LANDMARC

D2.8: CASE STUDY LEAFLETS

ON LAND-BASED MITIGATION AND NEGATIVE EMISSION SOLUTIONS IN THE LANDMARC CASE STUDY COUNTRIES

LEAD BENEFICIARY: JIN CLIMATE & SUSTAINABILITY

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LANDMARC

Land-use based Mitigation for Resilient Climate Pathways

GA No. 869367 [RIA]

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Contributor(s)	*Eise Spijker, Ida Terluin, all case study partners*
Reviewer(s)	*Jenny Lieu (TUD)*
Changes with respect to the DoA	- *Venezuelan case study: DoA refers to Colombia and Venezuela but it focusses only on Venezuela.* - *Kenyan case study: DoA refers to Kenya and Uganda but it focusses only on Kenya.* - *Swedish case study: DoA focus on BECCS in Sweden but has shifted its focus towards biochar in Europe and East Africa.* - *Netherlands (paludiculture and agroforestry) and Switzerland (organic cropping and reduced tillage) would deliver only one leaflet per country but have chosen to deliver two leaflets per country.*
Dissemination and uptake	*This deliverable provides an overview of all the case study leaflets on land-based mitigation and negative emission solutions of the LANDMARC project. Aside from this integrated deliverable (includes all leaflets) the individual leaflets will also be used as stand-alone documents to help inform stakeholders (i.e. as pdf/downloadable at case study section at www.landmarc2020.eu).*
Short Summary of results	
This document describes the case studies and puts them into the context of the LANDMARC project (contributions to key research objectives). This document also includes leaflets of each case study, that will be used as basic material for engagement with stakeholders in relation to the LANDMARC research activities. The case study leaders have co-developed these leaflets in conjunction with local stakeholders and therefore also describe the nature of the collaboration with external case study stakeholders.	
Evidence of accomplishment	
This report and all the individual leaflets.	

Preface

Negative emission solutions are expected to play a pivotal role in future climate actions and net zero emissions policy scenarios. To date most climate actions have focussed on phasing out fossil fuels and reducing greenhouse gas emissions in, for example, industry, electricity, and transport. While zero emission trajectories in these sectors will remain a priority for decades to come, it is expected that residual GHG emissions will remain. To be able to fulfil the Paris Agreement and meet the world's climate goals research, policy and markets are increasingly looking at negative emission solutions.

This is why the nineteen LANDMARC consortium partners work together in order to:

- Estimate the climate impact of land-based negative emission solutions, in agriculture, forestry, and other land-use sectors
- Assess the potential for regional and global upscaling of negative emission solutions
- Map their potential environmental, economic, and social co-benefits and trade-offs

LANDMARC is an interdisciplinary consortium with expertise from ecology, engineering, climate sciences, global carbon cycle, soil sciences, satellite earth observation sciences, agronomy, economics, social sciences, and business. There is a balanced representation of partners from academia, SMEs, and NGOs from the EU, Africa, Asia and the Americas, which ensures a wide coverage of LMTs operating in different contexts (e.g. climates, land-use practices, socio-economic etc.) and spatial scales.

The LANDMARC project consortium:

Contents

1. Purpose of this document

This document (Deliverable 2.8) provides an overview of the various land-based mitigation and negative emission solutions applied within the (16) LANDMARC country case studies (see Figure 1 below) and highlights their main contributions to the key objectives and research activities of the LANDMARC project. All two-page case study leaflets are attached to this report in Annex 1 – Case study leaflets.

Canada

BECCS: Bio-energy generation with willow from reclaimed open pit mine land in Canada

Partner: Innolab Space

Venezuela

Indigenous forest management: Indigenous fire management for climate change mitigation and adaptation (Canaima National Park in Amazon forest.

Partner: Cobra Collective

Portugal / Spain

Pastures for carbon and biodiversity - Business model(s) on Agroecosystems in Spain (dehesas) and Portugal (montados)

Partner: Agroinsider

Spain

Agroforestry: Evaluation and monitoring of carbon sequestration capacity and degraded agricultural lands refore-station program in Extremadura,

Partner: Ambienta

Sweden

Biochar for carbon sequestration: Deployment, innovation and upscaling in Europe and East Africa

Partner: Stockhom Environment Institute

Burkina Faso

Forestry: Support the World Bank Forest Investment Program (FIP) to assess its investments (integrated policy to reduce GHG emissions from land use changes and forestry)

Partner: eLEAF

Germany

Forest management – Options for climate smart forestry in the private sector
Partner: Okö Institut

The Netherlands

Agroforestry & paludiculture

Partners: Bioclear Earth & Joint Implementation Network

Switzerland

Reduced tillage & Organic cropping

Partner: ETH Zürich

Nepal

Land management: Improving farm resilience and reducing emissions through sustainable rice production

Partner: University of Sussex

Vietnam

Agroforestry: Increasing carbon storage in soils and trees and decreasing emissions from fertilizer use and deforestation in coffee landscapes

Partner: Int. Centre for Tropical Agriculture

Indonesia

Compost: Decarbonisation from composts including biogas in Indonesia.

Partner: Sustainability & Resilience Company

Kenya

Integrated soil fertility management (ISFM) in Kenya: large-scale potential to improve soil carbon storage and reduce soil N2O emissions in Kenya

Partner: ETH Zürich

South Africa

Eddy Covariance (EC) flux measurements in South Africa to calibrate and validate satellite-based estimates of carbon sequestration

Partner: eLEAF

Figure 1: Overview of LANDMARC case studies

2. Introduction

2.1 LANDMARC key objectives, scope, and activities

Land and sea represent a large reservoir of stored carbon and other precursors of greenhouse gases, locked in plants, soil, and waters. Anthropogenic activities on land and sea interfere with the natural carbon cycle, eventually leading to more emissions of GHGs than nature can absorb in one or multiple cycles; thereby increasing atmospheric GHG concentrations.

There is a broad consensus among scientists and governments that the way humankind manages land and sea plays a crucial role in achieving serious emission reductions and ultimately net negative emissions (Masson-Delmotte, et al., 2018) ; (European Commission, 2020)). As an example, net stored carbon in the EU AFOLU sector decreased from some 300 million tons CO_2eq. in 2010 to 263 million tons CO_2eq. in 2018, due to changes in land use and climate change effects (European Commission, 2020). By 2030 net stored carbon is expected to decrease even further to 225 million tons CO_2eq. in a business-as-usual scenario. Hence, actions to counteract the degradation of natural carbon sinks and enhance their GHG storage volumes are needed. In these actions, the use of our natural GHG sinks should be included, both in regional and international GHG emission strategies.

In this context, the LANDMARC project has the following key research objectives (see Table 1).

Table 1: Key research objectives LANDMARC

	Key Objectives	Corresponding research/societal question
1	Determine the potential and effectiveness of land based GHG emission reduction and removal solutions using Earth Observation (EO) data	How much carbon are we storing in land (soil and vegetation) and for how long?
2	Improve climate resilience of LMT solutions at the local level for large-scale implementation	How robust / resilient are the proposed solutions in light of (future) climate change?
3	Assess the risks, co-benefits, and trade-offs of scaling up local LMTs nationally	Are there any (un)wanted, (un)intended side effects or trade-offs associated with scaling up the proposed solutions?
4	Scaling up LMT solutions to the continental and global level to assess effectiveness	What (quantified) contribution over which time periods could land based reduction and removal solutions provide to reduce the impacts of climate change?
5	Improve current methodologies to estimate emissions and removals for LMTs	What methods can be used to better measure the net GHG impact of these solutions?
6	LMT capacity building and developing new tools and services for decision making	How can we best support / enable / facilitate the implementation of LMTs and develop new business models and tools for decision makers?

LANDMARC assesses the potential and feasibility of scaling land-based reduction and removal solutions in the Agriculture, Forestry and Other Land Use (AFOLU) sector. The scope of LANDMARC can be fine-tuned as follows:

- **Focus on land-based options** in the Agriculture, Forestry and Other Land Use (AFOLU) sector.[1]
- **Includes both GHG emission reductions and GHG removals.**
- **Focus on 'supply-side' technologies and practices** and not on demand-side mitigation options (diet adjustment, reduction of food waste, etc.).

[1] Sea-based mitigation options (ocean fertilisation, etc.) are therefore not considered.

The LANDMARC project aims to achieve these objectives by assessing the impacts of land-based mitigation (reduction) and negative emission (removal) technologies and practices by applying a unique mixed-methods approach. The country case studies provide the necessary bottom-up oriented, empirical evidence needed to validate, verify, and improve top-down oriented integrated assessment work. The mixed-method approach consists of a range of research activities including:

a. Application of earth observation techniques;
b. Climate hazard and sensitivity assessment;
c. Scaling scenario co-design with stakeholders;
d. Qualitative risk and impact assessment of scaling;
e. Quantitative impact assessment with simulation models (economic, land use and climate); and
f. Capacity building, policy support and business model development.

2.2 Case studies contribution to LANDMARC

The LANDMARC case studies all contribute directly and/or indirectly to one or more of the abovementioned key research objectives and activities. The specific mix of methods applied within the country case study context depends on the design of the case study as well as the working arrangements made between the LANDMARC case study leaders and the local external stakeholders. Table 2 provides an indicative overview of the respective contribution of each individual case study to the various mixed-method based activities listed above (a-f).

Table 2: Overview of case study contributions

	Case study name	a.	b.	c.	d.	e.	f.
1	**Agroforestry**: Improved carbon storage in soils and trees in The Netherlands	X	X	X	X	X	X
2	**Paludiculture**: Climate change mitigation through land use on rewetted peatlands in The Netherlands	X	X	X	X	X	X
3	**Forest management** in Germany - Opportunities for robust forest management strategies in Germany to enhance land-based climate change mitigation	X	X	X	X	X	X
4	**Reduced tillage**: Large-scale potential to improve soil carbon storage and reduce soil N2O emissions in Switzerland	X	X	X	X	X	X
5	**Organic cropping**: Large-scale potential to improve soil carbon storage and reduce soil N2O emissions in Switzerland	X	X	X	X	X	X
6	**Indigenous forest management**: Indigenous fire management for climate change mitigation and adaptation. The experiences from Canaima National Park, Venezuela	X	X	X	X	X	X
7	**Forestry**: Support the World Bank Forest Investment Program (FIP) in Burkina Faso to assess its investments (integrated policy to reduce GHG emissions from land use changes and forestry, and support women's	X	X	X	X	X	X

	Case study name	a.	b.	c.	d.	e.	f.
	economic activities for reforestation), link with the Forest Carbon Partnership						
8	**Eddy Covariance (EC) flux measurements** in South Africa Calibrate and validate satellite-based estimates of carbon sequestration	X				X	
9	**Integrated soil fertility management** (ISFM) in Kenya: large-scale potential to improve soil carbon storage and reduce soil N2O emissions in Kenya	X	X	X	X	X	X
10	**BECCS**: Bio-energy generation using Willow crops from reclaimed open pit mine land in Alberta, Canada	X	X	X	X	X	X
11	**Biochar** for carbon sequestration: Deployment, innovation and upscaling in Europe and East Africa[2]	(X)		X	X		X
12	**Compost**: Decarbonisation from composts including biogas in Indonesia.	X	X	X	X	X	X
13	**Agroforestry**: Evaluation and monitoring of carbon sequestration capacity and degraded agricultural lands reforestation program in Extremadura, Spain (1993-2008) and synergies with other social challenges including depopulation and masculinisation of rural areas.	X	X	X	X	X	X
14	**Agroforestry**: Increasing carbon storage in soils and trees and decreasing emissions from fertilizer use and deforestation in coffee landscapes of Vietnam	X	X	X	X	X	X
15	**Land management**: Improving farm resilience and reducing emissions through sustainable rice production in Nepal	X	X	X	X	X	X
16	**Pastures** for carbon and biodiversity - Business model(s) on Agroecosystems in Southwest of the Iberian Peninsula in Spain (dehesas) and Portugal (montados)	X	X	X	X	X	X

Note: This is the initial scoping of the case studies. These scopes may change as stakeholders are being consulted. Each case study will apply a minimum of one earth observation tool, one modelling tool as well as engage with local stakeholders for scenario co-design. The case studies' scope will be confirmed in Deliverable D2.1.

While most case studies contribute to all six general assessment activities within LANDMARC, there are a few exceptions to this. For example, the South African case study's primary and single focus is to advance remote sensing earth observation data with the help of eddy covariance data. This case study will help with a better quantification of C stock changes in land and vegetation.

2.3 Case study scope and clustering

The LANDMARC case studies all focus on land-based mitigation and/or negative emission technologies and practices. All case studies rely on the management of natural processes or accelerating occurring

[2] The scope of the Swedish case study is still to be confirmed.

processes in relation to carbon sinks (i.e., are nature-based). Table 3 presents an overview of the case studies and indicates if the case study focusses resp. on:

- Forests, land management or a mixture of both,
- GHG emission reductions or removals or a mixture of both

Table 3: LANDMARC case study information

	Case study name	Forest, Land, or mix	Reduction, removal, or mix
1	**Agroforestry**: Improved carbon storage in soils and trees in The Netherlands	Mix	Removal
2	**Paludiculture**: Climate change mitigation through land use on rewetted peatlands in The Netherlands	Land	Reduction
3	**Forest management** in Germany - Opportunities for robust forest management strategies in Germany to enhance land-based climate change mitigationOptions	Forest	Removal
4	**Reduced tillage**: Large-scale potential to improve soil carbon storage and reduce soil N2O emissions in Switzerland	Land	Reduction
5	**Organic cropping**: Large-scale potential to improve soil carbon storage and reduce soil N2O emissions in Switzerland	Land	Mix
6	**Indigenous forest management**: Indigenous fire management for climate change mitigation and adaptation. The experiences from Canaima National Park, Venezuela	Forest	Reduction
7	**Forestry**: Support the World Bank Forest Investment Program (FIP) in Burkina Faso to assess its investments (integrated policy to reduce GHG emissions from land use changes and forestry, and support women's economic activities for reforestation), llink with the Forest Carbon Partnership	Forest	Mix
8	**Eddy Covariance (EC) flux measurements** in South Africa Calibrate and validate satellite-based estimates of carbon sequestration	Mix	Mix
9	**Integrated soil fertility management** (ISFM) in Kenya: large-scale potential to improve soil carbon storage and reduce soil N2O emissions in Kenya	Land	Mix
10	**BECCS**: Bio-energy generation using Willow crops from reclaimed open pit mine land in Alberta, Canada	Forest	Mix
11	**Biochar** for carbon sequestration: Deployment, innovation and upscaling in Europe and East Africa	Land	Mix
12	**Compost**: Decarbonisation from composts including biogas in Indonesia.	Land	Mix
13	**Agroforestry**: Evaluation and monitoring of carbon sequestration capacity and degraded agricultural lands reforestation program in Extremadura, Spain (1993-2008) and synergies with other social challenges including depopulation and masculinisation of rural areas.	Mix	Removal

14	**Agroforestry**: Increasing carbon storage in soils and trees and decreasing emissions from fertilizer use and deforestation in coffee landscapes of Vietnam	Mix	Mix
15	**Land management**: Improving farm resilience and reducing emissions through sustainable rice production in Nepal	Land	Mix
16	**Pastures** for carbon and biodiversity - Business model(s) on Agroecosystems in Southwest of the Iberian Peninsula in Spain (dehesas) and Portugal (montados)	Land	Mix

2.4 Case study leaflets

For each case study, a leaflet (two-pager) has been developed with information on the specific LMT and a description of case study goals. The leaflets are going to be used to make a broad audience familiar with the LANDMARC activities on climate change mitigation in a specific case study.

The full leaflets are attached to this document in Annex 1 – Case study leaflets.

References

European Commission. (2020). *Stepping up Europe's 2030 climate ambition - Investing in a climate-neutral future for the benefit of our people.* Brussels: European Commission.

Masson-Delmotte, V., Zhai, P., Pörtner, H.-O., Roberts, D., Skea, J., Shukla, P., . . . Waterfield, T. (2018). *An IPCC Special Report on the impacts of global warming of 1.5°C .* IPCC.

Annex 1 – Case study leaflets

LANDMARC has received funding from the European Unions' Horizon2020 Grant Agreement No 869367

AGROFORESTRY

CS1- Improved carbon storage in soils and trees in the Netherlands

About the initiative

Together with relevant stakeholders, including the water boards 'Aa en Maas', 'De Dommel', and the partners from the FARM LIFE project, the LANDMARC H2020 research project on land-based negative emission solutions will explore the potential of carbon storage in soils and trees in the Netherlands. In close collaboration with these stakeholders, a series of research and engagement activities will be implemented in the 2020-24 period.

Focus Area

Within the FARM LIFE project, three agroforestry pilot sites (Liempde, Alphen and Drimmelen) have already been set up (Figure 1). At these pilot sites, novel agroforestry technologies are demonstrated to enable the transition from conventional agriculture towards more climate-resilient agroforestry. In agroforestry up to seven layers are applied: canopy trees (as nuts, oil, timber, nitrogen fixation species and fruit species), smaller trees (fruit and forage species), higher shrubs (nuts, fruit and forage species), lower shrubs (fruit species), climbers (fruit species), herbs, annual crops and livestock. The FARM LIFE project covers a range of actions geared towards further developing and promoting agroforestry business models and developing agroforestry transition roadmaps and toolkits, for farmers and policymakers.

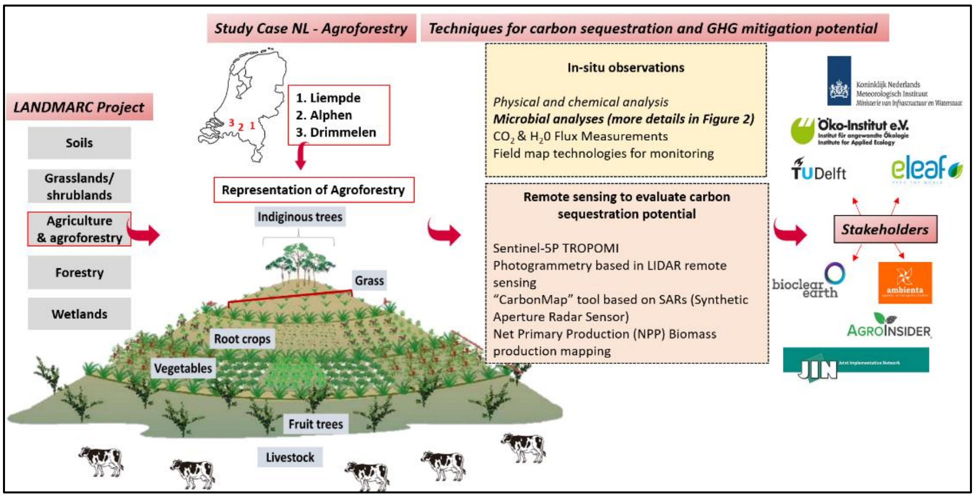

Figure 1: Overview of the LANDMARC project focusing on the Dutch agroforestry case study. In LANDMARC we will take representative soil samples in the Netherlands at three different locations (Liempde, Alphen and Drimmelen). A combination of in situ observations, models and remote sensing techniques are going to be used to evaluate carbon sequestration and climate change mitigation in the collaborative work of beneficiary partners and stakeholders.

What LANDMARC offers

LANDMARC complements the ongoing work on agroforestry in the Netherlands through:

1. **Measuring:** Deploying of earth observation technologies and methods (satellite methods, soil chemical and microbial analyses) that will lead to a better determination of the carbon storage potential of agroforestry practices. Specifically, for microbes, soil DNA (organisms leave behind

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DNA that can be detected from soil) is used to characterise microbiota. Molecular analysis enables rapid species identification and quantification and offers the potential to discriminate between locations and treatments for a more detailed picture (Figure 2). Additional information about soil microbiology is presented in *Section I*. The in-situ soil and satellite data together generate knowledge that leads to the accumulation of a wealth of new information concerning soil health, climate change, plant development, and response to environmental stress.

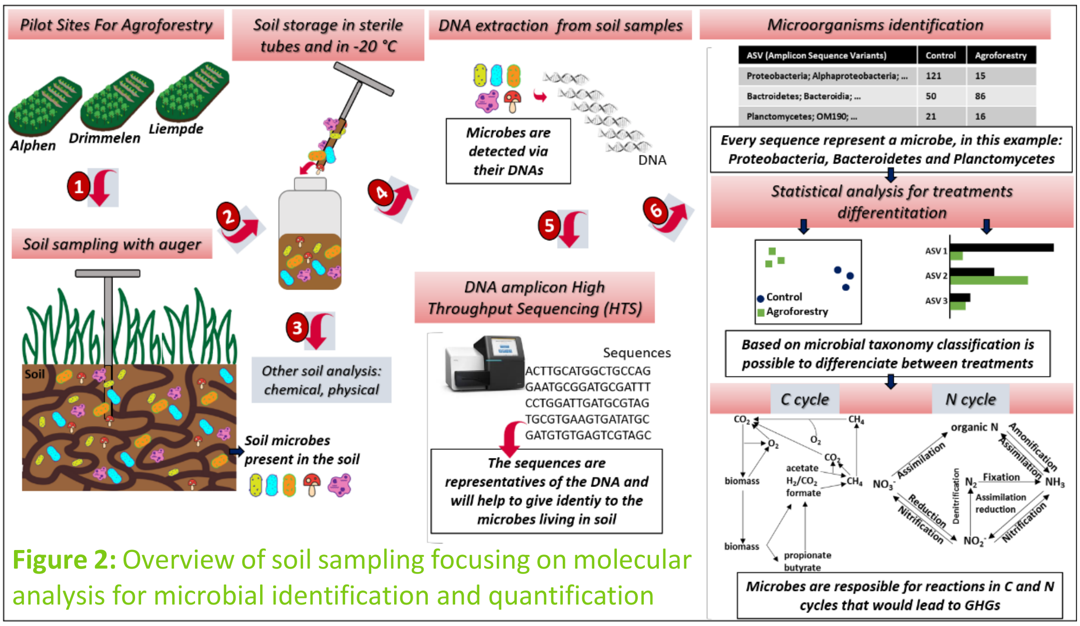

Figure 2: Overview of soil sampling focusing on molecular analysis for microbial identification and quantification

2. **Business:** Here we aim at the development of better carbon mapping and monitoring tools and methods for agroforestry, GHG inventory accounting and/or carbon offset schemes. Furthermore, a detailed description of specific agroforestry technologies will be included in the WOCAT Global Sustainable Land Management database which allows communities around the world to benefit from the Dutch experience with agroforestry to store carbon. Also, the development of *carbon offset markets* for land-based negative emission solutions is going to be explored and supported. That includes the collection of human systems data for agroforestry (i.e. data about costs, markets, policies, social acceptance, land use competition).
3. **Adaptation:** A *climate risk and sensitivity analysis* of agroforestry practices in the Netherlands will be performed with the help of the latest (regional) climate scenarios and strategies that could be deployed to improve its resilience.
4. **Scaling:** Performing an exploratory assessment of potential co-benefits and trade-offs related to nationwide *scaling-up of agroforestry technologies* and practices by land-use and economic simulation models. Subsequently, policy strategies to mitigate unwanted side-effects will be (co-) developed with stakeholders.

Section I - Additional information

Microorganisms are crucial in regulating climate change. Higher CO_2 levels in the atmosphere increase primary productivity which leads to higher carbon emissions due to microbial degradation. Higher temperatures promote higher rates of terrestrial organic matter decomposition. The effect of temperature is not just an effect on microbial reaction rates but also results from plant inputs stimulating microbial growth. Another example is methane which is also produced by microbes. Therefore, knowledge of global CH_4 sources and sinks is essential to devise efficient mitigation strategies to combat global warning. Microbial CH_4 production (methanogenesis) is performed by a specific group of Archaea (methanogens) and microbial CH_4 consumption (methanotrophy) is achieved by a unique group of bacteria (methanotrophs). Hence, recognizing soil microbes with closer examination in the main players of fundamental biogeochemical processes can help to control fluxes of GHGs. The provided information will be crucial to join efforts with other research activities to supply more detailed insights on the effectiveness and climate resilience of LMTs.

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PALUDICULTURE

CS2-Climate Change Mitigation through Land Use on Rewetted Peatlands

About the initiative

Sustainable peatland management practices such as paludiculture are crucial for restoring degraded peatland ecosystems. Paludiculture involves wet cultivation practices in peatlands and can maintain peat bodies and sustain ecosystem services. To restore degraded peatlands and reduce C losses in the form of CO_2 emissions in the Netherlands, **land users**, stakeholders from water boards '**Aa en Maas'** and the local partnership '**BOER BIER WATER**' in collaboration with **LANDMARC** and **CCONNECTS** plan to use approaches of soil rewetting and revegetation of peat soils with cattail for the restoration of the peatland ecosystems and the contribution to zero or negative carbon balances in peatlands in a pilot site in Swinkels. This pilot site acts as a case study on paludiculture in the Netherlands in the LANDMARC project during 2020-2024.

Peatlands in the Netherlands

What are peatlands? Peatlands are terrestrial wetland ecosystems in which waterlogged conditions prevent plant material from fully decomposing. Consequently, the production of organic matter exceeds its decomposition, which results in a net accumulation of *peat*. Large amounts of carbon, fixed from the atmosphere into plants, are locked away in peat soils, representing a valuable global carbon store.

Peatland benefits: Peatlands are ecosystems that store fresh water and host unique biodiversity. Peats are efficient climate regulators and buffer against drought and floods. These areas form the basis of the livelihood of people which benefit from the traditional use without degrading the peatland. Peatlands are also one of the world's largest carbon sinks, which means they are both a challenge and an opportunity to fight against climate change.

Where do they occur? Peatlands occur in every climatic zone and continent and cover 4.2 million km^2, which corresponds to **2.8% of the Earth's** terrestrial surface. The Netherlands has **8% of the land area** represented by peat soils (**Figure 1a**).

What is the issue with peatlands? A lack of awareness of the peatlands benefits means that they have been severely damaged as a result of drainage and agricultural conversion. As a consequence, peatlands in the Netherlands are threatened by reduced water levels. This has released huge amounts of greenhouse gases, such as **carbon dioxide (CO_2)**, from the carbon stored within the peat soils. In the Netherlands only, this accounts for annual emissions of around **4.2 Mt $CO_2.y^{-1}$**.

Paludiculture case study in the Netherlands

Within the CCONNECT project, the pilot site of 1 ha in Swinkels (Figure 1b) aims to make use of paludiculture keeping the water table high and block the drainage ditches. Furthermore, in this area cattails are cultivated, a plant adapted to wet conditions to provide an alternative product for farmers. The pilot was implemented in August 2020 with the infilling of the central drainage ditch and construction of low peat bunds as well as the construction of a subsoil irrigation system at the perimeter of the pilot field. Cattail was planted in September 2020, as well as an installation that shall prevent severe damage by geese grazing of the young plants. Figure 1b shows a comparison of the situation before and after the paludiculture implementation.

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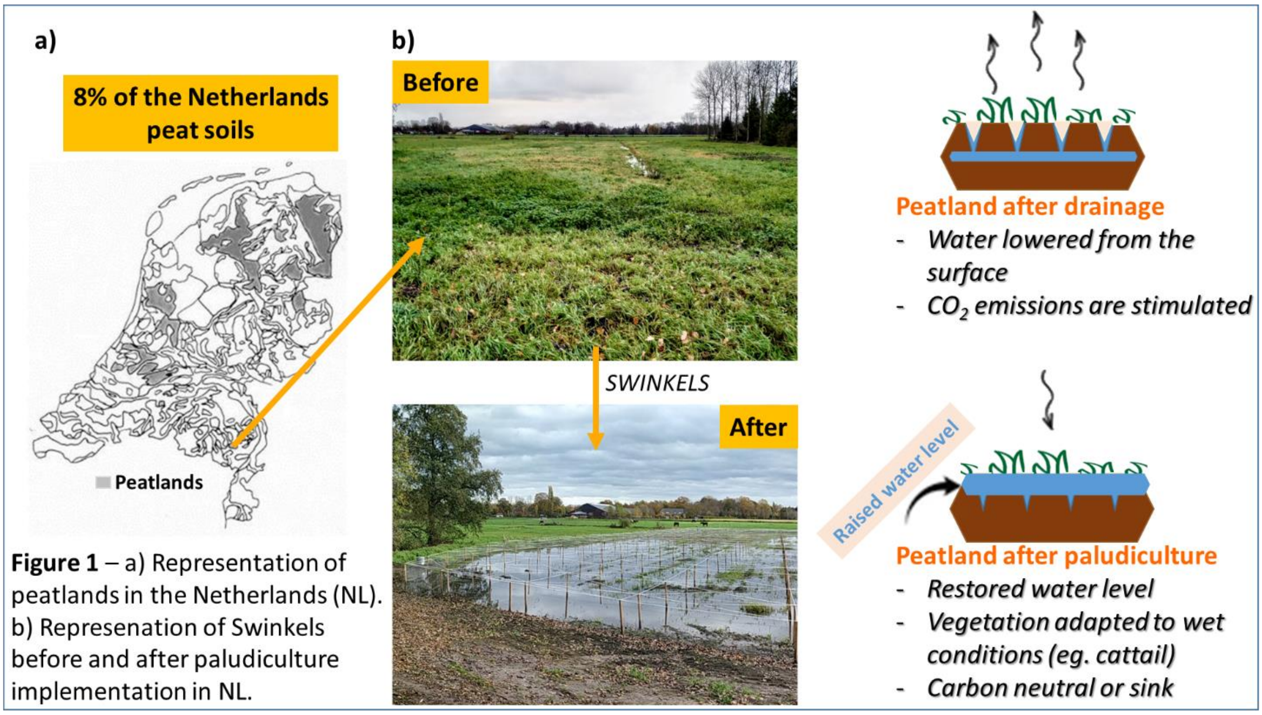

Figure 1 – a) Representation of peatlands in the Netherlands (NL). b) Represenation of Swinkels before and after paludiculture implementation in NL.

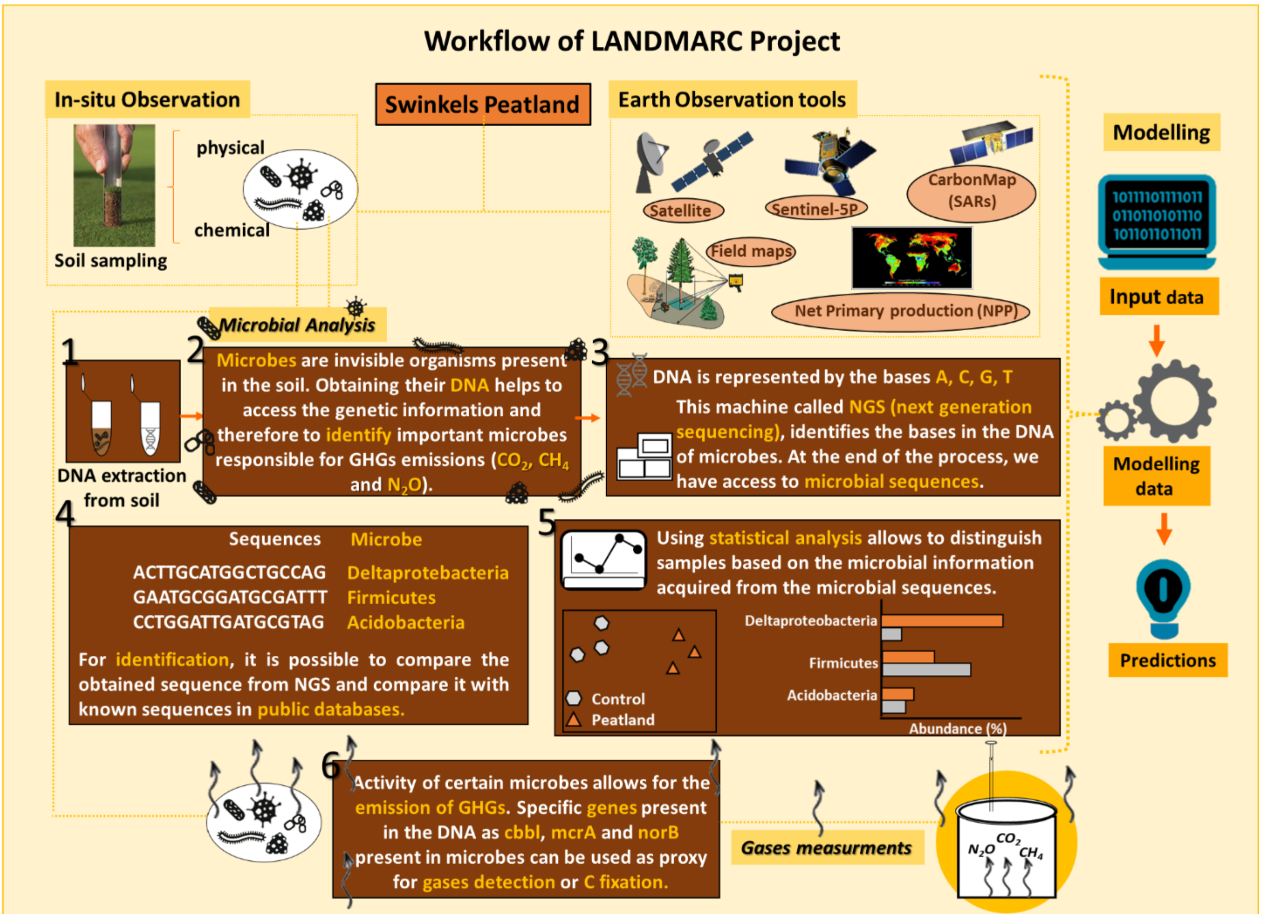

Figure 2 – Workflow of the LANDMARC project from in-situ-observation tools including microbial analysis (1, 2, 3, 4, 5), GHGs measurments (6), earth observation tools and modelling.

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What LANDMARC offers

Within the LANDMARC project, we plan to focus on more accurate and cost-effective monitoring of the peatlands potential to sequester carbon from the atmosphere. For that we follow the next steps:

5. **Measuring:** Deploying in-situ observations in soil, estimation of GHG concentrations, remote sensing data and available spatial resolutions tools that will lead to a better determination of the carbon storage potential of paludiculture practices. Specifically, for microbes, soil DNA (organisms leave behind DNA that can be detected from the soil) is used to (1) characterise microbiota and (2) as proxies for GHG monitoring (Figure 2).
6. **Business:** Here we aim at the development of better carbon mapping and monitoring tools and methods for paludiculture, GHG inventory accounting and/or carbon offset schemes. Furthermore, a detailed description of specific paludicultural technologies will be included in the WOCAT Global Sustainable Land Management database which allows communities around the world to benefit from the Dutch experience with paludiculture to store carbon. Besides, the development of *carbon offset markets* for land-based negative emission solutions is going to be explored and supported. That includes the collection of human systems data for paludiculture (i.e. data about costs, markets, policies, social acceptance, land use competition).
7. **Adaptation:** A *climate risk and sensitivity analysis* of paludicultural practices in the Netherlands will be performed with the help of the latest (regional) climate scenarios and strategies that could be deployed to improve its resilience.
8. **Scaling:** Performing an exploratory assessment of potential co-benefits and trade-offs related to nationwide *scaling-up of paludicultural technologies* and practices by land-use and economic simulation models. Subsequently, policy strategies to mitigate unwanted side-effects will be (co-) developed with stakeholders.

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FOREST MANAGEMENT

CS3-Opportunities for robust forest management strategies in Germany to enhance land-based climate change mitigation

Background

Land-based mitigation technologies related to forest management aim at restoring forest carbon stocks in managed forests. Managed forests in the EU and other industrialised countries currently take up more carbon than they emit. This is due to historic effects related to regrowth after overexploitation and reforestation and the resulting age structure. Keeping sequestration rates at current levels or extending them can be an important contribution to national mitigation targets but also bears risks if forests are not sufficiently adapted to climate change.

German forests are characterized by rather high carbon stocks. Especially small private forest owners have underutilized their forest resources in the past. Currently, few monetary incentives exist for maintaining low harvest intensities in forests. These are driven by nature protection policies and thus not directly addressing climate change mitigation measures in forests. This is despite the fact that there is a high motivation by forest owners to participate in carbon markets.

About the case study

The case study aims at developing an LMT concept for robust forestry, forest restoration and conservation strategies in Germany including results-based finance mechanisms for carbon accounting and crediting.

We model forest dynamics in Germany for different management types and assumptions for climate change impacts. Different groups of stakeholders will be engaged to contribute to designing forest development scenarios and concepts for finance mechanisms. Outputs are stakeholder maps, scenarios of forest development and robust management strategies, an overall assessment based on specific indicators, and finally a concept for finance mechanisms (see Fig. 1 below).

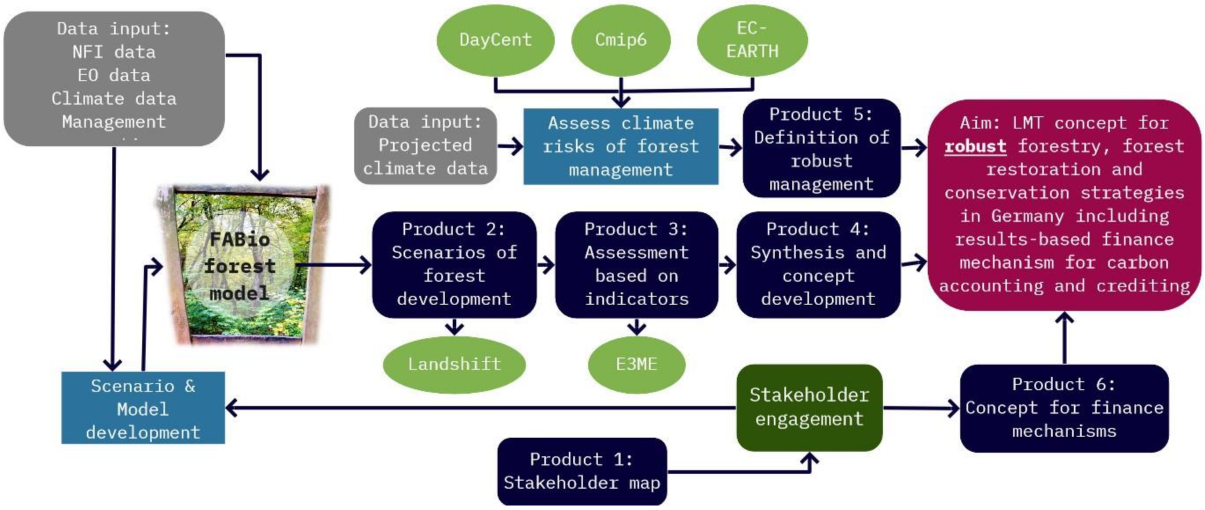

Figure 1: Case study flow chart of data input, products, activities and linkages to other models/tasks in LANDMARC.

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Focus Area

The case study covers the whole forest area in Germany, which is 11,4 Mha. Coniferous trees, mainly spruce (*Picea abies*) and pine (*Pinus sylvestris*) cover 54 %. Deciduous trees make up 46 % and the most common species are beech (*Fagus sylvatica*) and oak (*Quercus petraea*, *Q. robur*). Half of the forests are privately owned, with an average property size of 3 ha. About 50 % of private forest property is below 20 ha and only 13 % of private forest owners manage forest of more than 1000 ha. Due to the federal structure of Germany, every federal state has its forest law determining forest management and funding regulations for private forest owners.

What the LANDMARC case study offers

Data basis: National Forest Inventory (NFI) data will be stratified by ownership, forest type, biogeographical region etc. Using climate projections, we then assign climate risk classes to the strata and develop specific forest management options as responses to risks.

Modelling: FABio-Forest is a single tree-based simulation model. Parameters for tree growth and mortality are derived from NFI data, including tree density and competition, soil and climate conditions. Assumptions on forest management as well as climate change drive the future development of tree stands. Results indicators include, e.g., potential wood supply, carbon storage and deadwood (see Fig. 2 below).

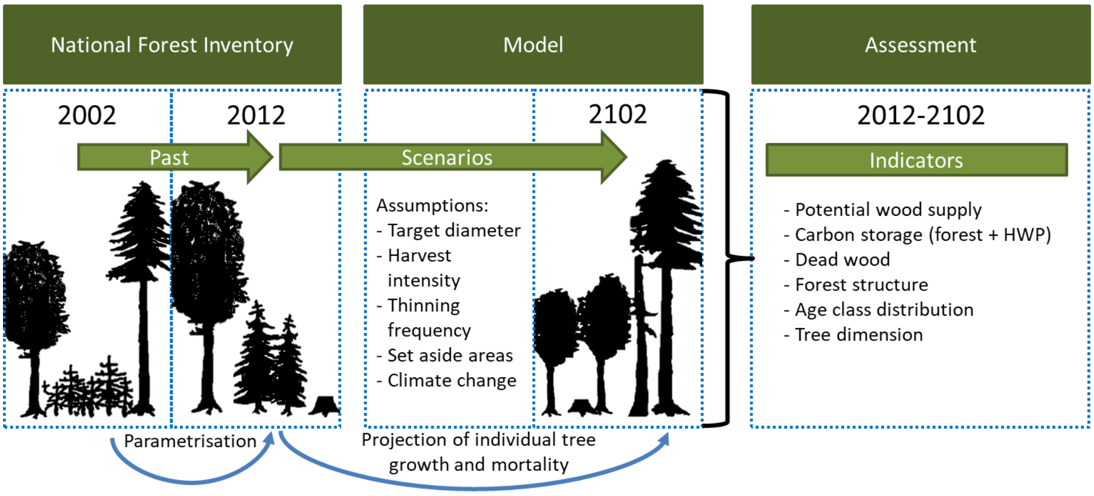

Figure 2: Work and information flow in FABio-Forest model applied in the case study.

Risk assessment: A climate risk and sensitivity analysis of forest management strategies will be performed with the help of the latest (regional) climate scenarios and forest management strategies for more resilient forests will be developed.

Stakeholder engagement: Relevant forest stakeholder groups will be identified following their role as, e.g.: forest owner, governance, forester, scientist and NGO. The practical experience of foresters and the knowledge of scientists will be an essential input to evaluate forest development scenarios, whereas forest and climate policymakers will contribute to applying concepts of finance mechanisms.

Policy instruments: Instruments for supporting management change in forests especially need to target the private sector. We will develop a concept for funding mechanisms that will test the use of market mechanisms and results-based finance for carbon credits and other ecosystem services. The

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instruments will be consistent with national support schemes and legislation as well as with international reporting and accounting rules.

Expected impacts

- The case study provides a database and method to assess LMT solutions in German forests.
- National climate and forest policy makers have a basis to develop policy instruments for implementing measures to sustain and enhance forest carbon sinks by obtaining adapted forest management practices.
- These instruments make use of market mechanisms and results-based finance.
- Carbon crediting and certification organisations benefit from risk assessments to ensure environmental integrity.
- Findings from the case study support the German national sink strategy towards its GHG neutrality target.

References

1. BMEL (2012): Ergebnisdatenbank der Bundeswaldinventur. Bundesministerium für Ernährung und Landwirtschaft. Online verfügbar unter https://bwi.info/, zuletzt geprüft am 31.08.2017.

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Reduced tillage

CS4-Large-scale potential to improve soil carbon storage and reduce soil N_2O emissions in Switzerland

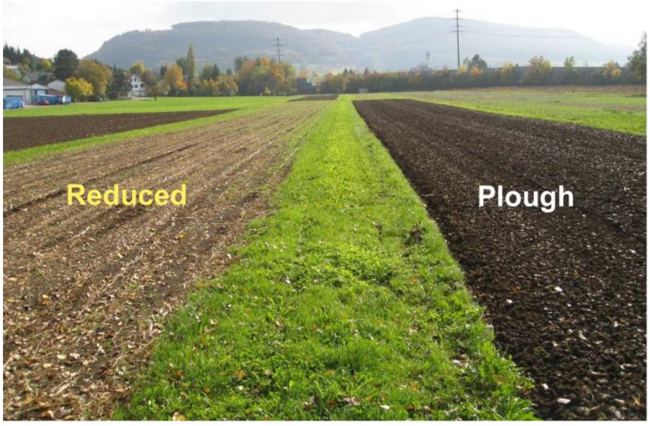

Photo credit Paul Mäder (FiBL, Switzerland)

About the initiative

Together with relevant stakeholders, including Agroscope and partners from the LANDMARC H2020 research project on land-based negative emission solutions, we will explore the long-term and large-scale potential and limitations of reduced tillage to provide sufficient and economically viable crop production and to mitigate soil GHG emissions through the improved soil carbon storage and reduction of soil N_2O emissions in Switzerland. Ecosystem, land use and economic modelling research complemented with stakeholder engagement activities will be implemented in the 2021-2024 period.

Additional information - Reduced tillage

Reduced tillage is a soil management strategy used to achieve reduced soil disturbance in arable fields while preparing the soil for row cropping, thereby limiting or reducing the need for the deep inversion tillage. It involves a variety of practises represented by lower tillage intensity, shallower tillage depth or reduced tillage frequency (e.g., in the crop rotation) leading to less soil disturbance, either in the seedbed, field or across the farm.

Reduced soil disturbance due to reduced tillage can promote a higher soil organic matter content in the surface layer, which is beneficial for soil structure and stability, soil biological activity and seedling emergence. It can also reduce soil erosion (tillage erosion) and preserve soil fertility. Furthermore, more continuous soil pores developed in response to this practice allow for increased rainfall infiltration, which is beneficial for water availability for crops and thus climate change adaptation.

Reduced tillage might lead to long-term increases in crop yields and thus farm income in some environments, but this is not valid for all soils and climates. Nevertheless, it contributes to savings of labour, time and fuel through the elimination or reduction of intensive tillage operations. The adoption of reduced tillage has been hindered due to a yield reduction and consequently an income loss in the short-term as well as due to weed management problems, which might need extra labour or use of herbicides for weed control. Furthermore, reduced tillage might increase soil bulk density, inhibiting root growth in some environments.

Focus Area

The long-term ongoing experiment evaluating effects of soil tillage management options differing in tillage depth on crop yields and various soil properties was established in Changins, Switzerland in 1969 (Fig. 1, 46°24' N, 06°14' E, 430 m above sea level). The experiment follows a randomized complete

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block design with four main treatments of soil tillage related to conventional deep inversion tillage on the one hand, and reduced tillage treatments on the other hand. Until 2007, the following treatments were applied: deep inversion tillage (plough to 25 cm), deep non-inversion tillage (chisel to 25 cm), reduced tillage (cultivator to 10 to 15 cm) and minimum tillage (rototiller to 8 cm). In 2007, the deep non-inversion tillage treatment was converted into a no-till treatment (last tillage: autumn 2006). Each treatment is replicated three times on clayey soil (46% clay, 16% sand) and four times on silty soil (26% clay, 30% sand). A four-year crop rotation has been implemented at this site, consisting of rapeseed (*Brassica napus*), winter wheat (*Triticum aestivum*), grain maize (*Zea mays*) and winter wheat. Research management and regular data collection (yields, soil properties) at the plot level allowed the development of a long- term dataset spanning 54 years. The experiment is aligned with a network of farmers and local stakeholders, which will provide a valuable asset for the LANDMARC project.

Figure 1: a) Location of the P29C long term experiment in Changins, close to Nyon and b) a photograph of the experiment. Photo credit Lucie Büchi (Natural Resources Institute, UK)

What LANDMARC offers

LANDMARC complements the ongoing work on reduced tillage practices in Switzerland through:

1. **Complementary data collection:** A human systems data for reduced tillage (i.e., local contextual data, socio-economic data such as costs, markets, policies, social acceptance, land use competition) will be collected through reviews of scientific literature, local/national databases, survey tools and stakeholder workshops.
2. **Assessment of climate vulnerability/risk and potential effectiveness of the large-scale implementation of reduced tillage:** A climate risk and sensitivity analysis of reduced tillage in Switzerland will be performed based on stakeholder knowledge, locally available data and by analysing the results from the Coupled Model Intercomparison Project, phase 6.
3. **Ecosystem and socio-economic impact assessment of reduced tillage**: A qualitative and quantitative exploratory assessment of potential co-benefits and trade-offs related to nationwide scaling-up of reduced tillage will be performed through the stakeholder engagement and by employing ecosystem (DayCent), land-use (ALCES, LandSHIFT) and macro-economic (E3ME) simulation models across the medium to long term. The outcomes of these analyses will have implications for the national climate change mitigation policy strategy development.

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Organic cropping

CS5-Large-scale potential to improve soil carbon storage and reduce soil N_2O emissions in Switzerland

About the initiative

Together with relevant stakeholders, including Agroscope, the Research Institute of Organic Agriculture (FiBL) and partners from the LANDMARC H2020 research project on land-based negative emission solutions, we will explore the long-term and large-scale potential and limitations of organic cropping to provide sufficient and economically viable crop production and to mitigate soil GHG emissions through the improved soil carbon storage and reduction of soil N_2O emissions in Switzerland. Ecosystem, land use and economic modelling research complemented with stakeholder engagement activities will be implemented in the 2021-24 period.

Additional information - Organic cropping

Organic cropping can preserve natural resources from degradation and promote long-term environmental health and economic profitability based on resilient agroecosystems. It is defined as crop production using animal or green manures, or diverse crop rotations with the aim to conserve soil structure and functions as well as biodiversity, improve the sustainability of crop production, and control weeds and pests. The use of agricultural chemicals (synthetic fertilizers, herbicides, and pesticides) is strictly avoided. Instead, animal manures are used, or leguminous cover crops and green manures are integrated into the crop rotation to provide nutrients for the crop and to suppress weeds and pests. This crop production relies in large part on more closed nutrient cycles by returning plant residues and manures from livestock back to the land and/or by integrating perennial plants, mainly grass–clover mixtures or forage legume leys, into the system. It has been often combined with reduced tillage practices to preserve soil fertility, despite known disadvantages such as high pressure from enhanced weed infestation.

As a systems approach, organic cropping can provide many benefits, such as increased biodiversity at different trophic levels, improved soil quality (fertility, structure and soil biological activity) and adaptation to climate change. Numerous studies show that organic cropping can lead to a reduction of soil organic carbon losses or even to higher soil organic carbon concentrations and net carbon sequestration over time and lower soil N_2O emissions compared to conventional systems per hectare.

Nevertheless, organic cropping generally leads to weed management problems, which might require extra labour or an occasional use of a deep inversion tillage, and a delay in soil nitrogen mineralization in spring, which might together contribute to a crop specific yield reduction (by 20% in general). On the other hand, organic products receive a price premium. The adoption of organic cropping might be hindered by a lack of organic manures due to a limited number of animal husbandries in the area. In summary, despite lower yields, organic farming can deliver more ecosystem services and social benefits and could lead to an improvement of rural livelihood.

Focus Area

The long-term ongoing experiment evaluating effects of several agricultural input systems on crop yields and various soil properties was established in 1977 in Therwil, Switzerland (Fig.1, 47°30'9.6" N, 7°32'21.0" E) as a result of a collaboration between Agroscope Reckenholz-Tänikon station and the Research Institute of Organic Agriculture (FiBL). Initially, the main goal was to investigate the feasibility of organic farming systems. Nowadays, the main research questions are related to soil and product quality. The experiment compares farming systems differing concerning fertilization and plant protection management: a) biodynamic and organic systems fertilized with farmyard manure and slurry at the typical intensity of Swiss organic farms (at 1.2, later at 1.4 LU ha^{-1} yr^{-1}); b) conventional system with the same organic fertilizer input and additional mineral fertilization up to recommended plant-specific levels (on average 149 kg N ha^{-1} yr^{-1}); c) mineral conventional system fertilized with mineral fertilizers, representing a stockless system (on average 125 kg N ha^{-1} yr^{-1}); and d) unfertilized system. The N, P and K inputs in the biodynamic and organic systems are 34-51% lower than in the conventional systems. Organic and conventional systems are managed at two fertilization levels,

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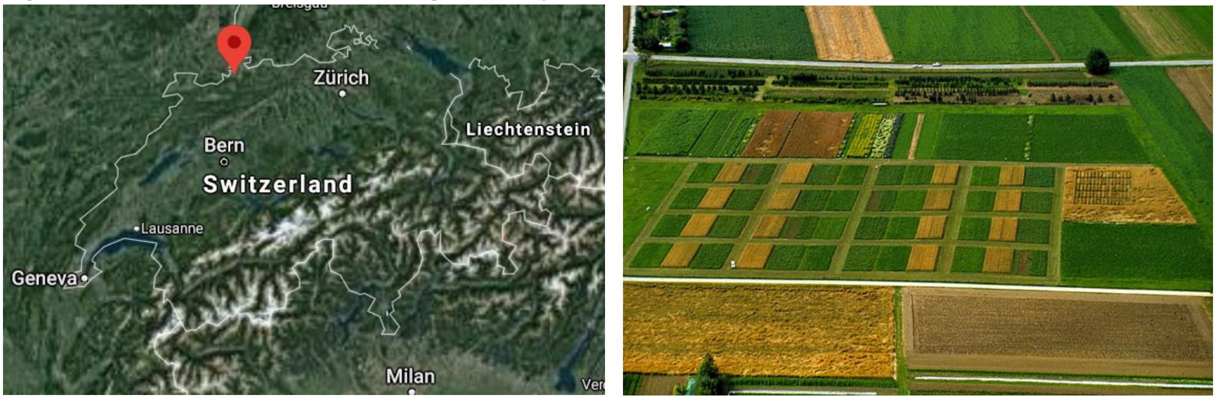
corresponding to 100% and 50% of typical fertilization. Systems are arranged in a split-split-plot design with four replicates. A seven-year crop rotation consists of potatoes (*Solanum tuberosum*), green manure, winter wheat (*Triticum aestivum*), fodder intercrop, white cabbage (*Brassica oleracea*), winter wheat, winter barley (*Hordeum vulgare*) and a two-year grass-clover ley (*Trifolium pratense, Trifolium repens, Dactylis glomerata, Festuca rubra, Phleum pratense, Lolium perennne, Poa pratensis, Festuca pratensis*). White cabbage was replaced with beetroot (*Beta vulgaris*) and soybeans (*Glycine max*), and one winter cereal with silage maize (*Zea mays*) in later years. As fodder intercrops, rye and vetch or sunflower and vetch mixtures are planted. The crop rotation is planted with a temporal shift on three rotation subplots so that three crops are grown simultaneously in each system each year. Soils are managed with conventional tillage and cereal straw is removed. The plant protection in the organic and unfertilised systems is based on mechanical weeding, indirect disease control measures and plant extracts together with bio-controls against insects, while in the non-organic systems herbicides, fungicides and pesticides are applied. Research management and regular data collection (yields, soil properties) on a plot level allowed the development of a long- term dataset spanning 43 years. The experiment is aligned with a network of farmers and local stakeholders, which will provide a valuable asset for the LANDMARC project.

Figure 1: a) Location of the DOK long term experiment in Therwil close to Basel (Switzerland) and b) a



photograph of the experiment. Photo credit Paul Mäder (FiBL, Switzerland)

What LANDMARC offers

LANDMARC complements the ongoing work on organic cropping in Switzerland through:

1. **Complementary data collection:** A human systems data for organic cropping (i.e., local contextual data, socio-economic data such as costs, markets, policies, social acceptance, land use competition) will be collected through reviews of scientific literature, local/national databases, survey tools and stakeholder workshops.
2. **Assessment of climate vulnerability/risk and potential effectiveness of the large-scale implementation of organic cropping:** A climate risk and sensitivity analysis of organic cropping in Switzerland will be performed based on stakeholder knowledge, locally available data and by analysing the results from the Coupled Model Intercomparison Project, phase 6.
3. **Ecosystem and socio-economic impact assessment of organic cropping**: A qualitative and quantitative exploratory assessment of potential co-benefits and trade-offs related to nationwide scaling-up of organic cropping will be performed through the stakeholder engagement and by employing ecosystem (DayCent), land-use (ALCES, LandSHIFT) and macro-economic (E3ME) simulation models across the medium to long term. The outcomes of these analyses will have implications for the national climate change mitigation policy strategy development.

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INDIGENOUS LAND MANAGEMENT

CS6-Indigenous fire management for climate change mitigation and adaptation. The experiences from Canaima National Park, Venezuela

BACKGROUND

Together with Pemón Indigenous communities from Canaima National Park (CNP; Fig. 1), Universidad Simón Bolívar researchers, Park administrators, INPARQUES fire-fighters body, government and developing organisations from Venezuela, and other national and regional stakeholders, a series of research actions based on data collection, stakeholder engagement, and LMT (Land-use Mitigation Technology) assessment will be implemented in the 2020-2024 period.

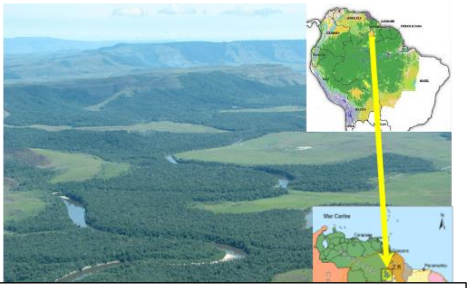

Figure 1. Canaima National Park (CNP) landscape and location.

PARTNERS' ROLE IN THE LANDMARC PROJECT

COBRA Collective will take the role of case study leader in Venezuela (CS6) focused on Indigenous ways of fire management as an LMT, to prevent catastrophic wildfires and preserve large carbon sinks in the Amazon forests (Fig.2). Also, COBRA will co-lead the regional case study for the Americas as proposed in WP6. We will cooperate with KNMI (WP3), who are useTropomi satellite data to model natural disturbances. The aim is to compare and describe the Venezuelan Amazon fires of CNP with Australian bushfires, from which KNMI has vast experience (Fig. 3).

We will also collaborate in the implementation of CS6 as one of the two pilot studies for ALCES model simulation (WP5) led by Matt Carlson (ALCES). The comparison of the model output with contrasting conditions and location (temperate forest of The Netherlands) and the inclusion of tropical wildfires/Indigenous fire management will be novel and key challenges for the ALCES model.

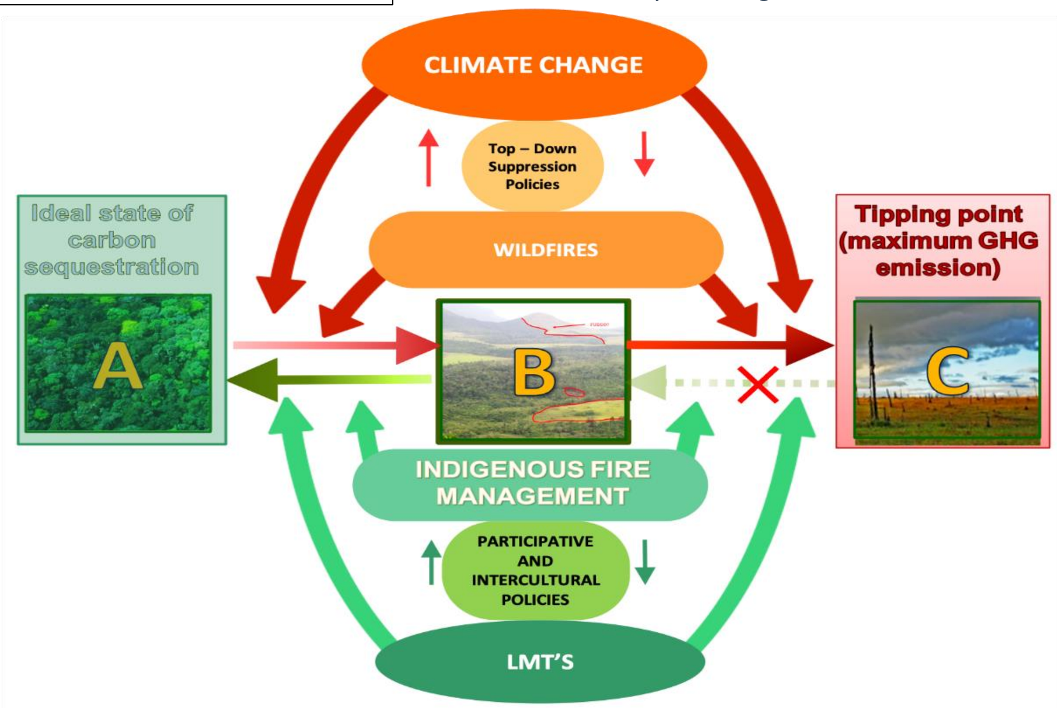

Figure 2. Conceptual framework of CS6 describing the transition states of CNP ecosystems affected by wildfires and their interaction with climate change, as well as the effect of LMT's measures and comprehensive Indigenous land management.

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DATA AND METHODS

A set of data collection, earth observations technologies, simulation modelling, stakeholder engagement, and qualitative assessment (fig. 3) will be implemented in cooperation with other LANDMARC partners to explore LMT at a local, national, and continental level according to the following activities:

Activities to achieve case study (CS6) goals:

1. Characterisation of the ecological and human dimensions of Indigenous LMTs related to Indigenous fire management for agricultural purposes and forest protection in CNP (Fig. 3).

2. Implementation of Earth observation technologies to estimate the effectiveness of Indigenous LMTs. We will determine wildfires occurrence and fuel accumulation patterns in areas under fire suppression policy since 1980 within CNP (Fig 3).

3. Estimation of co-benefits and trade-offs, climate vulnerability, and scaling potential of Indigenous LMTs. A suite of climate and land-use simulations will be applied to better understand this system.

4. Strengthen the undergoing transformative process of national policies about fire management in protected areas and climate change in Venezuela. We expect to create opportunities for open discussions and exchanges to develop viable continental narratives and scenarios of fire management as LMT in the Americas (Fig. 2 and 3).

5. Promotion of intercultural and participatory policies for LMTs and engagement with local, regional, and continental stakeholders in the Americas already working on implementing negative emission solutions based on Indigenous or local fire management practices (Fig. 2 and 3).

Figure 3. a) and b) Examples of participative and cooperative methods using audio-visual techniques (enrichment pictures, script videos, etc.) to implement in activities 1, 2, 3, 4, 5 of case study CS6 of LANDMARC project. Stakeholder's participation will support c) ALCES model simulation, d) characterisation of LMT, and e) Interpretations of Earth Observations. Previous experiences showed how powerful are participatory tools to achieve engagement and commitment of local and regional stakeholders, particularly in conflicting socio-economic and environmental contexts such as those affecting Latin America region.

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Support the World Bank Forest Investment Program (FIP) in Burkina Faso

CS7-Assess the impact of FIP interventions that target the reduction of GHG emissions from land-use change and deforestation.

About the initiative

How can we assess the impact of interventions that target to reduce Green House Gases (GHG) emissions from land-use change and forest degradation? In Burkina Faso, the LANDMARC H2020 research project will evaluate the potential of satellite earth observation and land-use change models to monitor and evaluate interventions that target carbon sequestration under the Forest Investment Program (FIP), a strategic program of the Strategic Climate Fund (SCF) within the Climate Investment Funds (CIF).

The goal of FIP is to reduce poverty and increase economic growth in rural populations through improved management of forest natural resources. Through a series of local investments, the FIP supports Burkina Faso's efforts to Reduce Emissions from Deforestation and Forest Degradation (REDD+). From 2020-2024 LANDMARC will closely collaborate with stakeholders in Burkina Faso, including the World Bank, and the FIP Coordination and REDD+ Technical Secretariat under the Ministry of the Environment to assess the impact of these interventions.

Focus Area

Local FIP interventions address the direct and indirect causes of deforestation and forest degradation. They were implemented as a pilot operation in 32 communes – but is already scaling up to at least 50 communes - and 12 protected forests, distributed across 5 regions of Burkina Faso: Boucle du Mouhoun, Center-West, South-West, Center-South, East. The interventions include the creation of conservation areas and sylvo-pastoral zones, afforestation, reforestation, fencing, drilling wells and training on good management practices (stone and soil walls, support natural regeneration). Under LANDMARC, the research will focus on selected geographic areas and interventions.

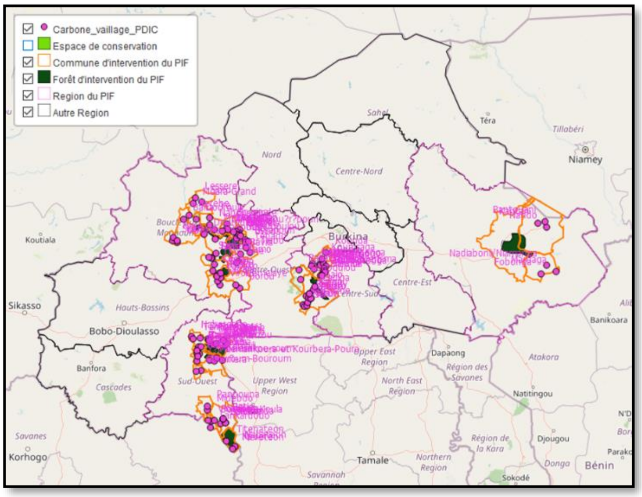

Figure 1: Overview of the PIF interventions in Burkina Faso (source: www.pif-burkina.org)

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What LANDMARC offers

LANDMARC supports the monitoring and evaluation of the FIP investments targeting carbon storage in vegetation and negative carbon emissions and provides local stakeholders with satellite-based observations:

1. **Measuring:** LANDMARC will provide spatial and temporal information on vegetation growth and carbon intake by deriving satellite-based Net Primary Production (NPP). The NPP is one of the parameters describing carbon fluxes between an ecosystem and the atmosphere and is expressed in grams of carbon absorbed and converted to biomass per m^2. Optionally, information on water consumption (via the Evapotranspiration (ET)) can also be delivered to the local partners. The goal is to map the before and after an intervention situation using satellite data. NPP and ET will be calculated from eLEAF's energy balance ETlook model together with open access high-resolution satellite imagery and meteorological data. From the NPP, the model to estimate carbon storage in vegetation and related negative CO_2 emissions will be further developed and assessed. Upon successful results of the method, it will be used as a tool to monitor the conservation and restoration efforts of the selected FIP practices and compare vegetation status in areas with and without intervention.

2. **Scaling:** The potential and barriers of scaling-up the selected FIP interventions on the sub-national/national level will be evaluated using land-use models and considering various scenarios. Projections will be made regarding the change that can be expected from the newly implemented land-use practice under different scenarios

Figure 2: Reforestation and conservation are the main land-use mitigation techniques implemented through the FIP in Burkina Faso. Above are examples of such interventions in the commune of Sapouy: plantation maintenance (left), marker showing the boundaries of the conservation area (right, source: WB FIP project team)

Section I - Additional information

Burkina Faso is a Sahelian country whose economy is mainly based on agriculture. Due to limited resources and demographic growth, the population faces severe poverty challenges and environmental degradation. This concerns above all the rural communities who depends heavily on the natural resources for their livelihoods (charcoal, sale of forest products). While the country needs agriculture for its economic growth, past and current practices involving continuous expansion of agricultural land and overexploitation of the natural forest resources are not sustainable. In view of these challenges, the WB FIP Decentralized Forest and Woodland Management project was designed to promote: the potential of multi-use dryland for carbon sequestration; sustainable forest management practices to ensure climate change resilience while improving rural life conditions. The communal development interventions (PDIC/REDD+) under this FIP project were officially launched in July 2018 and are aimed to end in December 2020. Other similar projects aligned with FIP and the REDD+ strategy will take place in 2022 and will be included in the LANDMARC research as well.

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Eddy Covariance (EC) flux measurements in South Africa

CS8-Calibrate and validate satellite-based estimates of carbon sequestration

About the initiative

With this case study, the LANDMARC H2020 partners focus on further developing the methodology to estimate carbon sequestration and by doing so, better understanding the role that vegetation plays in carbon storage. The research is executed in a two-steps approach. First, in situ EC flux measurements are collected from expert scientists and used to calibrate and validate satellite-based estimations of energy balance and carbon fluxes. Second, the calibrated inputs are used to estimate carbon sequestration in vegetation for larger areas.

Focus Area

Eddy covariance towers are in situ instruments measuring turbulent fluxes at the surface of the Earth. In this project, flux measurements obtained by expert scientists at different locations of South Africa are used as field/reference data to calibrate and validate satellite-based estimates. Supported by local scientists, LANDMARC will use measurements of EC towers located in areas with different land use: natural vegetation (Karoo semi-desertic vegetation, arid savannas, woody areas), rangeland, and agricultural lands (orchards).

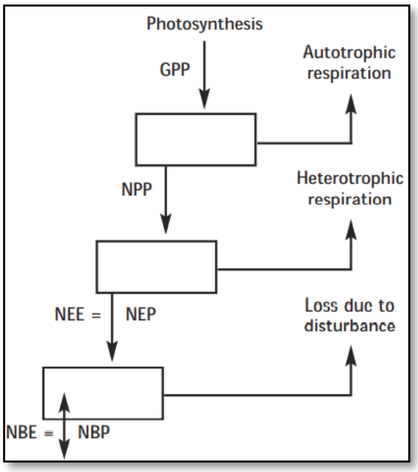

Figure 1: Eddy covariance system used to estimate energy balance fluxes (left); main processes in ecosystem carbon balance (Kirschbaum, M. U. F., et al., 2001) (right)

What LANDMARC offers

LANDMARC offers the opportunity to improve the current tools to model carbon fluxes and exchange between vegetation and the atmosphere and to develop a robust methodology to estimate carbon sequestration by plants.

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1. **ETLook:** The role of vegetation in carbon sequestration will be calibrated and validated by comparing EC flux measurements with satellite Earth Observation (EO) estimates. The satellite-based data is acquired and processed at eLEAF using (among others) the eLEAF ETLook energy balance model. ETLook is an algorithm making use of the Penman-Monteith equation together with meteorological data and remote sensing imagery to model the exchange of energy fluxes at the surface of the Earth. In this project, ETLook will be used to compute the Net Primary Production (NPP), one of the parameters describing the amount of carbon dioxide converted into biomass through photosynthesis. While EO-based models such as ETLook are an efficient way to simulate carbon fluxes between vegetation and atmosphere spatially and temporally, they require proper parametrization. In situ flux measurements from EC towers are an important tool for calibration and validation. As CO_2 measurements from EC towers, NPP and medium-term carbon storage in vegetation describe different components of the ecosystem carbon dynamics, they will need to be linked. In this project, the acquired data will therefore be developed into a prototype model to improve EO-based NPP and use it to estimate long term carbon sequestration. If the prototype is operational, it will be assessed and tested upon the Land-use Mitigation Techniques of other case studies (e.g., interventions of the World Bank Forest Investment Program (FIP) in Burkina Faso).

2. **Sentinel 5P TROPOMI:** The in-situ data gathered in the frame of this case study will also offer the opportunity to further establish the link between land-use change and two different observations from the TROPOMI (TROPOspheric Monitoring Instrument) instrument aboard the Copernicus Sentinel-5 Precursor:
    - Solar-induced chlorophyll fluorescence (SIF) observations: SIF is an electromagnetic signal representing the photosynthetic activity. It can be used to estimate the Gross Primary Production (GPP) of ecosystems at the Earth surface (ESA-TROPOSIF project).
    - Formaldehyde (HCHO) observations: HCHO is a tropospheric gas that can be used as a proxy for volatile organic compounds (VOC) emissions from vegetation.

    In case of land-use change, we'd expect (1) a carbon uptake, (2) a strong SIF signal where previously there was none, and (3) enhanced HCHO columns where previously there was only background HCHO levels.

Section I - Additional information

Definitions of relevant components of the carbon balance [expressed in gC/m^2]:

Gross Primary Production (GPP)

The GPP refers to the total amount of carbon fixed in the process of photosynthesis by plants in an ecosystem.

Net Primary Production (NPP) or short-term carbon uptake

The NPP represents the amount of carbon dioxide converted into biomass through photosynthesis (or GPP) minus the carbon dioxide released through autotrophic respiration. NPP does not account for the carbon transferred to the soil for heterotrophic respiration and is therefore not a good measure of net carbon storage.

Net Ecosystem Production (NEP) (Net Ecosystem Exchange (NEE)) or medium-term carbon uptake

The NEP is defined as the NPP minus the carbon losses due to soil heterotrophic respiration. NEP and NEE are often used interchangeably. NEE is the net CO_2 flux from the ecosystem to the atmosphere, usually referred to when measured by the EC towers (mounted with an infra-red gas analyzer). NEE is defined as the inverse of NEP when disregarding other sources and sinks than organic carbon.

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Integrated soil fertility management (ISFM)

CS9- Large-scale potential to improve soil carbon storage and reduce soil N_2O emissions in Kenya

Photo credit Johan Six (ETH, Switzerland)

About the initiative

Together with relevant stakeholders, including the International Institute of Tropical Agriculture (IITA) and partners from the LANDMARC H2020 research project on land-based negative emission solutions, we will explore the long-term and large-scale potential and limitations of Integrated Soil Fertility Management (ISFM) to provide sufficient and economically viable crop production and to mitigate soil GHG emissions through enhanced soil carbon storage and reduction of soil N_2O emissions in Kenya. Ecosystem, land use and economic modelling research complemented with stakeholder engagement activities will be implemented in the 2021-24 period.

Additional information - Integrated soil fertility management (ISFM)

Integrated Soil Fertility Management combines agronomic practices that include the use of mineral fertilizer, organic inputs, and improved germplasm combined with the knowledge on how to adapt these practices to local conditions with the aim of maximizing the agronomic use efficiency of applied nutrients and increased crop productivity, and thus profitability for smallholder farming systems (i.e., achieving a sustainable intensification). ISFM pursues that all inputs are managed following sound agronomic practices and promotes the use of:

a) Locally available organic resources such as crop residues, manure, compost and other types of organic wastes, rotation or intercropping with legumes;
b) Nitrogen, phosphorus and potassium mineral fertilizers and practices that enhance nutrient uptake such as micro-dosing, deep placement, banding, and harmonizing of inputs with rainfall and nutrient demands;
c) An improved germplasm (involves the selection of early maturing and drought tolerant varieties, spacing and harmonizing of planting time with rainfall predictions);
d) Liming to address soil acidity;
e) Inputs of sulphur, calcium, zinc and other nutrients to counteract nutrient deficiencies;
f) Deep tillage to resolve soil compaction;
g) Pesticides or herbicides to combat severe insect and weed infestations.

ISFM can lead to short and long term increases in crop productivity, enhanced stability of yields under adverse rainfall oscillations, increased input use efficiency and profitability of food production as related to use of land, labour, fertilizer inputs and financial investments and therefore can lead to major improvements of livelihoods. Combining mineral fertilizers and organic inputs provides conservation and build-up of soil carbon stock and reduction in soil greenhouse gas emissions due to a greater uptake of nitrogen fertilizers by crops and soil carbon sequestration. ISFM practices are designed to limit soil nutrient depletion and thus have the potential to reduce deforestation.

Despite the potential significant benefits of ISFM for food security, household income and environmental protection, the adoption of practices by farmers is usually low and incomplete, especially in African smallholder systems, due to high costs of inputs (i.e., improved varieties and mineral fertilizers require a significant investment), scarcity of organic residues and competition for residues with livestock, and low awareness about the benefits of ISFM.

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Focus Area

The long-term ISFM experiment was established at four research farms with continuous maize (*Zea mays*) in 2002 in central Kenya (Embu and Machanga) and 2005 in western Kenya (Sidada and Aludeka). The experiment has a randomized complete block design set up in a split-plot arrangement with three factors: a) quantity (main plot) and b) quantity of organic resources (main plot), and c) quantity of N mineral fertilizer (subplot). The organic resources are incorporated at the beginning of the long rain season in two different quantities (1.2 vs 4.0 t C ha^{-1} yr^{-1}) in combination with mineral N fertilization at 0 vs. 120 kg N ha^{-1} yr^{-1}. Five types of organic resources, classified in quality classes according to their lignin-, phenol- and N-content, are used: *Tithonia diversifolia* (class I), *Calliandra calothyrsus* (class II), *Zea mays* stover (class III), *Grevillea robusta* sawdust (class IV) and farm-yard manure of local quality. Research management and regular data collection (yields, soil properties) on a plot level allowed the development of a long-term dataset spanning 30-36 growing seasons. The experiment is aligned with a network of farmers and local stakeholders, which will provide a valuable asset for the LANDMARC project.

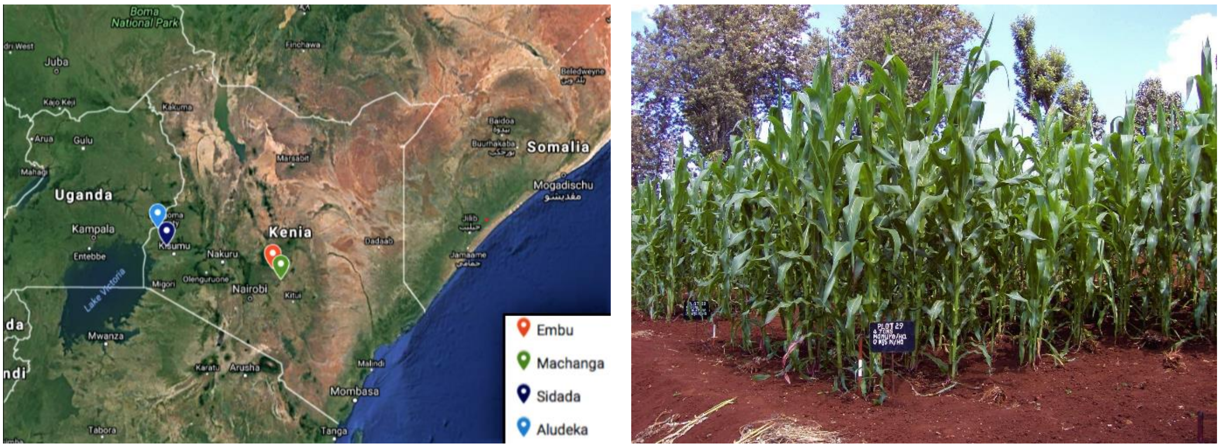

Figure 1: a) Location of the long term ISFM experiment in Kenya and b) a photograph from the experiment in Embu. Photo credit Johan Six (ETH, Switzerland)

What LANDMARC offers

LANDMARC complements the ongoing work on ISFM practices in Kenya through:

1. **Complementary data collection:** A human systems data for ISFM (i.e., local contextual data, socio-economic data such as costs, markets, policies, social acceptance, land use competition) will be collected through reviews of scientific literature, local/national databases, survey tools and stakeholder workshops.
2. **Assessment of climate vulnerability/risk and potential effectiveness of the large-scale implementation of ISFM:** A climate risk and sensitivity analysis of ISFM in Kenya will be performed based on stakeholder knowledge, locally available data and by analysing the results from the Coupled Model Intercomparison Project, phase 6.
3. **Ecosystem and socio-economic impact assessment of ISFM**: A qualitative and quantitative exploratory assessment of potential co-benefits and trade-offs related to nationwide scaling-up of ISFM will be performed through the stakeholder engagement and by employing ecosystem (DayCent), land-use (ALCES, LandSHIFT) and macro-economic (E3ME) simulation models across the medium to long term. The outcomes of these analyses will have implications for the national climate change mitigation policy strategy development.

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BECCS

CS10-Bio-energy generation using Willow crops from reclaimed open pit mine land in Alberta, Canada

About the initiative

The primary focus of this case study is to evaluate bio-energy generation using biomass crops from reclaimed mine land. Carbon capture, utilization, and storage will be assessed as carbon emission reduction strategies while economic models will be explored as opportunities for local communities in support of a just transition in Alberta and Canada. In close collaboration with stakeholders from various sectors (mining, agricultural, energy supply, transportation, manufacturing, and indigenous communities), this study will use a combination of stakeholder engagement and modelling tools to estimate its emission reduction potential, scalability, as well as socio-economic and policy innovation opportunities. The research activities performed within 2020-2024 are expected to contribute to the development of environmentally responsible economic activities capable of supporting vulnerable communities affected by the energy transition while supporting global sustainable development goals (SDGs).

Focus Area

Within the Canadian Bioenergy with Carb

on Capture and Storage (BECCS) project, we will be focusing on the energy conversion, distribution, and use of downstream biomass crop from willow plantation farm to reclaim abandoned mine lands in Alberta (Figure 1). Various biomass processing and transformation technologies will be evaluated based on best market potential, environmental performance, and community recognition. Life-cycle carbon emissions will be estimated along with the exploration of business opportunities for local communities. The carbon sink capacity of the biomass (Salix) plantation and land management will be considered from project partners and literature data. Climate risks and socioeconomic barriers will be studied as factors affecting the feasibility and scalability of such an approach. Existing and new policy mixes will be evaluated to identify regulatory opportunities to accelerate deployment.

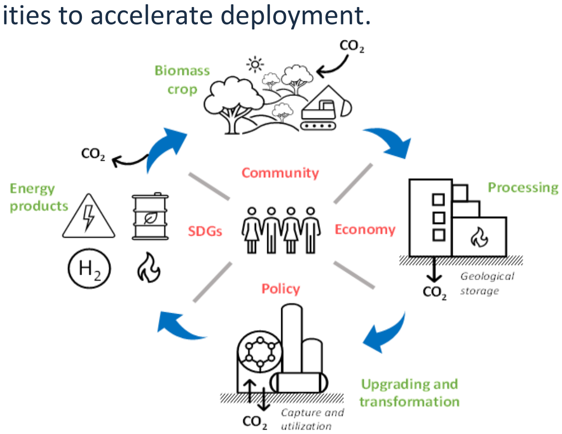

Figure 1. Overview of Canada BECCS project focused on processing, transformation and use of bioenergy crops from reclaimed mine land in Alberta.

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What LANDMARC offers

LANDMARC complements the ongoing work on BECCS in Canada through:

1. **Mapping and Modelling:** Deploying various tools (Figure 2) that can be potentially applied such as earth observation (satellite methods), LCA, land-use modelling, and socio-economic evaluation technologies/methods that will lead to a better assessment of carbon storage, reduction of GHG emission and socio-economic potential of BECCS.
2. **Business potential:** Understanding stakeholder priorities and business culture in the region and identifying areas for new business potential. Also, identifying priority areas and multi-sector economic success opportunities (Figure 1). We will also emphasize the potential relevant environmental, social, and economic costs and benefits on carbon emission trading and restoration of critically disturbed land. Key project partners/stakeholders including governmental and private organizations will contribute to our diversification of stakeholder portfolio to provide insights and information of technological and business research and development and impacts on local community among social, economic and environmental perspectives.
3. **Climate adaptation:** Assessing the impact and vulnerability of land restoration on forest fires, floods, and biodiversity. Besides, potential climate risks will be assessed along with socioeconomic exposure of local communities to further changes in the ecosystem and dominant economic activities.
4. **Scaling up good practices:** Since mining activities and land degradation occur across Canada and many countries, scaleup potential will be pursued by land use and economic simulation models. Trade-offs including biodiversity, land restoration, socio-economic benefits, GHG emissions, will be analyzed. Among the trade-off's assessment, the relation of forest fire risk and prevention with agroforestry may have continental and transcontinental implication from potentially synergetic findings with other LANDMARC case studies (e.g. South America, Australia) to increase our global scalability.

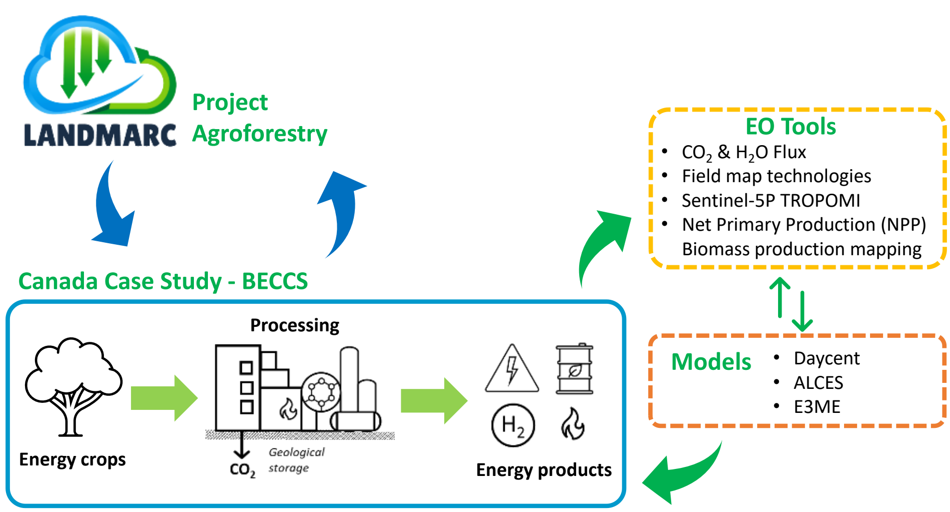

Figure 2. Overview of LANDMARC project focusing on the Canada BECCS case study and its matching EO tools and models.

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BIOCHAR for carbon sequestration

CS11-Deployment, innovation and upscaling in Europe and East Africa

Overview

Biochar offers a stable and persistent form of carbon, produced from pyrolysis (thermochemical treatment at high temperature and anaerobic conditions). It is a key land-based mitigation technology (LMT) because of its wide applicability and high global potential for both carbon sequestration and emission reductions. By offering a wealth of applications that contribute to numerous ecological functions and multiple sustainable development goals, low and high-income countries alike are considering biochar as part of their strategies. Biochar is among the most cross-cutting and cross-sectoral of all negative emission technologies (NETs), as it can include multiple components and application options across a wide variety of deployment and implementation schemes.

During the past decade or so, biochar has been intensively researched and a variety of pilot tests have been undertaken across many applications. The record suggests that in addition to its direct climate benefit as a carbon sink, biochar can be used in agriculture in other profitable and beneficial ways. Biochar can help to increase yields, promote humus formation, increase the water storage capacity of soils (thus raising their resistance to drought) and reduce GHG emissions from methane and nitrous oxide as well as reducing nitrate leaching. **Figure 3** provides a schematic of the main impacts.

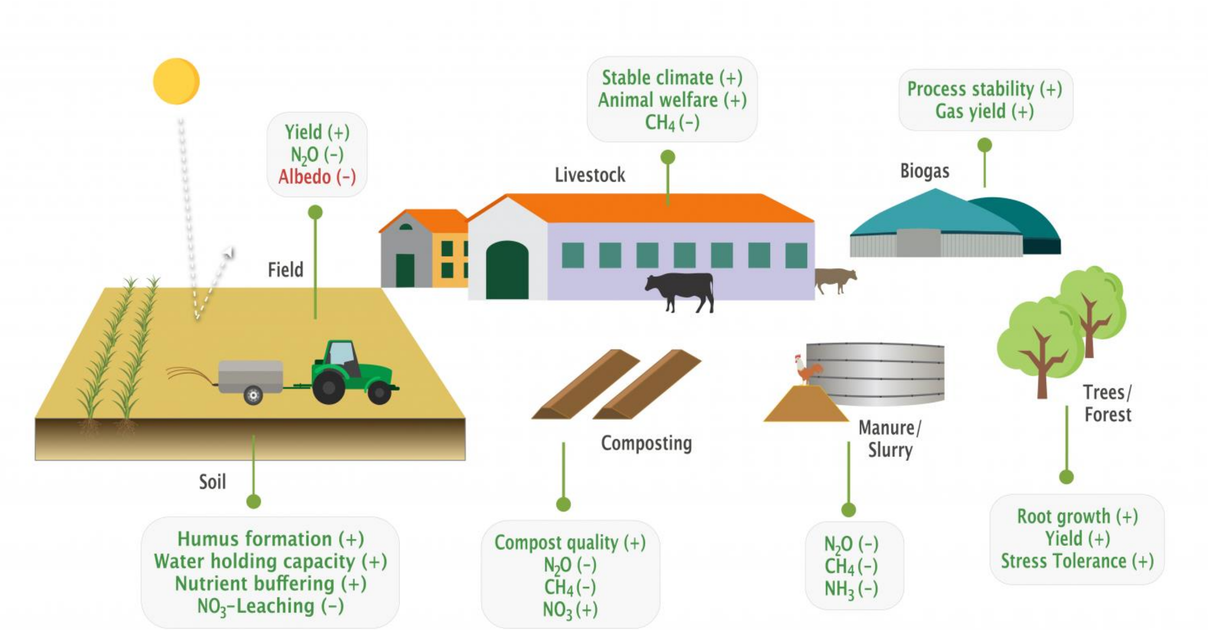

Figure 3: Biochar impacts in agricultural systems generally fall across seven categories: Soil/Field, Livestock, Energy (Biogas), Composting, Fertiliser (Slurry) and Forests (trees). Ecological and climate impacts are shown as decreasing or increasing; only one impact (albedo) is likely to be negative (in red). ***Source: EBI, 2020 [1].***

Stockholm Biochar Project

An innovative project in Stockholm (Sweden) exhibits the cross-cutting and cross-sectoral nature of biochar application [2]. Farm and garden wastes are gathered to provide biomass for conversion into gas and biochar through pyrolysis. The gas is used within the city's district heating system while the biochar is used to sequester carbon, enhance tree-planting, and provide soil benefits for farmers. In addition to the climate and ecological benefits [3], the project has also suggested innovative and

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complementary partnerships between urban and rural areas. There is considerable interest in the approach for cities elsewhere in the EU and a replication manual was developed for this purpose. There is a voluntary European Biochar Certification system for quality assurance to promote best practice.

Biochar in East Africa

Biochar has benefits that are potentially even greater in tropical climates and soils, where increased yields and other benefits add to the proven carbon sequestration and climate mitigation benefits. However, unlike northern Europe, it is more difficult to find applications or demand for pyrolytic gas, and therefore one approach to the biochar innovation system has been to rely on household-scale gasifiers that can be used for household cooking while the biochar is used by local farmers. Consequently, scaling up biochar use faces significant transaction costs as well as logistical barriers. The possibility of deploying larger-scale systems could reduce these transaction costs as well as offering more cost-effective biochar production. The African-EU partnerships on energy and agriculture offer some opportunities for technology transfer to support upscaling options while at the same time the specific applications chosen can benefit from outscaling across different geographies.

The LANDMARC platform

This dual case study in Europe and East Africa complements national case studies conducted within LANDMARC by looking at upscaling of biochar from the perspectives of trans-national replication and cross-regional learning. Replication of biochar applications can occur from one metropolitan region or one sub-national region to another and may also occur from the process of *outscaling*, in which innovation systems evolve through improvements in deployment, implementation and governance. Unlike economies-of-scale that depend on a greater volume, biochar as a multi-sector measure also requires experimentation across different logistical, biophysical, and economic conditions.

Stakeholder engagement is critical in ensuring the success of biochar upscaling and outscaling. The case study will operate especially at the regional level in Europe and East Africa through engagement with stakeholders across the biochar value chain. Representatives from a variety of African, European, and international stakeholders will be consulted, such as the International Biochar Initiative, Africa Biochar Partnership, Stockholm Exergi, the World Agro-forestry Centre, and the European Biochar Industry Consortium. Cross-regional learning on biochar has been emphasised by the recently completed GEF/UNEP project conducted in six countries across Africa, Asia, and Latin America [4].

Regional Potential

The regional potential in Europe and East Africa will be investigated through the use of a qualitative meta-analysis and expert consultation that will facilitate consideration of deployment and implementation constraints based on the heterogeneity of biochar applications. The results will then be used in conjunction with the E3ME modelling platform to compare biochar measures to other LMTs in a regional context and will also provide input to global scenario analyses.

References and Links

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[4] B4SS project: https://biochar.international/.

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CS12-INDONESIAN CASE STUDY

Decarbonisation from Compost and Biogas

Background

Together with local and national stakeholders, including support and contribution from BMKG and BAPPENAS, the LANDMARC H2020 Research Project on Land-based negative emission solutions will explore the potential of carbon storage through biogas and compost in Bali and Bajawa (NTT), Indonesia. A series of data collection, stakeholders' engagement, and LMT (Land-use Mitigation Technology) assessment will be implemented in the 2020-2024 period.

Focus area

Indonesia case studies will be focusing on biogas and compost (Figure 1). Biogas promotes firewood reduction, animal and food waste management, and bio-slurry as organic fertilizer. Also, compost will provide safe waste management and essential nutrients from organic fertilizer. Biogas will capture carbon from the anaerobic process and compost will contribute to carbon sequestration from associated plant growth and compost application. Both biogas and compost will mitigate emission production.

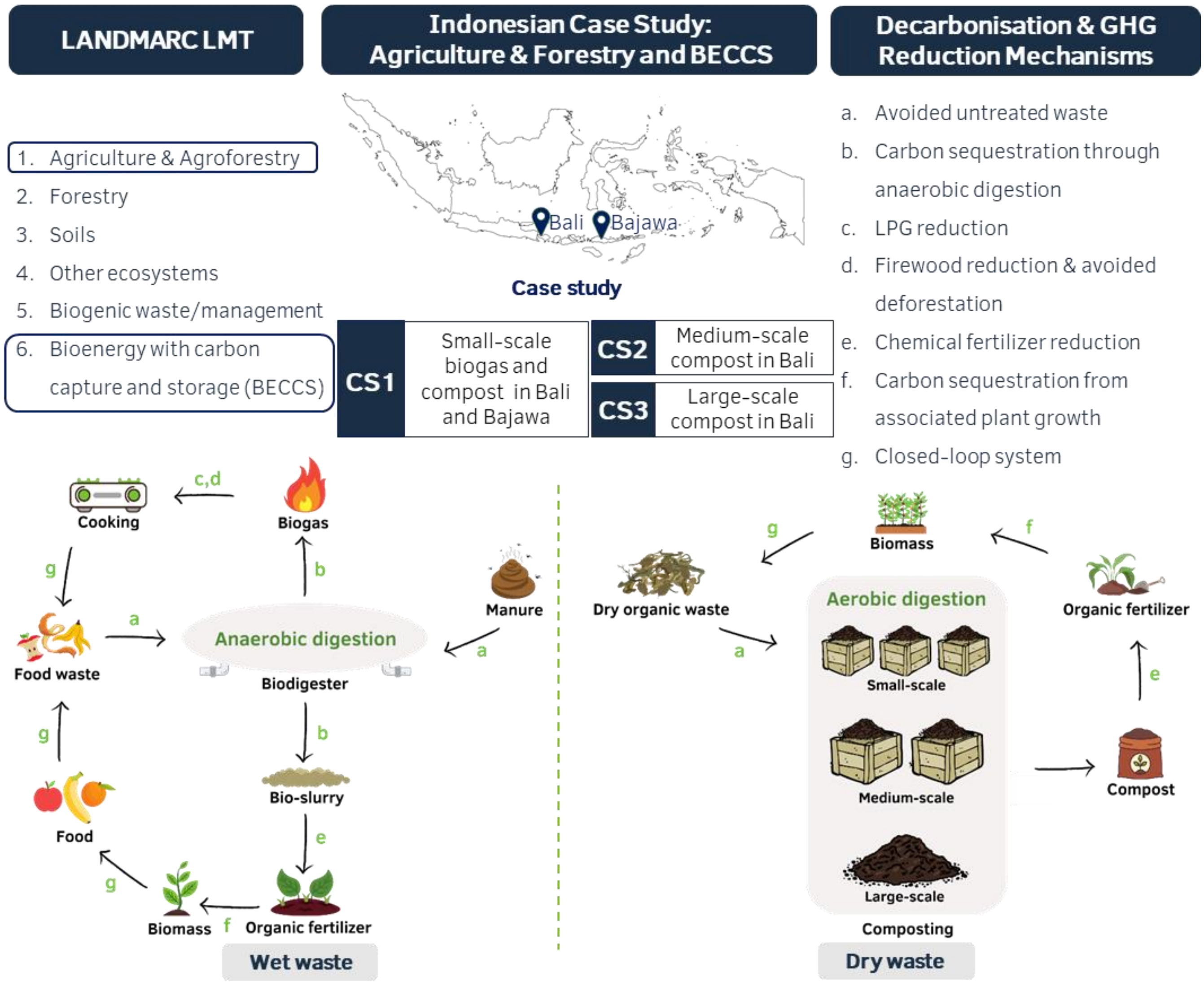

Figure 1. Overview of the LANDMARC project, focusing on biogas and compost in Indonesia as one of the case studies. Indonesia will provide data collection, in-situ observation, modelling, remote sensing techniques, and qualitative climate risk assessment to evaluate decarbonisation and climate change mitigation in collaborative with partners & stakeholders.

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Data and methods

Biogas and compost users will get direct benefits to users and the environment, such as decarbonisation, alternative energy, organic fertilizer, and waste management. A set of data collection, modelling, and qualitative assessment will assess this potential LMT at the local and national level.

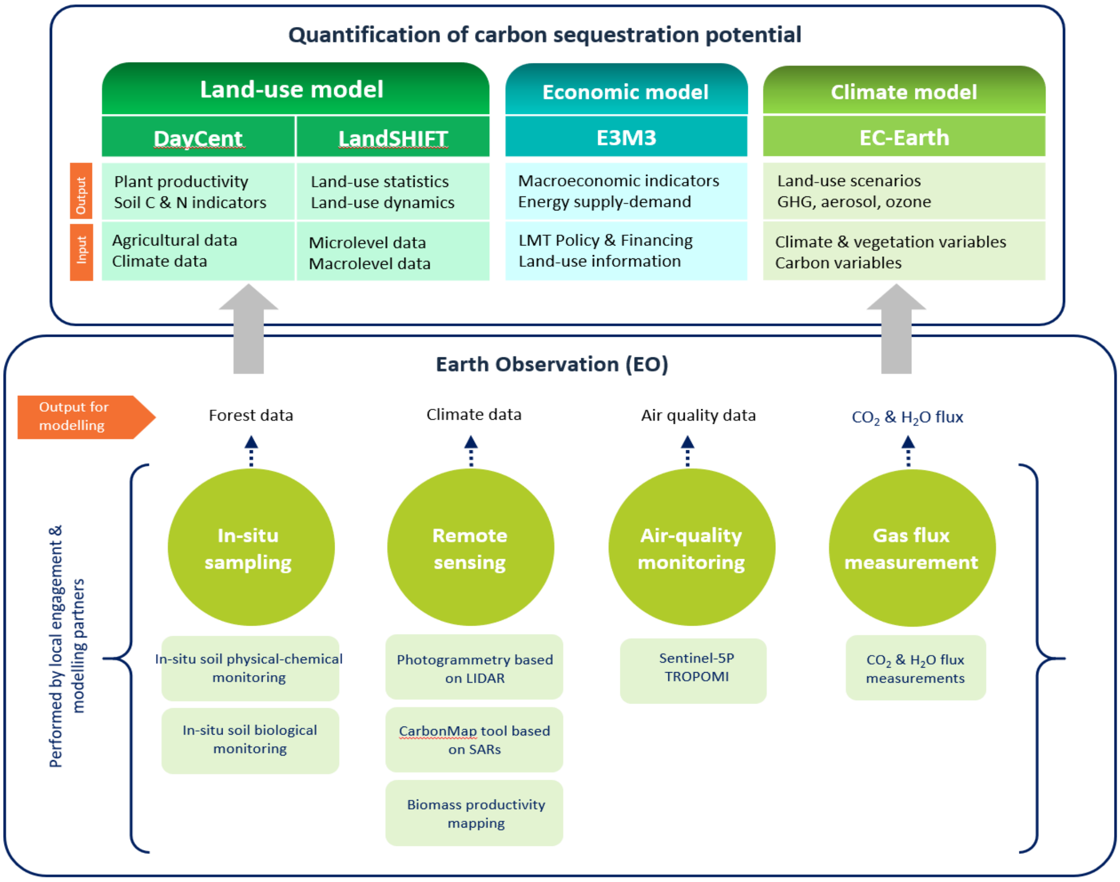

Figure 2. Overview of LANDMARC modellings on earth observation, land use, economic, and climate

What LANDMARC offers

1. Implementation

The socio-economic and environmental benefits of biogas and compost for rural Indonesia communities are the savings gained from reducing reliance on fossil fuel and organic fertilizer as well as adding value to the farming products.

2. Measuring

There is a set of data collection and modelling to assess soil biological and physical, carbon mapping, land use, and climate to assess potential decarbonisation from biogas and compost, including implementation on agricultural land.

3. Business

We are developing our business model to be a biogas and blockchain system. Assessment of decarbonisation and potential land-use mitigation technology from biogas and compost will help to improve the system. Thus, farmers and users will get more benefits by selling carbon captured to the carbon offset market.

4. Scaling

Assessing potential co-benefits, trade-offs, and climate assessment from LMT at the national level will be conducted. Also, policy strategies of local and national stakeholders will be assessed.

About su-re.co

Established in 2015, **su-re.co** is a young environmental think-do-be-tank, based in Bali, Indonesia. su-re.co works on climate change, energy, and circular business and synergy.

Role in the project: su-re.co is responsible for managing, organizing, and coordinating stakeholder engagement events within Indonesia on WP2. Also, collecting and providing complementary data at the local and regional level if necessary. WP4 involvement relates to conducting a qualitative climate vulnerability assessment in Indonesia case study. Within WP7, su-re.co's task is to create (inter)national LMT learning and dissemination, including international publications and science-policy workshop with Indonesian policy makers.

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AGROFORESTRY

CS13-Evaluation and monitoring of carbon sequestration capacity and degraded agricultural lands reforestation program in Extremadura, Spain (1993-2008) and synergies with other social challenges including depopulation and masculinisation of rural areas.

About the initiative

Between 1993 and 2008, the Agrarian Degraded Land Reforestation Program was executed in Extremadura, Spain, which consisted of the reforestation of abandoned agricultural lands or those with very poor economic productivity. This meant, therefore, the change of use from agricultural to forestry of these lands, more than 70,000 hectares. After several years of that experience, LANDMARC wants to focus its research on the inventory and monitoring of some of these farms, and the evaluation of the potential of these lands which, apart from other ecosystem benefits, have the advantage of storing carbon in biomass and soil above the pre-program values.

Focus Area

With the support of the Forest Service of the Regional Government of Extremadura, three representative farms of the Agrarian Degraded Land Reforestation Program will be evaluated. To this end, meetings are held with the regional Administration, and the farms are chosen which, due to their special characteristics, both in the afforestation and subsequent maintenance work, have led to a successful implementation of the measures.

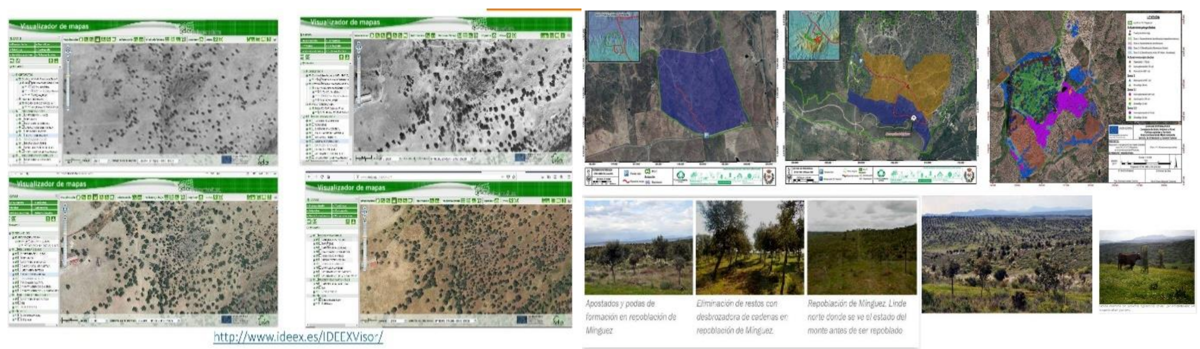

Figure 1: Cartographic and photogrammetric compilation of different years to evaluate the evolution of the forest mass, which will allow an analysis of the growth of the trees and will translate into carbon sequestration values. There is an extensive administrative, technical, cartographic and photographic documentation of several years to make an evaluation and monitoring of precise effectiveness in time and space.

Once the farms have been selected, all the technical, administrative and economic documentation of the files related to the Program is compiled. Likewise, the cartographic documentation is compiled and organized and a Geographic Information System is elaborated where all the shapefiles necessary for the monitoring, evaluation and analysis of the evolution in time of the pilot farms are stored.

The works also combine a compilation of coverage and analysis on georeferenced information from remote sensing and LIDAR mapping, taken in different years, to assess the growth of the forest mass. It is complemented with field measurements and monitoring with in situ forest technologies (Field Map and drones) for the inventory of trees and shrubs, and of all current forest vegetation, biodiversity indices are estimated, and the entire existing forest mass is characterized. This allows validation of satellite monitoring and comparison with current and previous orthophotos and maps. Along with the

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initial edaphological documentation and the soil maps, new soil samples are extracted and analyzed to evaluate the edaphological variables of organic matter, carbon and nitrogen, among others.

What LANDMARC offers

LANDMARC complements the ongoing work on agroforestry in Extremadura (Spain) through:

1. **Measuring:** The work focuses on the monitoring and evaluation of the carbon stored in the forest mass and the soil by these pilot farms in recent years. This ecosystem service is also an added value that can be valued in addition to soil conservation, improvement of biodiversity indices, or the fight against erosion and desertification. The application of new technologies for this monitoring will improve the accuracy of the measurements and reduce the costs of the inventory of natural resources. New inventory and measurement methodologies are designed that combine in situ measurements with remote sensing analyzes.

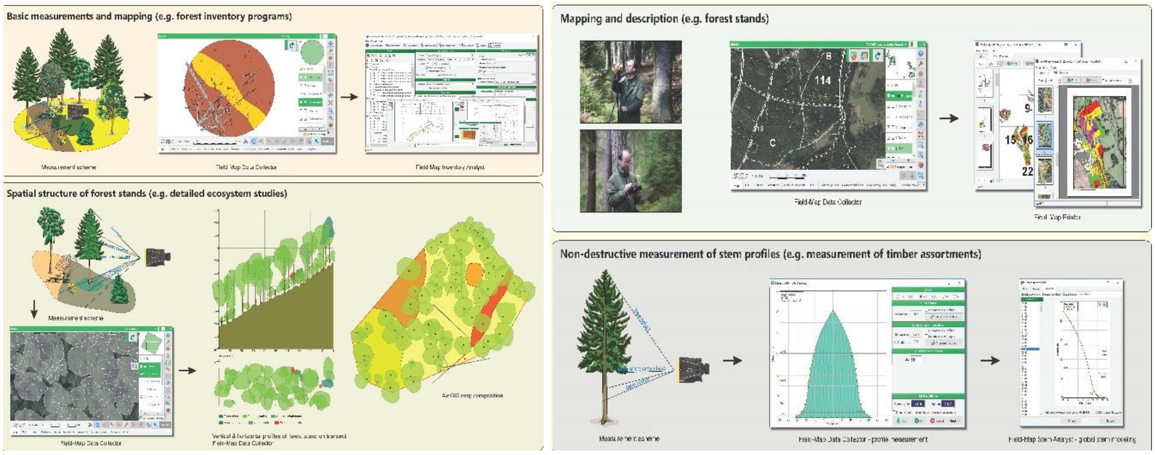

Figure 2: System for computer-aided field data collection. The use of new technologies for the forest inventory in situ (Field Map), with objectives of carbon measurement in the forest mass, and indicators of biodiversity, together with remote sensing techniques, are key to improving precision, reducing costs and the expansion of the territories to be evaluated, and therefore the expected impact**.**

2. **Business:** Monetization and the economic value of ecosystem services continues to be a challenge. There are opportunities in the mitigation potential of degraded lands that are transformed into forest lands with high levels of biodiversity. New technologies, and technology consulting services, are also employment niches and new lines of business that can attract young and female talent to rural areas.
3. **Adaptation:** Reforestation of degraded agricultural lands is a real and viable solution in many territories in which the advance of desertification, erosion, or the loss of biodiversity are problems that are exacerbated by climate change. They are very degraded lands whose adaptation to the climate goes through correct territorial planning that considers ecological, economic, social and climatic variables. The direct and indirect benefits in terms of ecosystem services are multiple and must be evaluated.
4. **Scaling:** Scalability in Mediterranean degraded agricultural areas in South of Europe and North of Africa. Lined with new CAP objectives.

Section I - Additional information. Many of Europe's rural regions have serious depopulation and masculinization problems. In the towns of Extremadura, where there are vast degraded agricultural territories, the social problem has a negative influence on the conservation of resources. Drought, desertification and forest fires are compounded by the loss of young people of working age who migrate to urban areas. Forest restoration, and new technologies, offer opportunities to attract youth and female talent to these areas, in the form of new jobs that offer solutions to urban societies.

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SUSTAINABLE COFFEE AGROFORESTRY

CS14-Increasing carbon storage in soils and trees and decreasing emissions from fertilizer use and deforestation in coffee landscapes of Vietnam

About the initiative

The Central Highlands of Vietnam is the biggest Robusta coffee producer in the world with approx. 600,000 hectares of coffee, predominantly produced in high-input monoculture systems. Sustainable farming practices in combination with intercropping and agroforestry systems have received increased interest leading to substantial efforts by an interdisciplinary consortium of national and international partners to design sustainable farming systems. The LANDMARC H2020 research project on land-based negative emissions solutions will explore the potential of these farming system practices to store carbon in soils and trees while reducing emissions.

Focus area

The activities are conducted in three districts of the Central Highlands: Krong Nang in Dak Lak, Dak Song in Dak Nong and Dak Doa in Gia Lai. The benefits of a combination of soil remediation techniques (liming and biochar application), bio inoculants, good farming practices and associated multipurpose trees (i.e. fruits, timber, nitrogen-fixing) are assessed in 5-10 experimental trials per district. Value chain approaches and policies are explored that facilitate the adoption of improved practices at scale, while landscape approaches are evaluated that reconcile sustainability at farm and landscape level.

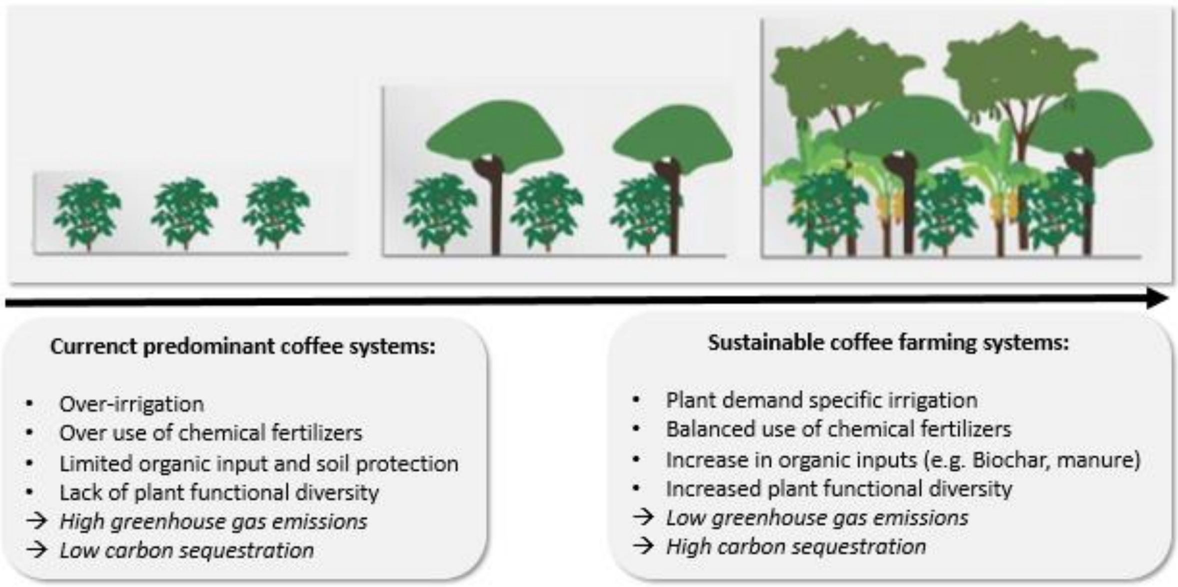

Figure 1: Land-use transition pathways in Robusta coffee areas of Vietnam. Association of coffee with multipurpose trees, soil remediation techniques (i.e. biochar) and good farming practices.

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What LANDMARC offers

LANDMARC will add value to existing activities in coffee landscapes of the Central Highlands in Vietnam by:

1. **Assessing LMT potential:** The feasibility of the land-based mitigation technologies (LMTs), i.e. scaling of agroforestry and biochar, will be assessed with stakeholders to identify barriers to adoption and conducive enabling environments. Together with stakeholders, we will co-develop scenarios that exemplify plausible scaling pathways. Based on the identified pathways the carbon sequestration potential will be modelled.
2. **Climate risk assessment:** Climate change-related increase in temperature, changing precipitation patterns and increasing frequency of climate extremes is threatening coffee production globally. Agroforestry systems are not only an important LMT strategy but also key in adapting coffee to changes in climate. Trade-offs and synergies between climate change adaptation and mitigation will be modelled for different future climate scenarios to inform different pathways of climate-resilient coffee and related LMTs. Together with local stakeholders, this will enable the development of climate risk management plans.
3. **Regional and global scaling:** Identifying LMT portfolios and assessing their potential at national, continental and global scales will be done together with various stakeholders and through alignment with regional and global initiatives and developments. Integration of scenario construction efforts from multiple scales will be used and the LMTs of the Vietnamese case study contextualized within a broader assessment.

Agroforestry

Current coffee agroforestry systems reach up to 25 Mg C ha-1 in above-ground vegetation. About 2/3 of the coffee system of the 600,000 ha coffee are monocropping systems. Therefore, there is substantial potential for carbon storage above- and below ground. Various coffee practices including agroforestry have been included in Vietnam's Intended Nationally Determined Contributions

Biochar in the Vietnamese coffee sector

Biochar quality depends on the feedstock and pyrolysis protocol. There are different biochars available from artisanal to industrialized technology at the cooperative level. For example, a low-cost pyrolysis technology is used at the Binh Minh cooperative and implemented by the Vietnamese Viet Hien Mechanical Company. Currently, coffee husk is used as feedstock and the produced heat is used for drying coffee cherries. The biochar can then be used to remedy soil acidification, improve soil water holding capacity and soil fertility and sequester carbon (2.45 ton CO_2/ton biochar). It can also be used for non-agricultural purposes. The main challenge for agricultural use, however, is that the amount of biochar needed to reach the desired soil pH level can be substantial, making it logistically challenging and economically unfeasible. Yet, depending on the size of the production facility and the price of carbon in the carbon market, carbon credits could subsidize a substantial part of the costs and make biochar an attractive soil enhancer.

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CS15-Improving farm resilience through sustainable rice production

The EU H2020 LANDMARC research project (2020-2024) is exploring the potential of land-use based mitigation technologies (LMTs) for sustainable rice production in Nepal. These technologies offer the potential of reduced emissions, sustainable soil management and improved well-being for farmers.

Challenges associated with conventional rice farming in Nepal

Rice is a staple crop in Nepal and accounts for half of the country's agricultural production area. It is a primary source of income and employment for about two-thirds of farming households and plays a critical role in the food and nutrition security of smallholder farmers. Multiple challenges are threatening the sustainability of small farms practising this form of rice cultivation, including:

- Water scarcity due to increasing uncertainty in the timing of the annual monsoon's onset.
- Labour shortages in the peak labour period, due to out-migration of adult males from the villages.
- High energy costs for farmers using pump irrigation to maintain standing water.
- The high cost of production, due to the conventional practice of raising rice seedlings in nurseries before being transplanted in the fields, after the soil is ploughed multiple times and puddled.
- Low yield related to declining soil fertility.

Figure 1 Rice cultivation in Nepal

The role of the project in addressing the challenges

We will explore appropriate pathways to sustainable rice production. We will investigate a range of mitigation options in rice farming, such as tillage, residue, fertilizer and water management, with a focus on no-till dry seeded rice technology. The proposed technology is based on the resource conservation principle, which involves sowing rice seeds directly in the field with the help of a tractor-drawn seed planter. Direct planting of seeds avoids costs associated with land preparation, nursery raised seedlings and transplanting of the seedlings. Besides, since the technology does not require standing water in the early stages of rice cultivation, both water requirements and methane emissions are reduced. The no-till method contributes to the sustainable management of soil by improving the soil structure, reducing erosion and increasing soil carbon.

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Our study area is located in Nepal's Sunsari and Morang districts. In these pilot areas, participatory field demonstrations will be established to compare no-till dry seeded rice technology with traditional rice production. We will monitor the rice crop and soil in the demonstration plots, using various methods, including soil microbial analysis, carbon mapping and satellite data. This will improve our understanding of the ability of these mitigation technologies to reduce greenhouse gas emissions from rice cultivation, and also explore their carbon sequestration potential (see Figure 2).

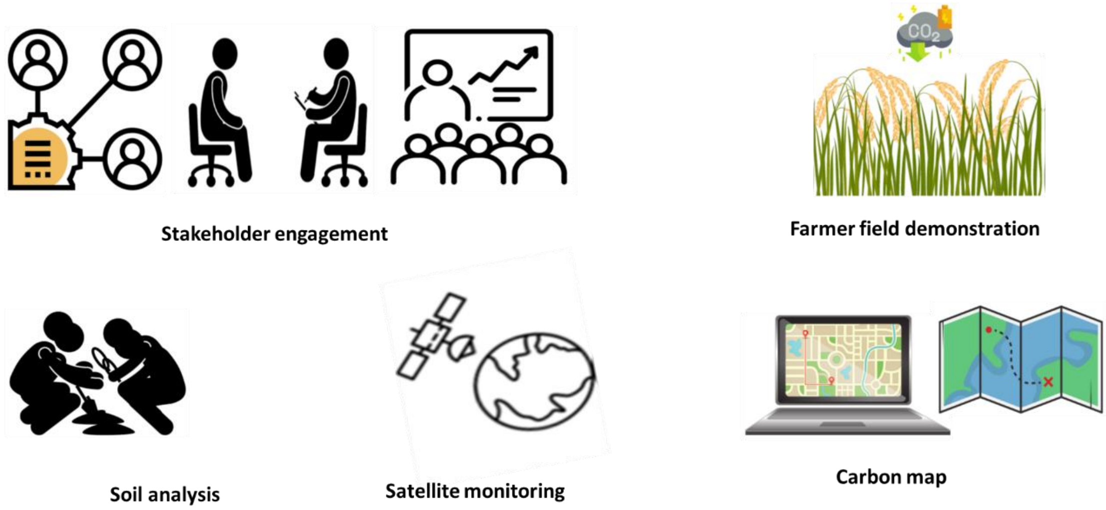

Figure 2: Overview of Nepal rice case study activities

Project outcomes

1. Environmental and technical impacts: Improving soil fertility and reducing emissions

We will investigate the potential for mitigation technologies in rice cultivation and explore pathways for scaling up these technologies at the sub-national and national level. Our findings will help identify ways to make rice farming more environmentally sustainable, by managing soil fertility and reducing emissions.

2. Economic impacts: Improving the economic sustainability of farms

We explore the potential role of mitigation technologies in reducing production costs associated with land preparation and water requirements, without affecting farm yield. Farmers can improve farm productivity and soil fertility, whilst also avoiding erosion and depletion of nutrients. Increased income through productivity improvements will have ripple effects on household well-being, for both current and future generations.

3. Social impacts: Cooperation, knowledge sharing and exchange

New knowledge and skills will be shared and co-produced with farmer groups and cooperatives, through workshops, training and knowledge exchange events. The application of mitigation technologies that require new machinery needs cooperation amongst farmers. This will further foster mutual trust and cooperation in agrarian societies.

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PASTURES

CS16-Pastures for carbon and biodiversity - Business model(s)

About the initiative

Dryland pastures of the Mediterranean region (Montado, in Portugal and Dehesa, in Spain), with about 8 914 000 ha, occupy low fertility soils and are the main source of animal feed in extensive animal production systems. These two countries could achieve significant soil CO_2 sequestration rates with a 1% increase in soil organic matter in 50% of the permanent pastures. This way, 134 million tons of CO_2 could be captured into the soil. The increase of soil organic matter can occur through very simple practices available to any farmer, such as i) soil pH correction (pasture soils have normally low pH values); ii) soil nutrients correction (pasture soils normally have a low nutrient concentration); iii) pasture species biodiversity correction (balance between legumes and grasses); and iv) water management availability in the growing season. Between 2021 and 2024, a series of research and engagement activities with farmers will be implemented.

Focus Area

In the LANDMARC project, the delineation of the Montado/Dehesa pasture management zones will be constituted by some pilot farms in Portugal and Spain (Figure 1). At these pilot farms, in some particular management zones, soil/grass samples will be collected. In addition to field data, Remote Sensing (RS) data obtained from Sentinel-1 and Sentinel-2 imagery will be used to monitor pasture quality and support farm management decisions. These data will allow the development of differentiated prescription maps for fertilizers with variable application rate technology by capturing the variability of soil characteristics and pasture development, contributing to the sustainability of this ecosystem. This work will be geared toward LANDMARC of actions for the development and promotion of pastures business models and development of pasture transition roadmaps and toolkits for farmers and policymakers.

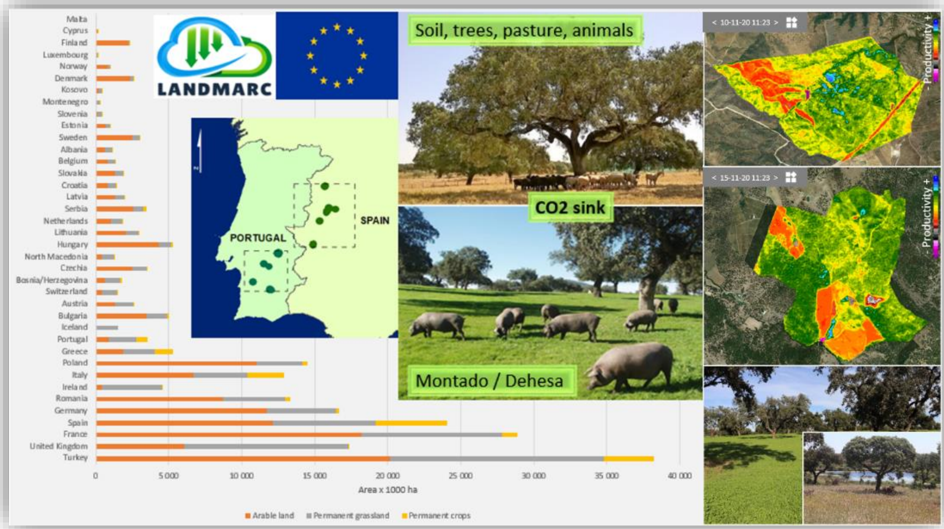

Figure 1. Montado/Dehesa pastures pilot farms in Portugal and Spain of Landmarc project.

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What LANDMARC offers

LANDMARC complements the ongoing work on Montado/Dehesa pastures in Portugal and Spain through (Figure 2):

1. **Measuring:** The work will focus on smart sampling strategies of soil/grass in particular management zones of the pilot farms based on field and RS data. The implementation plan consists of doing experiments with farmers, such as i) delineate management zones; ii) collect soil/grass samples; iii) use RS time-series satellite data to calculate pasture productivity and pasture water stress; iv) delineate small plots to apply pH and/or plants diversity correction; v) measuring yield differences between corrected and not corrected plots and comparing the differences in terms of biomass production (CO_2 potential sink) and plants diversity.
2. **Business:** With low soil inputs correction, biomass production can be tripled, and soil organic matter can rapidly grow in the soil. Improving the balance between legumes and grasses in the pasture, the technology will reduce nitrogen fertilization and promote floristic biodiversity to pollinators. Regarding business, a farmer can increase each year by 0.1% of organic matter in the soil (pasture) by sinking approximately 3 ton of CO_2/ha. If the price of 1 ton of CO_2 in the market reaches 50 €, a farmer can make 150 €/ha per year.

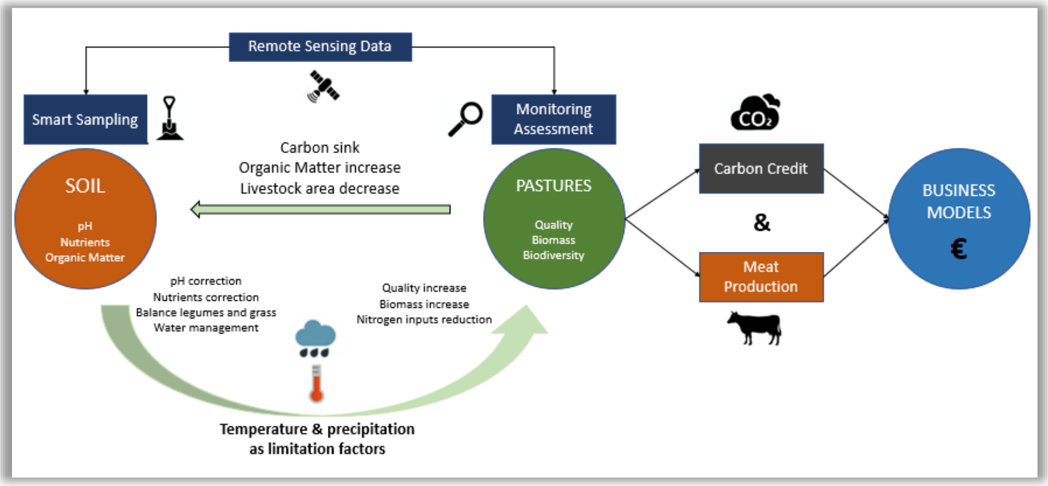

Figure 2. Technologies for monitoring soil, pasture and animals in the Montado/Dehesa systems and respective business model(s).

3. **Adaptation:** Fertilization and soil correction will be applied to improve soil fertility and, consequently, productivity/quality of pastures. Pastures biodiversity will be assess using floristic composition patterns to monitor the recommended management practices (Section I).
4. **Scaling:** Performing this work model on a European scale, an increase of 1% of soil organic matter in 50% of European permanent pastures will lead to the sequestration of 921 million tons of CO_2.

Section I - Additional information

Montado/Dehesa pastures are an agro-silvo-pastoral system characterized by a high complexity as a result of the interactions between climate, soil, pasture, trees, and animals. In this context, monitoring the pasture quality is a key element in the decision making process of a farm manager, since these pastures are the main source of animal feed in extensive animal production systems in Portugal and Spain. The important inter-annual variability of rainfall, characteristic of the Mediterranean region, places agricultural decision-makers in a scenario of great unpredictability regarding the availability of food for animals in an extensive regime. Montado/Dehesa pastures are generally established in low fertility and high spatial variability soils. Rational application of fertilizers requires knowledge of spatial variability of soil characteristics and crop response, which reinforces the interest of technologies that facilitates the identification of homogeneous management zones. Pasture nutritional value varies seasonally, annually, and with spatial location and is strongly related to species composition, namely abundance of legumes or grasses and overall plant diversity. Certain botanical species may even be biological indicators of ecosystem degradation situations, such as acid soils or manganese toxicity. The incorporation of Smart Agriculture technologies in the Montado/Dehesa ecosystem represents an important advancement in pasture and landscape management, carbon storage and biodiversity improvement.