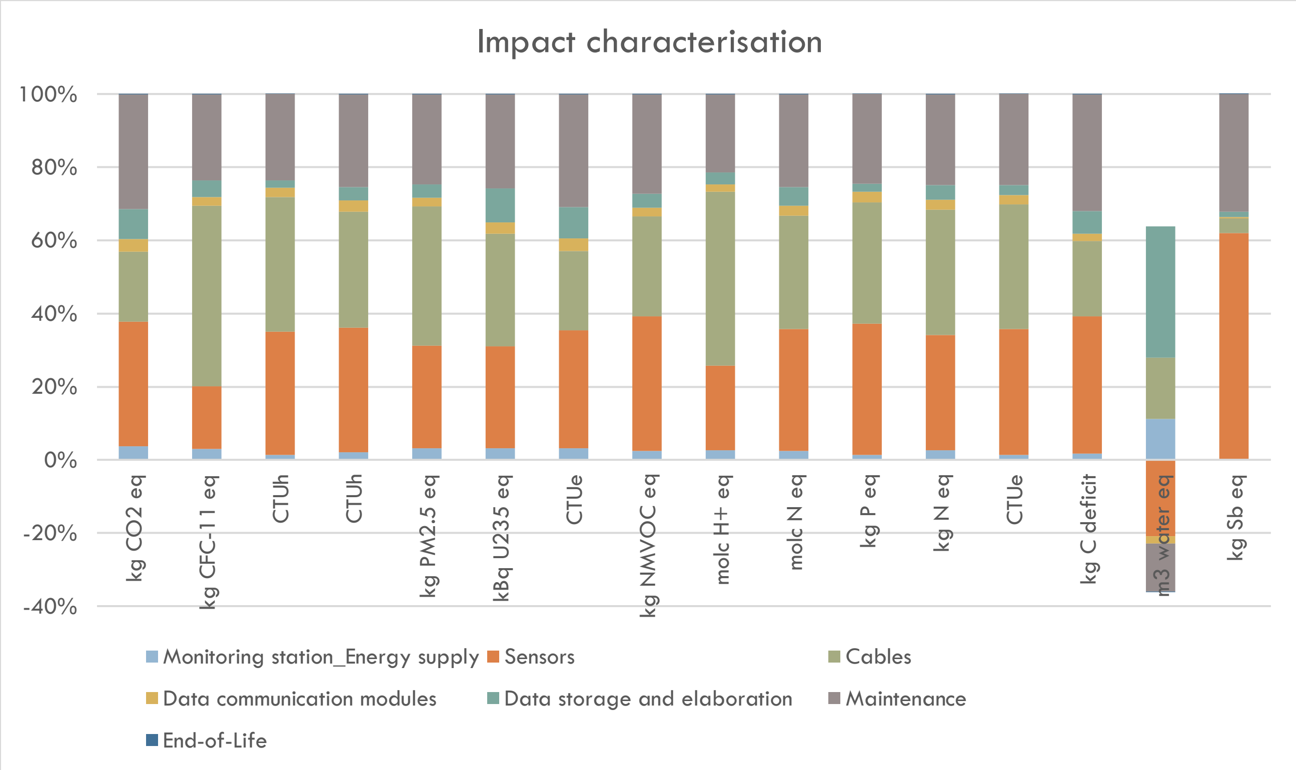


Figure 3 – Detail of Climate Change impact (kg CO2 equivalent), by process

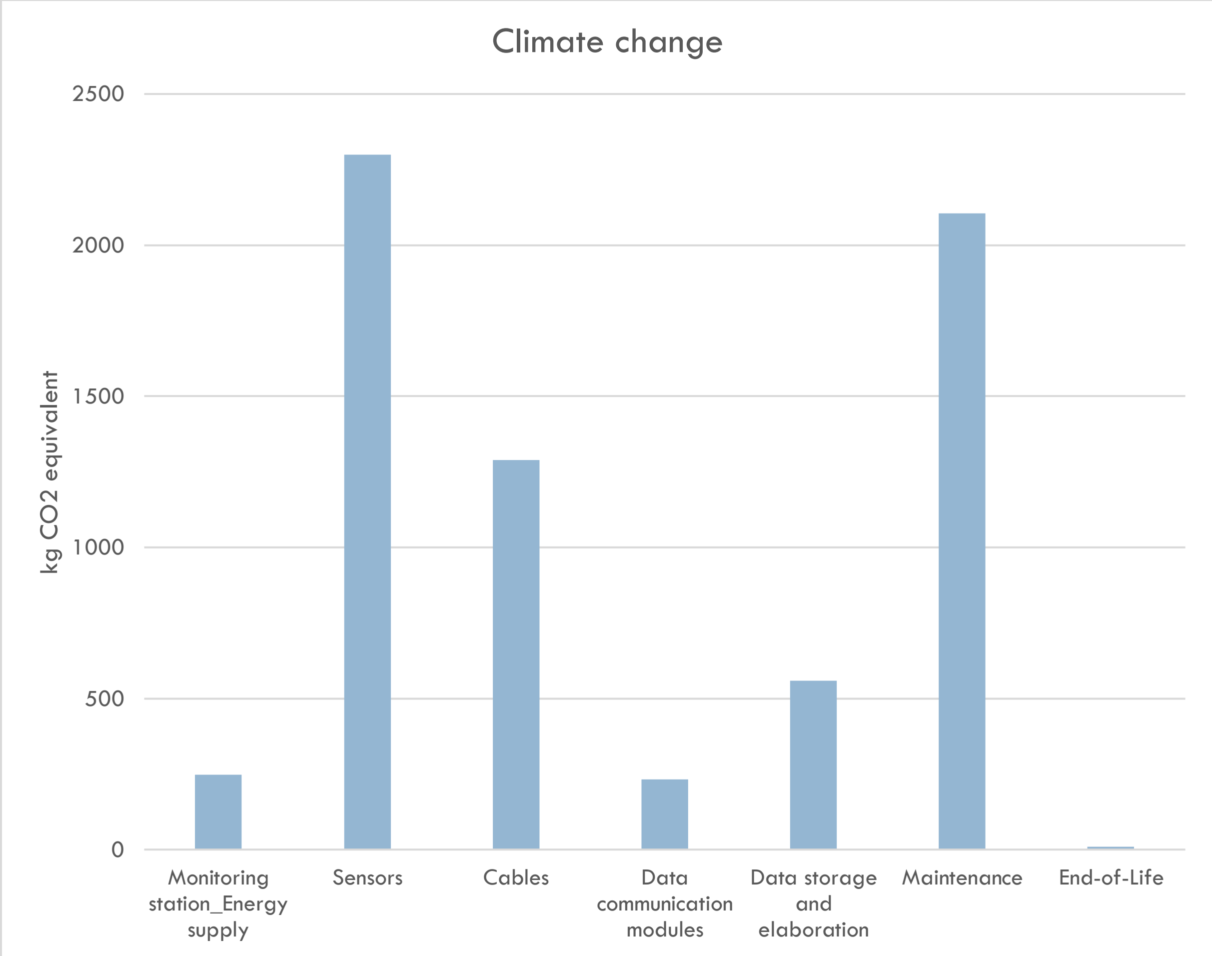


Figure 4 – Overall impact of the project, correspondence with equivalent impact generated by a passenger's car

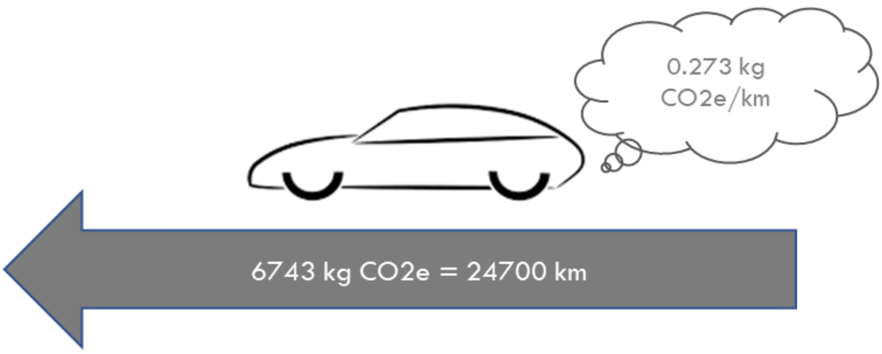
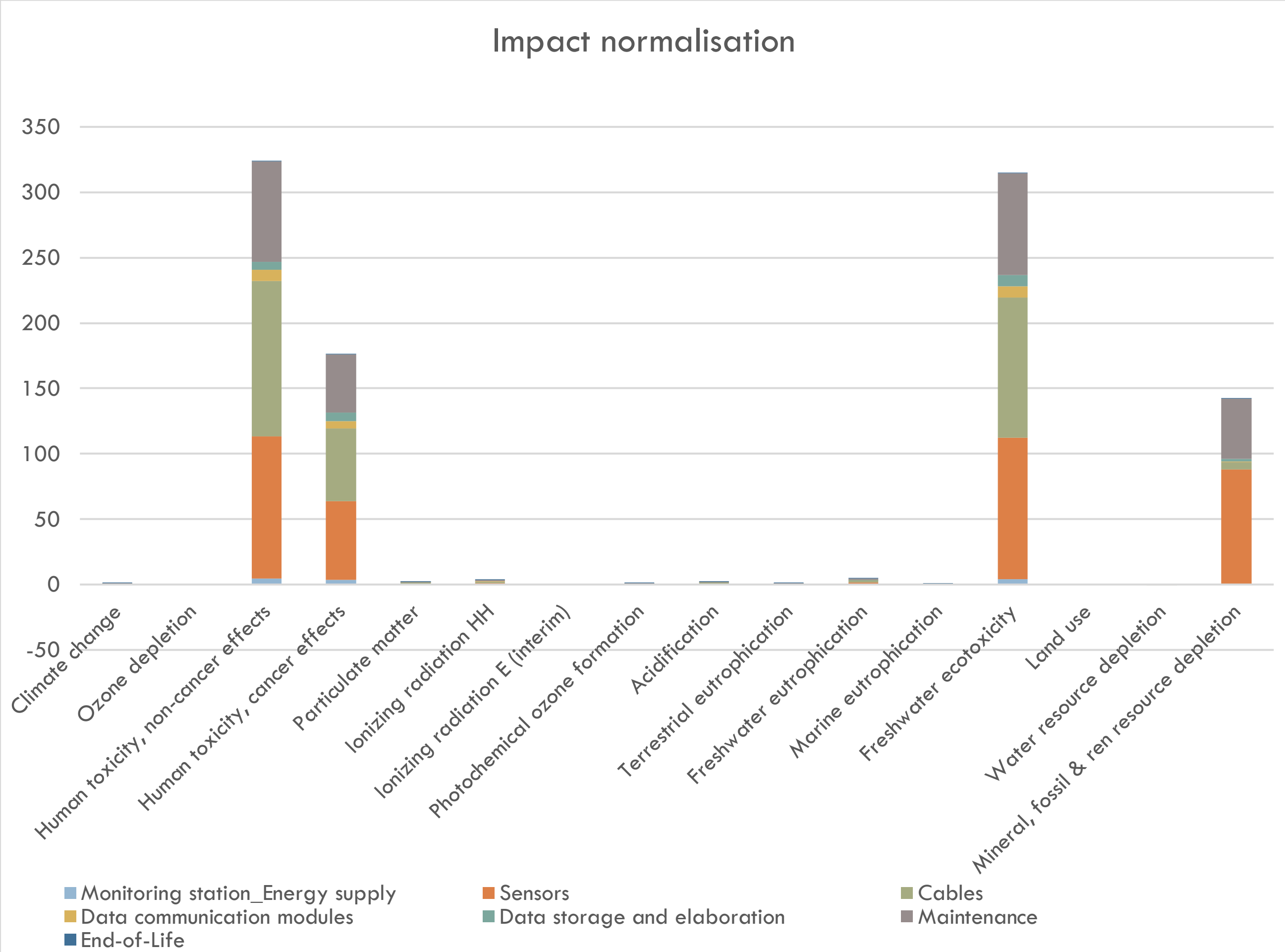


Figure 5 – Impact normalisation, by process



CONCLUSION AND OUTLOOKS

The environmental sustainability assessment of the project has been developed considering the overall goal of the project, i.e. to provide precise information, and yet developed in time, about environmental parameters on agricultural areas wider than the individual plot. This kind of information has relevance not only for the farmers, but also at a wider scale, for government and resource management agencies of the territory, responsible for irrigation water distribution and conservation. These environmental benefits are hardly captured by the standard Life Cycle Assessment approach, as it is product/Process oriented, and, therefore, is able to capture direct environmental impacts, both positive or negative, triggered by an innovative solution, but it is unlikely to be able to appreciate benefits on a larger scale or more location-specific. It is, unfortunately, the case of alleviation of local water stress or salinity intrusions or improvements in the water balance for fruits and crops, possibly leading to a higher quality in the products. Future research will be aimed at framing such contribution to the overall environmental quality into a comprehensive assessment which would allow to balance the impacts generated by the implementation of the technological infrastructure with the benefits triggered in the longer period and at local scale. This assessment will take advantage from the multiplication of the modules in the network, allowing cross-evaluation in different areas and, possibly, on different crops.

At the present stage of development, the simplified LCA approach applied, allowed the evaluation of the impact hotspots, outlining areas of improvement for the environmental performance of the solution

proposed. In particular, a possible criticality in the scale-up of the project emerges from the impact generated by the sensing infrastructure, which would worth further investigation based on the cooperation with manufacturing companies, overcoming possible limitation in the actual modelling and stimulating a systemic approach toward sustainability by promoting the commitment of the whole supply chain. In addition to this, a deeper evaluation of the issue related to the lifespan of electronic components could be applied. In a Eco-design perspective, in fact, the Life Cycle design approach would suggest the application of possible measures to prolong the expected lifespan of the sensing infrastructure, in order to limit the negative impacts related to the depletion of critical raw materials and chemicals release into environment typically related to electronic equipments.

The overall environmental impact appears relatively limited, as the network is designed based on optimisation, but compensating measures could be outlined, for example by offsetting the overall CO_2 emission with the planting of autochthonous trees at the border of cultivated lands included into the project or in the nearby areas of Regional Park of “Delta del Po”.

The present LCA study shows an inherent limitation in the unavailability of element to properly account for the environmental benefit deriving from the implementation of the project. In order to capture the entity of the overall environmental benefit triggered by the innovative solution proposed and to better outline the trade-off between negative and positive environmental impacts, a specific data collection over the next 5 years will be performed, assessing:

i) The net water saving deriving from the application of DSS
ii) The reduced water stress at local level
iii) Possible improvement in the overall management of the local water supply for agriculture
iv) The impact on local salinity of groundwater.

The longer time span for the appreciation of such benefits is required to overcome the possible seasonal and singular effects related to changing climate.

REFERENCES

Cipolla et al., 2019
S.S. Cipolla, M. Maglionico, M. Masina, A. Lamberti, I. Daprà. **Real time monitoring of water quality in an agricultural area with salinity problems.**
Environmental Engineering and Management Journal, 18-10 (2019), pp. 2229-2240.

Frischknecht and Rebitzer, 2005
R. Frischknecht, G. Rebitzer. **The ecoinvent database system: a comprehensive web-based LCA database**
J. Clean. Prod., 13 (2005), pp. 1337-1343, 10.1016/j.jclepro.2005.05.002

IPCC, 2007
Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.). **Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.**
Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Pascual-González et al., 2016
J. Pascual-González, G. Guillén-Gosálbez, J.M. Mateo-Sanz, L. Jiménez-Esteller. **Statistical analysis of the ecoinvent database to uncover relationships between life cycle impact assessment metrics**
J. Clean. Prod., 112 (2016), pp. 359-368

Speranza, 2020
LIFE AGROWETLANDS II - **Guida all’utilizzo del sistema Smart Agrowetlands per gli agricoltori. Il portale di interfaccia Agrowetlands.** ISBN 9788854970342 - DOI 10.6092/unibo/amsacta/6502

Speranza et al., 2020
M. Speranza, E.Tavelli, C. Mazzotti, P. Pietrobon, A. Lamberti. **Reti wireless di sensori in agricoltura.**
Ecoscienza, 2 (2020), pp. 32-34.

Steduto et al., 2009
Steduto P., Hsiao T.C., Raes D., Fereres E. **AquaCrop - The Fao crop model to simulate yield response to water: I. Concepts and underlying principles**
Agronomy Journal, 101(2009), pp. 426-437.
Swiss Centre For Life Cycle Inventories, 2007
Swiss Centre For Life Cycle Inventories. **Ecoinvent Data V2.0**
Ecoinvent Cent (2007)
WOLF et al., 2012
WOLF Marc-Andree; PANT Rana; CHOMKHAMSRI Kirana; SALA SERENELLA; PENNINGTON David. **The International Reference Life Cycle Data System (ILCD) Handbook - Towards more sustainable production and consumption for a resource-efficient Europe**
Publications Office of the European Union, doi 10.2788/85670