# FarmBox

**The farmer's toolbox for climate change mitigation**

## O2-A2 Trainers' Guidelines

Co-funded by the Erasmus+ Programme of the European Union

Version History

| Version n° | Date | Description |
|---|---|---|
| v.0.1 | 17/04/2023 | First draft |
| v.1.0 | 27/04/2023 | First version |
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## 1. Introduction

Climate Smart Agriculture Simulator (CSA Simulator) is a Virtual Learning Environment (VLE) that aims to support projective simulations based on deterministic models. Its structure is strictly related to the contents and composition of the MOOC "Growing smarter for a greener tomorrow: FarmBox's MOOC on Climate Smart Agriculture" available on EduOpen. The Simulator, in fact, is designed to allow learners, small farmers and farmholders to simulate in a virtual environment the benefits of CSA measures presented in the MOOC.

The purpose of this document is to provide trainers with comprehensive guidelines on utilizing the Simulator for educational purposes. It offers a brief overview of the case study and presents a range of potential exercises that can be implemented. These guidelines aim to enhance the didactical experience and maximize the learning outcomes for trainers and students alike. By following this document, trainers will be equipped with valuable insights and practical tips to effectively utilize the Simulator as a powerful tool for interactive and engaging learning sessions.

## 2. Why using a CSA Simulator

The Simulator is a software component included in the project website and linked with the EduOpen platform that allows learners to simulate in a virtual environment the benefits of implementing the good practices presented in the course and is expected to improve the level of understanding and facilitate access to innovative agricultural education and solutions.

It is designed in a modular way so that the learning objectives can be achieved not only by motivated students who are willing to receive a well-rounded education, but also by those participants who have limited time or attention available.

There are several advantages in using simulation sessions in the training of agricultural students to learn about the impact of climate-smart agriculture on a test site:

- A simulation session provides a more immersive and engaging learning experience than traditional classroom-based training, allowing students to actively participate and observe the immediate impact of their actions.
- It can be conducted in a controlled environment, making it accessible to a wider range of students or young farmers who may not have access to real-world test sites.
- Moreover, it can be customized to meet the specific needs of the students or young farmers by simulating different environments, crops, and climate conditions, providing a broader understanding of the potential impacts of climate-smart agriculture.
- Additionally, a simulation session allows for risk-free experimentation, enabling students to try out different climate-smart agricultural practices on a test site without risking damage to crops or the environment, and it is cost-effective, eliminating the need for expensive field trials or equipment.

Moreover, simulation-based learning achieves several learning outcomes. For instance,

- promotes the development of critical thinking skills by allowing students to analyse and evaluate different situations.
- fosters teamwork and communication skills by allowing students to work together in a supportive environment.
- enhances problem-solving abilities by enabling students to identify problems and find solutions in a simulated environment.

## 3. Scenario explanation

Currently the Simulator hosts five learning scenarios that aligns with the five learning units of the Advanced course:

- Management of soil erosion in agricultural systems
- Sustainable farming
- Conservation agriculture for climate mitigation
- Biodiversity
- Precision farming

For each module, a description of the case study presented in the virtual simulation, including the objectives and desired learning outcomes is provided.

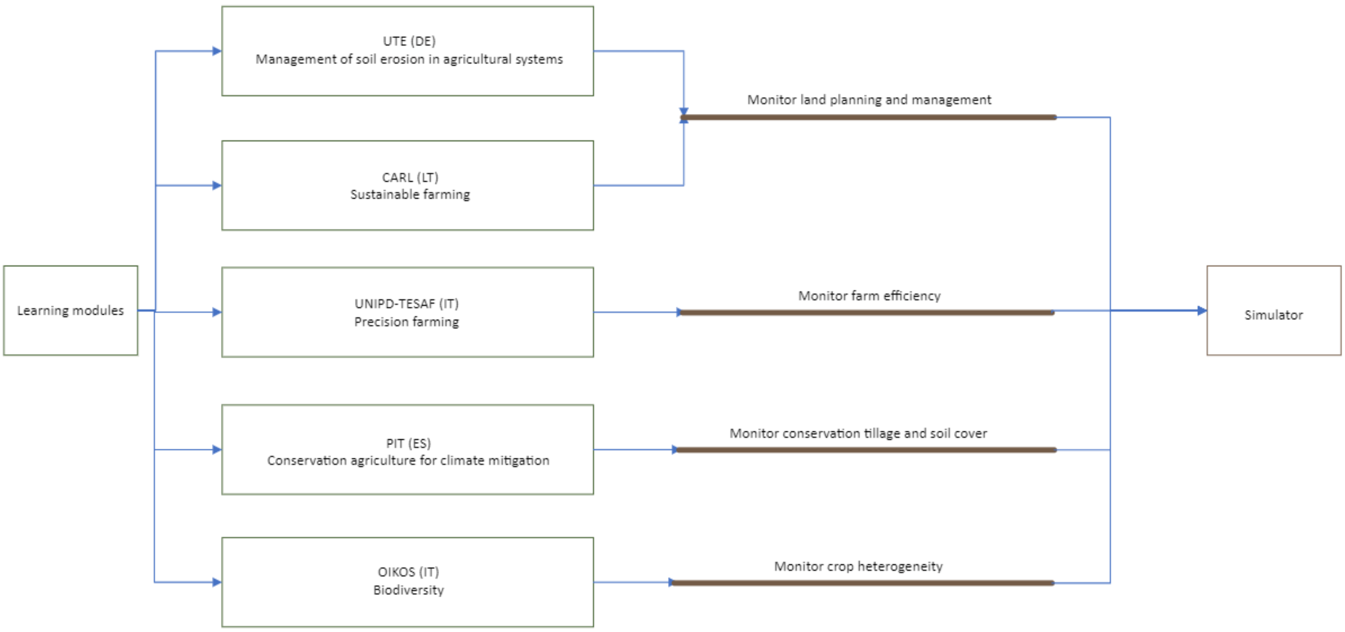


***Figure 1.*** *Connection between MOOC's learning modules and Simulator*

### 3.1 Management of soil erosion in agricultural systems

The course addresses the urgent need to mitigate soil erosion and increase organic matter content in agricultural systems, given the escalating challenges posed by climate change. By exploring the simulations within the CSA - Simulator, users will engage with the principles and techniques taught in the course, gaining hands-on experience in applying them within a virtual farming environment.

| Description Exercise 1 |
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| **Simulation title** | Simulation of the effects of good agricultural practices in vineyards on steeply sloping terrain. |
| **Simulation scope and learning outcomes** | The simulation, "Effects of good agricultural practices in vineyards on steeply sloping terrain," explores conservation tillage, cover crops, and contour farming.<br>Participants will learn the distinctions between these practices and their effects on soil erosion, organic matter content, and soil resilience. They will evaluate the suitability of each practice and gain practical knowledge for implementing them in vineyard settings. The simulation aims to equip learners with the ability to make informed decisions and apply effective strategies to combat soil erosion and promote soil health in vineyards. |
| **Coordinates of the simulation** | The simulation takes place in the Alzey-Worms district of Rhineland-Palatinate, specifically in the Alzey area. |
| **Variables and indexes involved** | The following variables are investigated in this simulation:<br>• Soil organic carbon (SOC): The simulation will explore the effects of different agricultural practices on SOC levels. SOC is an important indicator of soil health and fertility, and its variation can significantly affect soil resilience and overall agricultural productivity. By manipulating different practices, participants will observe changes in SOC and understand how they contribute to soil health.<br>• Soil erosion index: The simulation will also consider the soil erosion index, which measures the potential risk of soil erosion in a given area. This variable provides insight into the effectiveness of different practices in mitigating soil erosion on steep slopes.<br><br>By studying these variables in the simulation, learners will gain a comprehensive understanding of how different agricultural practices can affect SOC levels and soil erosion indices. |
| **Instructions to execute the simulation** | How to run the simulation<br><br>Simulation - Phase 1:<br>1. Open the Control Panel by clicking on the appropriate button.<br>2. Select the following parameters:<br>    1. Geographical identification:"Alzey, City", which corresponds to the specific geographical area.<br>    2. Level 1 Land Cover Classification: "Agricultural areas", which represents the initial land cover condition.<br>3. Initiate the simulation process by clicking on the "Run Simulation" button.<br><br>Simulation - Phase 2:<br>1. Refine the simulation for the previously selected geographical area and land cover type by managing the parameters in the Filter section.<br>2. Set the following parameters:<br>    1. Land Cover: "Vineyards".<br>    2. Agronomic practice: "Conservation tillage".<br>3. Use the filtering tools to evaluate the results of the simulation.<br>4. Examine the effects on variables such as SOC and Soil Erosion Index to understand the impact of the selected variables on the system.<br>5. Repeat the analysis session by changing the agronomic practice parameter first |

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| | to 'cover crops' and then to 'contour farming' (references to all these agronomic practices can be found in the Advanced MOOC *5.3 Impact of Land Cover on Soil Erosion* and *5.7 Measures to manage soil erosion*)<br>6. Repeat the examination of the effects on variables such as SOC and soil erosion index with each change in agronomic practice.<br><br>By following these steps, individuals can actively participate in the simulation, modify key variables such as agronomic practices, and observe the corresponding changes in the selected outcomes. This interactive approach will provide a deeper understanding of the effects of different variables on Soil erosion, SOC and overall soil resilience in steep slope vineyard systems. |
| **Feedback and explanation of the executed simulation** | The interactive simulation exercises helped participants understand the effects of different agronomic practices on soil erosion and soil health in steeply sloping vineyard systems. By manipulating the given variables, participants could see how changes in land cover and agricultural techniques could influence soil erosion and soil health indicators.<br>During the simulation, participants may have noticed that conservation tillage, when applied, had a positive effect on reducing soil erosion index (SEI) and a moderate effect on increasing soil organic carbon (SOC). This practice helps to minimize soil disturbance and retain organic matter, thereby reducing erosion and improving soil health.<br>In addition, the cover crop trials revealed another dimension of soil protection. The use of cover crops between rows of vines helps to stabilize the soil, reducing runoff and erosion. This practice often resulted in a moderate decrease in SEI and a consistent increase in SOC levels.<br>Finally, participants explored the effects of contour farming, an approach that involves planting crops along the contours of the slope. By implementing this practice, participants observed how it effectively combats soil erosion by slowing the flow of water, preventing gullies and promoting better water infiltration. As a result, contour farming showed a positive effect on reducing SEI and a moderate effect on improving SOC.<br>The varying impacts of these practices on SEI and SOC can be attributed to their distinct mechanisms and interactions with the vineyard system. Conservation tillage focuses on reducing soil disturbance and preserving organic matter, while cover crops and contour farming directly address erosion control. Each practice contributes to different aspects of soil health and erosion prevention, leading to diverse outcomes in terms of SEI reduction and SOC enhancement.<br>Cover crops are more efficient at sequestering $CO_2$ in the soil than conservation tillage or contour farming because they provide a continuous source of organic matter to the soil. They also add organic matter to the soil, which helps to improve soil structure and fertility. This organic matter can store carbon for long periods of time, helping to mitigate climate change.<br>By exploring these variables and observing the contrasting impacts, participants gained a deeper understanding of the importance of employing a combination of good agronomic practices in vineyard systems on steep slopes. The simulation exercises offered a valuable opportunity to explore these concepts in a controlled and interactive manner, aiding participants in making informed decisions regarding soil erosion management and promoting overall soil resilience.<br>Here are some additional details about the agronomic practices discussed in the |

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| | text:<br>• Conservation tillage: This is a type of farming that minimizes soil disturbance. It can be achieved by leaving crop residue on the soil after harvest, planting cover crops, or using other methods. Conservation tillage helps to reduce soil erosion and improve soil health.<br>• Cover crops: These are crops that are planted between cash crops. They help to protect the soil from erosion, improve water quality, and increase biodiversity. Cover crops also add organic matter to the soil, which helps to improve soil structure and fertility.<br>• Contour farming: This is a method of planting crops along the contours of the land. It helps to slow the flow of water, which can reduce soil erosion and improve water infiltration.<br><br>These are just a few of the agronomic practices that can be used to reduce soil erosion and improve soil health in vineyard systems. By using a combination of these practices, farmers can help to protect their land and ensure the long-term sustainability of their vineyards. |

| | **Description Exercise 2** |
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| **Simulation title** | Simulation of a distinct agronomic practice within an agricultural region exhibiting diverse land cover types. |
| **Simulation scope and learning outcomes** | The Intercropping Simulation Exercise assesses the impact of intercropping on soil erosion and soil organic matter content in specific land cover types.<br>Students monitor and analyze the growth and performance of intercropped crops in complex cultivation patterns, fruit trees and berry plantations, non-irrigated arable land, and vineyards. The exercise evaluates intercropping's effectiveness in reducing soil erosion and enhancing soil organic matter content across these land cover types. By incorporating these assessment elements, the simulation exercise provides a comprehensive understanding of intercropping's role in combating soil erosion, increasing soil organic matter, and promoting sustainable agricultural practices. |
| **Coordinates of the simulation** | The simulation takes place in the Mainz-Bingen district of Rhineland-Palatinate, specifically in the Bingen am Rhein area. |
| **Variables and indexes involved** | The following variables are investigated in this simulation:<br>• Soil organic carbon (SOC): The simulation will explore the effects of different agricultural practices on SOC levels. SOC is an important indicator of soil health and fertility, and its variation can significantly affect soil resilience and overall agricultural productivity. By manipulating different practices, participants will observe changes in SOC and understand how they contribute to soil health.<br>• Soil erosion index: The simulation will also consider the soil erosion index, which measures the potential risk of soil erosion in a given area. This variable provides insight into the effectiveness of different practices in mitigating soil erosion on steep slopes.<br><br>By studying these variables in simulation, students will gain a comprehensive |

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| | understanding of how specific agricultural practices affect soil organic carbon (SOC) levels and soil erosion indices differently depending on the type of land cover. |
| **Instructions to execute the simulation** | How to run the simulation<br><br>Simulation - Phase 1:<br>1. Open the Control Panel by clicking on the appropriate button.<br>2. Select the following parameters:<br>    1. Geographical identification: " Bingen am Rhein ", which corresponds to the specific geographical area.<br>    2. Level 1 Land Cover Classification: "Agricultural areas", which represents the initial land cover condition.<br>3. Initiate the simulation process by clicking on the "Run Simulation" button.<br><br>Simulation - Phase 2:<br>1. Refine the simulation for the previously selected geographical area and land cover type by managing the parameters in the Filter section.<br>2. Set the following parameters:<br>    1. Agronomic practice: "Intercropping".<br>    2. Land Cover: "Complex cultivation patterns"<br>3. Use the filtering tools to evaluate the results of the simulation.<br>4. Examine the effects on variables such as SOC and Soil Erosion Index to understand the impact of the selected variables on the system.<br>5. Repeat the analysis session by changing the land cover parameter to the following: fruit trees and berry plantations, non-irrigated arable land, and vineyards. (references to all these land cover and agronomic practices can be found in the Advanced MOOC *5.3 Impact of Land Cover on Soil Erosion* and *5.7 Measures to manage soil erosion*)<br>6. Repeat the examination of the effects on variables such as SOC and soil erosion index with each change in agronomic practice.<br><br>By following these steps, individuals can actively participate in the simulation, modify key variables such as agronomic practices, and observe the corresponding changes in the selected outcomes. This interactive approach will provide a deeper understanding of the effects of different variables on Soil erosion, SOC and overall soil resilience in steep slope vineyard systems. |
| **Feedback and explanation of the executed simulation** | Throughout Simulation - Phase 1 and Simulation - Phase 2, valuable insights have been gained regarding the impact of different variables on soil erosion, SOC (Soil Organic Carbon), and overall soil resilience. One significant finding from the simulation exercise indicates that intercropping performs better on land with permanent crops, specifically fruit trees and berry plantations, as well as vineyards, compared to land with complex cultivation patterns and non-irrigated arable land.<br>During Simulation - Phase 2, the effects of various land cover types, such as complex cultivation patterns and non-irrigated arable land, on soil erosion and SOC levels were explored. These land cover types often involve a higher degree of soil exposure, rendering them more susceptible to erosion. The absence of vegetation cover and intensive land use in these systems can result in increased soil erosion |

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| | rates and decreased SOC content.<br>In contrast, land with permanent crops like fruit trees and berry plantations, as well as vineyards, tends to exhibit improved performance when intercropping is implemented. Intercropping in these systems offers several advantages. Firstly, it enhances year-round soil coverage, reducing soil exposure and the risk of erosion. The presence of different crop species with diverse root structures and growth habits helps enhance soil structure, increasing its capacity to retain moisture and resist erosion.<br>Secondly, intercropping in land with permanent crops promotes better nutrient utilization and cycling. The range of crops optimizes resource usage by accessing nutrients at different soil depths and reducing nutrient leaching. This leads to improved soil fertility and increased SOC levels over time.<br>Lastly, intercropping in land with permanent crops contributes to pest and disease management. The crop diversity creates a more balanced ecological system, reducing the prevalence of specific pests and diseases that can adversely impact crop productivity.<br>By comparing the performance of intercropping in land with permanent crops to that in land with complex cultivation patterns and non-irrigated arable land, the significant benefits of intercropping in maintaining soil health and reducing erosion risks in permanent crop systems have been observed. This insight underscores the importance of implementing intercropping practices in such agricultural contexts, as it enhances soil resilience, improves nutrient cycling, and promotes sustainable land management practices.<br>Overall, this simulation exercise has provided a comprehensive understanding of the advantages of intercropping, particularly in land with permanent crops such as fruit trees and berry plantations, and vineyards. This knowledge enables informed decision-making and the implementation of effective measures to combat soil erosion, increase SOC content, and promote sustainable agricultural practices in various land cover types. |

## 3.2 Sustainable farming

The objective of this activity was to exemplify the application of multifunctional criteria risk analysis in evaluating the capacity for enhancing soil quality through the utilization of suitable quantities of protein crops. It aimed to showcase a modeling-based methodology for gauging the efficacy of various agronomic approaches in the enhancement of soil quality.

| | **Description Exercise 1** |
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| **Simulation title** | Evaluate the effectiveness of agronomic practices in increasing the amount of cover crops |
| **Simulation scope and learning outcomes** | The simulation will provide students with access to the Earth's surface and its topography, as well as to data on the area of protein crops declared in different regions of Lithuania, which are available in the databases of the Centre for Agricultural Information and Rural Business. The simulator uses geo-referenced |

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| | land cover databases, a digital elevation model and agronomic data from agronomic practices. The simulation will help students to understand the current state of the terrain and the associated farming practices and opportunities. It will also provide an insight into how agricultural practices can affect soil quality, as well as providing knowledge on ways in which data can be used to set priorities to improve farm sustainability. Finally, the simulation gives students the opportunity to explore and learn about the complexities of land features of soil and land conservation, helping them to become better informed and more responsible stewards of the Earth's soils. |
| **Coordinates of the simulation** | The region being tested is in Lithuania |
| **Variables and indexes involved** | The simulation includes a range of variables, including land cover, topography, morphology and agronomic practices.<br><br>• Land cover is a physical characteristic of the land and is usually determined by satellite imagery or aerial photography and is important understanding how land is used.<br>• Topography means the physical characteristics of the land, such as elevation, slope and landscape.<br>• Morphology is a measure of the shape and form of landforms, e.g. It is a measure of the shape of landforms, such as mountains and valleys.<br>• Agronomic practice refers to the various practices used to manage the land and its resources, e.g. Crop rotation, conservation tillage and cover crops.<br><br>All these variables are taken into account in the modelling in order to provide a comprehensive assessment of the impact of crop rotations using different protein crop species on soil quality in a given area. |
| **Instructions to execute the simulation** | The following describes how to run the simulation:<br>Step 1: Select a specific location on the map (using NUTS geographic data) based on factors such as topicality, land cover, topography.<br>Step 2: Enter the modelling parameters, including agricultural practices to be applied, and the percentage of protein crops.<br>Step 3: Run the simulation with the parameters.<br>Step 4: Compare the results before and after the simulation to observe the effect of the simulated agricultural practice of growing a certain percentage of protein crops on soil quality.<br>Step 5: Analyse the results and determine whether additional simulations are needed or whether changes to existing variables are required. |
| **Feedback and explanation of the executed simulation** | The aim of this activity was to show how multifunctional criteria risk analysis can be used to assess the potential for improving soil quality by applying appropriate amounts of protein crops, to demonstrate the use of a modelling-based approach to assess the effectiveness of different agronomic approaches in improving soil quality.<br><br>By manipulating variables in the simulator, participants were able to observe how specific agronomic practices affect soil quality and how different amounts of protein crops can change soil quality. |

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| | This exercise provided participants with a thorough understanding of the impact of crop rotations using appropriate amounts of protein crops on soil quality in a given region, as well as insights into the potential benefits of implementing agronomic practices to improve soil health and reduce soil damage. |

### 3.3 Conservation agriculture for climate mitigation

The simulation provides participants with a comprehensive understanding of the existing conditions of an area in relation to its potential for mitigating or adapting to climate change. It also familiarizes them with the impact of diverse agricultural activities on soil, while highlighting the significance of data utilization in prioritizing conservation initiatives. Ultimately, the simulation enables students to explore the intricate dynamics of land and soil conservation, empowering them to become informed and conscientious custodians of our planet's soil.

| | **Description Exercise 1** |
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| **Simulation title** | Evaluate the resilience of agricultural system in relation to slope and soil structure |
| **Simulation scope and learning outcomes** | The simulation will show the students the Earth`s surface so they can select an area to develop the simulation. Through its use of georeferenced land cover databases, a Digital Elevation Model, and agronomic practice data, the simulation will help them to comprehend the current state of an area in relation to its potential associated to mitigate or adapt to the climate change.<br><br>It will also introduce them to how different agricultural activities can affect the soil, while offering insight into the ways that data can be used to prioritize appropriate conservation efforts. Ultimately, the simulation allows students the opportunity to explore and learn about the complex nature of land and soil conservation, helping them to become better informed and more responsible stewards of the Earth's soil. |
| **Coordinates of the simulation** | The region being tested is located in Basque Country, Spain, and corresponds to the NUTS level 3 zone of Bizkaia. |
| **Variables and indexes involved** | The simulator involves, these variables:<br><br>• Tillage rate; it involves the mechanical manipulation of the soil for the purpose of crop production, and it affects significantly the soil characteristics such as soil water conservation, soil temperature, infiltration and evapotranspiration processes<br>• Ground cover: Crop residues are left on the soil surface, but cover crops may be necessary if the time interval between harvesting one crop and establishing the next is too long. Cover crops improve the stability of the conservation agriculture system, not only by improving soil properties, but |

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| | also by their ability to promote greater biodiversity in the agricultural ecosystem.<br>• Plant cycle: The life cycle of plants consists of germination, growth, reproduction and death. It is important for the soil that plants have long life cycles, since during this time, they keep the soil covered and protect it from processes that can increase soil erosion.<br><br>All of these variables are taken into account in the simulation to provide a comprehensive assessment of the soil adaptation to climate change. |
| **Instructions to execute the simulation** | In order to assess the impact of conservation tillage and soil coverage with crop residues on agriculture, it is necessary to evaluate the surface area affected by specific tillage practices in comparison to the total surface area affected by agricultural activities.<br><br>1. Choose a geographical area (utilizing NUTS geographical data) and a specific land cover classification<br>2. Execute the simulation with the designated parameters.<br>3. Visualize the tillage rate, soil cover with residues and affected area of agronomic practice.<br>4. Select "complex cultivation", "flat or moderate slope ", "east" and "south" exposure and "loam" soil structure.<br>5. Analyse the value of the tillage rate, soil cover with residues and affected area of agronomic practice.<br>6. Change the variables for slope and soil structure<br>7. Analyse the change on the tillage rate, soil cover with residues and affected area of agronomic practice.<br>8. Observe the impact of simulated agricultural practices on soil erosion. |
| **Feedback and explanation of the executed simulation** | The aim of this activity was to show how slope and soil structure can affect the potential of the land to mitigate or to be adapted to climate change.<br><br>By manipulating variables in the simulator, participants are able to observe how different soil properties can affect the soil resilience. |

| | **Description Exercise 2** |
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| **Simulation title** | Evaluate the resilience of agricultural system in relation to soil type |
| **Simulation scope and learning outcomes** | The simulation will show the students the Earth`s surface so they can select an area to develop the simulation. Through its use of georeferenced land cover databases, a Digital Elevation Model, and agronomic practice data, the simulation will help them to comprehend the current state of an area in relation to its potential associated to mitigate or adapt to the climate change.<br><br>It will also introduce them to how different agricultural activities can affect the soil, while offering insight into the ways that data can be used to prioritize appropriate |

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<tr><td></td><td>conservation efforts. Ultimately, the simulation allows students the opportunity to explore and learn about the complex nature of land and soil conservation, helping them to become better informed and more responsible stewards of the Earth's soil.</td></tr>
<tr><td>Coordinates of the simulation</td><td>The region being tested is located in Basque Country, Spain, and corresponds to the NUTS level 3 zone of Bizkaia.</td></tr>
<tr><td>Variables and indexes involved</td><td>The simulator involves, these variables:<br><ul><li>Tillage rate; it involves the mechanical manipulation of the soil for the purpose of crop production, and it affects significantly the soil characteristics such as soil water conservation, soil temperature, infiltration and evapotranspiration processes</li><li>Ground cover: Crop residues are left on the soil surface, but cover crops may be necessary if the time interval between harvesting one crop and establishing the next is too long. Cover crops improve the stability of the conservation agriculture system, not only by improving soil properties, but also by their ability to promote greater biodiversity in the agricultural ecosystem.</li><li>Plant cycle: The life cycle of plants consists of germination, growth, reproduction and death. It is important for the soil that plants have long life cycles, since during this time, they keep the soil covered and protect it from processes that can increase soil erosion.</li></ul>All of these variables are taken into account in the simulation to provide a comprehensive assessment of the soil adaptation to climate change.</td></tr>
<tr><td>Instructions to execute the simulation</td><td>In order to assess the impact of conservation tillage and soil coverage with crop residues on agriculture, it is necessary to evaluate the surface area affected by specific tillage practices in comparison to the total surface area affected by agricultural activities.<br><ol><li>Choose a geographical area (utilizing NUTS geographical data) and a specific land cover classification</li><li>Execute the simulation with the designated parameters.</li><li>Visualize the tillage rate, soil cover with residues and affected area of agronomic practice.</li><li>Select "complex cultivation", and any other parameters with results for the other variables.</li><li>Analyse the value of the tillage rate, soil cover with residues and affected area of agronomic practice.</li><li>Change the soil description maintaining the other parameters</li><li>Analyse the change on the tillage rate, soil cover with residues and affected area of agronomic practice.</li><li>Observe the impact of simulated agricultural practices on soil erosion.</li></ol></td></tr>
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| **Feedback and explanation of the executed simulation** | The aim of this activity was to show how soil type can be affected by other parameters in order to mitigate or to be adapted to climate change.<br><br>By manipulating variables in the simulator, participants are able to observe how different soil properties can affect the soil resilience. |

| | **Description Exercise 3** |
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| **Simulation title** | Evaluate the resilience of agricultural system in relation to soil exposure |
| **Simulation scope and learning outcomes** | The simulation will show the students the Earth`s surface so they can select an area to develop the simulation. Through its use of georeferenced land cover databases, a Digital Elevation Model, and agronomic practice data, the simulation will help them to comprehend the current state of an area in relation to its potential associated to mitigate or adapt to the climate change.<br><br>It will also introduce them to how different agricultural activities can affect the soil, while offering insight into the ways that data can be used to prioritize appropriate conservation efforts. Ultimately, the simulation allows students the opportunity to explore and learn about the complex nature of land and soil conservation, helping them to become better informed and more responsible stewards of the Earth's soil. |
| **Coordinates of the simulation** | The region being tested is located in Basque Country, Spain, and corresponds to the NUTS level 3 zone of Bizkaia. |
| **Variables and indexes involved** | The simulator involves, these variables:<br><br>• Tillage rate; it involves the mechanical manipulation of the soil for the purpose of crop production, and it affects significantly the soil characteristics such as soil water conservation, soil temperature, infiltration and evapotranspiration processes<br>• Ground cover: Crop residues are left on the soil surface, but cover crops may be necessary if the time interval between harvesting one crop and establishing the next is too long. Cover crops improve the stability of the conservation agriculture system, not only by improving soil properties, but also by their ability to promote greater biodiversity in the agricultural ecosystem.<br>• Plant cycle: The life cycle of plants consists of germination, growth, reproduction and death. It is important for the soil that plants have long life cycles, since during this time, they keep the soil covered and protect it from processes that can increase soil erosion.<br><br>All of these variables are taken into account in the simulation to provide a |

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| | comprehensive assessment of the soil adaptation to the climate change. |
| **Instructions to execute the simulation** | In order to assess the impact of conservation tillage and soil coverage with crop residues on agriculture, it is necessary to evaluate the surface area affected by specific tillage practices in comparison to the total surface area affected by agricultural activities.<br><br>1. Choose a geographical area (utilizing NUTS geographical data) and a specific land cover classification<br>2. Execute the simulation with the designated parameters.<br>3. Visualize the tillage rate, soil cover with residues and affected area of agronomic practice.<br>4. Select any parameters with results for the other variables.<br>5. Analyse the value of the tillage rate, soil cover with residues and affected area of agronomic practice.<br>6. Change the soil exposure maintaining the other parameters<br>7. Analyse the change on the tillage rate, soil cover with residues and affected area of agronomic practice.<br>8. Observe the impact of simulated agricultural practices on soil erosion. |
| **Feedback and explanation of the executed simulation** | The aim of this activity was to show how soil exposure can affect the potential of the land to mitigate or to be adapted to climate change.<br><br>By manipulating variables in the simulator, participants are able to observe how different soil properties can affect the soil resilience. |

### 3.4 Biodiversity

The purpose of this simulation is to understand the role of different agricultural and management practices to enhance biodiversity and ecosystem services. The promotion of crop heterogeneity and the presence of semi-natural habitats are the most useful practices to increase biodiversity in farmland, increasing useful ecosystem services such as pollination and natural pest control. By showing the effectiveness of these practices, this simulation will provide valuable information on how to best manage crops and non-crops elements to increase ecosystem services.

| | **Description Exercise 1** |
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| **Simulation title** | Effect of cover crops on farmland |
| **Simulation scope and learning outcomes** | Users are expected to understand the effect on farmland of the use of cover crops at different scales, times and species used. |

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| **Coordinates of the simulation** | The simulation takes place in the Pavia province. The area is largely cultivated and the predominant sectors are rice and wine production. The northern part of the province is located in the Po plain and the Po River crosses it from west to east, while other important rivers such as the Ticino and the Sesia flow from north to south to their confluence with the Po River. The southern part of the province is characterised by the Apennines and is thus mountainous.<br><br>Select a specific municipality to run the simulation. |
| **Variables and indexes involved** | The following variables/indexes are going to be investigated in this simulation:<br>-SOC refers to the organic matter present in soil, primarily derived from the decomposition of plant and animal materials.<br>-crop rotation index is a metric used in agriculture to measure the effectiveness and diversity of crop rotation practices. It quantifies the frequency and sequence in which different crops are grown on a particular piece of land over a defined period. A higher crop rotation index indicates a more varied and sustainable cropping system, which can enhance soil health, reduce pest and disease pressure, and optimize nutrient cycling.<br>-Shannon diversity index (SHDI) calculated at landscape scale. SHDI is a widely used metric in biodiversity and ecology and takes both the number of land cover classes and the abundance of each class into account. SHDI values increase as the number of different land cover types goes up and/or the proportional distribution of each vegetation type becomes more balanced. In Pavia Province SHDI varies from 0 to 1.3 and in general is higher around rivers and in the Apennine area.<br>-"Natural area index"; this is the distance between each point of the map and natural areas, namely forests and wetlands/water sources.<br>-"Natura 2000 index", which shows the distance between each point of the map and the Natura 2000 network of protected areas. |
| **Instructions to execute the simulation** | Before running the simulation users need to select a municipality, e.g. "Bereguardo".<br>Land cover, soil slope and soil texture for the area are presented.<br>1. Select "Cover crop" as Agronomic practice<br>2. Select the land cover type to run the simulation on (e.g. non-irrigated arable land)<br>3. In the "Cover crop index" select the % of the to manage with cover crops. Chose a range between 0 to 100%<br>4. Select cover crop duration, choosing between 4 options, from "no use of cover crops" to "perennial use of cover crops"<br>5. Select the number of botanical families to use in the cover crops, from 1 to more than 3 families.<br>6. Run the simulation and analyse the outcome<br>7. Repeat the simulation changing the parameters to see which combination gives a higher cover crop index. Reference to this agronomic practice can be found in the MOOC, Beginner course, in the lessons n. 3 and 5 of Unit 1 and lesson n. 7 Unit 4 in the Advanced course. |
| **Feedback and explanation of the executed** | The cover crops index varies from 0 to 3.65. The most important variable in building the cover crop index is the surface covered with cover crops. Of course, is necessary to find a balance between cover crop and productive surfaces.<br>The different management of cover crops has also an impact on SOC content, |

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| simulation | especially in different land cover context. |

| | Description Exercise 2 |
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| Simulation title | Effect of crop rotation on farmland |
| Simulation scope and learning outcomes | Users are expected to understand the effect on farmland of the use of crop rotation at different scales, times and species used. |
| Coordinates of the simulation | The simulation takes place in the Pavia province. The area is largely cultivated and the predominant sectors are rice and wine production. The northern part of the province is located in the Po plain and the Po River crosses it from west to east, while other important rivers such as the Ticino and the Sesia flow from north to south to their confluence with the Po River. The southern part of the province is characterised by the Apennines and is thus mountainous.<br><br>Users have to select a specific municipality to run the simulation. |
| Variables and indexes involved | The following variables/indexes are going to be investigated in this simulation:<br>-SOC refers to the organic matter present in soil, primarily derived from the decomposition of plant and animal materials.<br>-crop rotation index is a metric used in agriculture to measure the effectiveness and diversity of crop rotation practices. It quantifies the frequency and sequence in which different crops are grown on a particular piece of land over a defined period. A higher crop rotation index indicates a more varied and sustainable cropping system, which can enhance soil health, reduce pest and disease pressure, and optimize nutrient cycling.<br>-Shannon diversity index (SHDI) calculated at landscape scale. SHDI is a widely used metric in biodiversity and ecology and takes both the number of land cover classes and the abundance of each class into account. SHDI values increase as the number of different land cover types goes up and/or the proportional distribution of each vegetation type becomes more balanced. In Pavia Province SHDI varies from 0 to 1.3 and in general is higher around rivers and in the Apennine area.<br>-"Natural area index"; this is the distance between each point of the map and natural areas, namely forests and wetlands/water sources.<br>-"Natura 2000 index", which shows the distance between each point of the map and the Natura 2000 network of protected areas. |
| Instructions to execute the simulation | Before running the simulation users need to select a municipality, e.g. "Bereguardo".<br>Land cover, soil slope and soil texture for the area are presented.<br>1. Select "Crop rotation" as Agronomic practice<br>2. Select the land cover type to run the simulation on (e.g. non-irrigated arable land)<br>3. In the "Crop rotation index" select the % of the area to manage with crop |

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| | rotation. Chose a range between 0 to 100%<br>4. Select crop rotation function, choosing between 4 options. Here, choose how many global functions are present in the system in relation to the crops in the field (e.g Carbon sequestration, pollination, seed production,…). If a function is performed by more than one species, it will be counted more than once.<br>5. Run the simulation and analyse the outcome<br>6. Repeat the simulation changing the parameters to see which combination gives a higher cover crop index. Reference to this agronomic practice can be found in the MOOC, Beginner course, in the lessons n. 3 of Unit 1 and lesson n. 6 Unit 4 in the Advanced course. |
| **Feedback and explanation of the executed simulation** | The crop rotation index varies from 0 to 3.7. The most important variable in building the crop rotation index is the surface covered with cover crops.<br>The different management of crop rotation has also an impact on SOC content, especially in different land cover context. |

### 3.5 Precision farming

By utilizing the simulation, users can choose and implement farming techniques to enhance agricultural productivity. The simulation enables the analysis of collected data, facilitating an evaluation of the effects of precision agriculture on agricultural output. Users can explore the advantages of precision agriculture, including enhanced crop yields, variations in Soil Organic Carbon, efficient water management, and improved economic efficiency.

| | **Description Exercise 1** |
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| **Simulation title** | Evaluate the impact of agronomic practices on average cultivation costs |
| **Simulation scope and learning outcomes** | The simulation aims to assess the influence of different agronomic practices on average cultivation costs specifically in the province of Padua. By utilizing the simulation, users can explore and analyze the effects of various farming techniques on the financial aspects of farming in this region.<br><br>Participants can assess the economic implications of adopting farming practices. They can analyze the impact of different strategies on overall cultivation costs. This helps in understanding the potential benefits and challenges associated with implementing farming techniques and making informed business decisions. |
| **Coordinates of the simulation** | The simulation is based in province of Padua, Italy. |
| **Variables and indexes involved** | The simulation includes the following variables:<br><br>-Land cover is a physical characteristic of the land and is usually determined by |

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| | satellite imagery or aerial photography and is important understanding how land is used.<br><br>-Agronomic practice refers to the various practices used to manage the land and its resources, e.g. Crop rotation, conservation tillage and cover crops.<br><br>Two main indexes are going to be investigated:<br><br>-Average SOC content: refers to the average Soil Organic Carbon content in a given area or soil sample. Soil Organic Carbon (SOC) is the organic matter present in the soil, which includes decomposed plant and animal materials. It plays a crucial role in soil fertility, nutrient cycling, and carbon sequestration. Its change over time gives an indication of the Impact of agronomic practices on soil carbon sequestration.<br><br>-Average cost of using agronomic practices: refers to the average financial expenditure associated with implementing and applying various agronomic practices in agriculture.<br>It expresses the impact of agronomic practices on average cultivation costs per hectare.<br><br>-Crop yields refers to the amount of agricultural produce harvested per unit of land area. It is a measure of the quantity or volume of crops, such as grains, fruits, vegetables, or other cultivated plants, that are obtained from a specific area of land. |
| **Instructions to execute the simulation** | The following describes how to run the simulation:<br><br>Step 1: Select a specific location through the Base scenario<br>Step 2: Select that location and run the simulation<br>Step 3: Select one land cover and two agronomic practices<br>Step 4: Compare the results between the two agronomic practices<br>Step 5: Analyse the results and determine what is the best agronomic practice to achieve a win-win situation that contributes to increase SOC contents, does not implicate high farming cost and increases the crop yields. |
| **Feedback and explanation of the executed simulation** | Simulation incorporates the concept of precision agriculture, which involves the use of advanced technologies and data-driven approaches to optimise agricultural practices. By incorporating precision agriculture techniques, the simulation allows users to explore the benefits of targeted and precise interventions in agriculture.<br><br>Through simulation, users can select a specific agricultural area and apply precision farming methods to improve agricultural production.<br><br>The simulation offers the opportunity to analyse the data collected during the simulation and assess the impact of precision agriculture on agricultural production. Users can examine the benefits of precision agriculture in terms of increasing crop yields and improving economic efficiency.<br><br>By engaging in this simulation, participants can gain practical knowledge on the importance of precision farming in modern agriculture and the importance of |

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| | value for money in the adoption of advanced agronomic techniques, as presented in Unit 2 of the MOOC. |

| | Description Exercise 2 |
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| **Simulation title** | Evaluate the impact of agronomic practices on average cultivation costs |
| **Simulation scope and learning outcomes** | The simulation aims to assess the influence of different agronomic practices on average cultivation costs specifically in the province of Padua. By utilizing the simulation, users can explore and analyze the effects of various farming techniques on the financial aspects of farming in this region.<br><br>Participants can assess the economic implications of adopting farming practices. They can analyze the impact of different strategies on overall cultivation costs. This helps in understanding the potential benefits and challenges associated with implementing farming techniques and making informed business decisions. |
| **Coordinates of the simulation** | The simulation is based in province of Padua, Italy. |
| **Variables and indexes involved** | The simulation includes the following variables:<br><br>-Land cover is a physical characteristic of the land and is usually determined by satellite imagery or aerial photography and is important understanding how land is used.<br><br>-Agronomic practice refers to the various practices used to manage the land and its resources, e.g. Crop rotation, conservation tillage and cover crops.<br><br>Two main indexes are going to be investigated:<br><br>-Average SOC content: refers to the average Soil Organic Carbon content in a given area or soil sample. Soil Organic Carbon (SOC) is the organic matter present in the soil, which includes decomposed plant and animal materials. It plays a crucial role in soil fertility, nutrient cycling, and carbon sequestration. Its change over time gives an indication of the Impact of agronomic practices on soil carbon sequestration.<br><br>-Average cost of using agronomic practices: refers to the average financial expenditure associated with implementing and applying various agronomic practices in agriculture.<br>It expresses the impact of agronomic practices on average cultivation costs per hectare. |

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| | -Water consumption refers to the amount of water utilized for irrigation and other agricultural activities. It includes both the water applied directly to crops through irrigation systems and the water lost through evaporation and transpiration. |
| **Instructions to execute the simulation** | The following describes how to run the simulation:<br>Step 1: Choose a specific location using the Basic scenario.<br>Step 2: Select the chosen location and run the simulation.<br>Step 3: Choose one land cover and three agronomic practices.<br>Step 4: Compare the results between the three agronomic practices.<br>Step 5: Rank on a scale of 1-3 the results to determine the best agronomic practice to achieve a cost-benefit situation by increasing the SOC (Soil Organic Carbon) content, decreasing water consumption costs and reducing farming costs. |
| **Feedback and explanation of the executed simulation** | Simulation incorporates the concept of precision agriculture, which involves the use of advanced technologies and data-driven approaches to optimise agricultural practices. By incorporating precision agriculture techniques, the simulation allows users to explore the benefits of targeted and precise interventions in agriculture.<br><br>Through simulation, users can select a specific agricultural area and apply precision farming methods to improve agricultural production.<br><br>The simulation offers the opportunity to analyse the data collected during the simulation and assess the impact of precision agriculture on agricultural production. Users can examine the benefits of precision agriculture in terms of water efficiency and improving economic efficiency.<br><br>By engaging in this simulation, participants can gain practical knowledge on the importance of precision farming in modern agriculture and the importance of value for money in the adoption of advanced agronomic techniques, as presented in Unit 2 of the MOOC. |

## 4. Learning activities

Based on the piloting activities we have performed within the project; we suggest organizing a group learning activity. Here we suggest two learning activities.

### 4.1 Learning activity 1

In the first learning activity we suggest to and select one of the available scenarios of the Simulator.

We suggest the following steps:

1. Ask the learners to make research about the target area of the simulator or another area they prefer (e.g., topography, morphology, most common agricultural practices, agronomic or agricultural main issues etc.) and encourage them to present their findings. Creating a graphical info sheet can be helpful.

2. Facilitate a group discussion on the most appropriate agronomic practices for addressing the identified issue or achieving the simulation exercise's goal.
3. Prepare a lesson on these agronomic practices. Refer to the MOOC contents to take some materials. Encourage the learners to search on the Internet for additional interviews with farmers in the same areas or facing similar issues or, alternatively, invite farmers to engage in conversation with the learners.
5. Ask the learners to access the simulator's use case and examine the base scenario. Prompt them with questions such as: *"Do the information you found align with the base scenario?"*, *"What are the differences?"*, *"What are the similarities?".* If they worked on a different geographic location from the one offered by the Simulator ask them: *"What differences do you observe between the two base scenario?"*, *"What are the similarities?", "Do you expect that the same agronomic practices we analysed are going to work in this scenario?"*
6. Divide learners in small groups so that each of them can work on a specific administrative unit. Alternatively, they can be divided per land cover.
7. Have each group perform the simulation on their assigned area.
8. Organize a group discussion to assess the simulation results. Ask questions like: *"Were your assumptions about the best agricultural practice correct?", "What was different or unexpected?", "Why did you receive different results from other groups?", "Are there any practices in the simulator that you didn't consider but could yield better results?", "Are there any practices in the simulator that you didn't consider but could yield worse results?", "Did you consider any practices that are not available in the simulator?".*

### 4.2 Learning activity 1

In the second learning activity we suggest creating small groups so that each one can work on a different scenario among the available ones.

We suggest the following steps:

1. Ask the learners to make research about the target area of the simulator or another area they prefer (e.g., topography, morphology, most common agricultural practices, agronomic or agricultural main issues etc.).
2. Ask learners to identify the most suitable agronomic practices for addressing the identified issue or achieving the simulation exercise's goal.
3. Select relevant contents from the MOOC to support learners during the simulation. Additionally, encourage them to search on the Internet for interviews with farmers in the same areas or facing similar issues, or invite farmers to interact with the learners.
4. Ask the learners to access the simulator's use case and examine the base scenario.
5. Assign each group a specific administrative unit or land cover and instruct them to run three simulations.
6. Allow learners to perform the simulation on their assigned area and rank the best agronomic practices before and after the simulation.

7. Organize a group discussion to share simulation results. Ask each group to present: the target area, the scope of the simulation, the assumption they made, the results they received, why they received these results.
8. At the end of the group presentation and discussion, encourage a discussion on why certain practices yielded better results. By the end of the group presentation, aim to establish a final ranking of agronomic practices among the different scenarios and explore why they are considered the best. Also, encourage reflections on the integration of other aspects for farmers to be considered climate-smart. Ask *"Is there a final rank of agronomic practices?" "In order to be considered as climate-smart, what other aspects should a farmer integrate?"* .

# 5 Technical requirements

To ensure the simulation activity works smoothly we recommend:

- Planning the activity well in advance and accessing the simulator. You can download the users' instructions from the project website. They are also available in other languages (Italian, German, Spanish, Lithuanian) or you can watch this short tutorial.
- Having an adequate number of laptops to allow the users work on it.
- Ensuring each device has access to Mozilla Firefox, which is the recommended browser.
- Registering your users in advance. They can register by their own or you can register a group of people simply by sending an email to helpdesk@uptoearth.eu to request access for one or more scenarios. A list of email addresses of the users is going to be requested and accounts are going to be generated.
- Getting in touch with the project team (francesco.marinello@unipd.it) or Uptoearth's team (info@uptoearth.eu) to have further support and ensure a dedicated session.

# 6 Assessment and evaluation

When assessing learner performance and progress within the CSA Simulation, the following assessment methods can be used:

- **Pre-simulation Knowledge Assessment:** Before learners engage with the virtual simulation, administer a pre-simulation knowledge assessment to gauge their understanding of the relevant concepts, theories, and practices. This assessment can help establish a baseline and identify areas where learners may need more support. You can use the self-assessment tool available at the beginning of the two courses in EduOpen.
- **Simulation Assignments:** Design specific assignments that require learners to apply their knowledge and skills, by choosing one or more case studies to perform. The assignments should be aligned with the learning objectives of the simulation and provide opportunities for learners to demonstrate their understanding and proficiency.
- **Reflection and Self-Assessment:** Encourage learners to reflect on their experiences and self-assess their progress within the simulation. Provide reflection prompts or structured reflection

activities that prompt learners to evaluate their own performance, identify strengths and areas for improvement, and set goals for further development, as suggested in the learning activities.

- **Peer Assessments:** Incorporate peer assessments as a means for learners to evaluate and provide feedback on each other's performance within the simulation. This can be done through peer reviews of simulation assignments, group discussions, or collaborative problem-solving activities. Peer assessments can provide additional perspectives and insights, fostering a collaborative learning environment.

# 7 Best practices and tips

- Based on the piloting activities performed we have defined the following tips:
- Users get more involved when they work on target areas, they are related to. Relating the simulation to real-world relevance enhances its effectiveness.
- Clearly define the learning outcomes of the activities you want to perform and refer to the learning outcomes reported in the MOOC and in each exercise to decide which is the most appropriate.
- Combine more activities and resources, as both project results are not developed to be comprehensive.
- Promote active participation by engaging learners in hands-on activities within the virtual simulation. Encourage them to make decisions, analyze data, and explore different scenarios. Active engagement enhances learning and increases motivation.
- Design the virtual simulation to have a logical learning progression, gradually introducing new concepts, features, or challenges.
- Help learners identify and reflect on the transferable skills they acquire through the virtual simulation, such as problem-solving, decision-making, data analysis, and collaboration. Highlight how these skills can be applied in other contexts or future endeavors.
- Remember to align the assessment methods with the specific learning objectives of the virtual simulation and ensure that they provide meaningful feedback and support learners' development throughout the process. Regularly review and adapt the assessment methods based on the observed learner performance to optimize their learning experience.

# FarmBox

**The farmer's toolbox for climate change mitigation**

Co-funded by the Erasmus+ Programme of the European Union