Carbonica

Low-carbon Farming: building a sustainable future

D1.1 Integrated framework of regional R&I excellence and toolbox of carbon farming solutions

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Executive Summary

Deliverable 1.1 "Integrated framework of regional R&I excellence and toolbox of carbon farming solutions" will be developed and implemented in the framework of the Carbonica project, which will be monitored under T1.1. WP1 D1.1 concerns a systematic literature review in the field of carbon farming. The D1.1 outlines the following areas (i) the current situation of carbon farming techniques globally and between CY, GR and NMK and countries' adoption of these agricultural practices, (ii) identification of the state-of-the-art research and gaps derived from highly cited papers based on previous and current funded projects, (iii) identify previous literature based on technologies and frameworks for measurement using Earth Observation methodologies and/or ground data collection on a farm level. Numerous previous works stated the importance of carbon farming from the ecological perspective and the urgent need for the adoption of these practices for food quality and security and the importance of a circular economy in the field of agriculture. Earth observation is the best ally for monitoring carbon stock. The purpose of D1.1 is to identify the existing carbon farming techniques and their results, performance, and outcomes of previous and current projects and how Earth Observation can facilitate the observation of carbon sequestration and footprint. The main goal is the gap identification derived from previous projects and literature in order to add more value.

The Carbonica Excellence Hub (EH) will interconnect 3 PBIES (CY, GR, NMK), to include key stakeholders of the carbon farming domain across the QH and form 3 regional Multi Actor Platforms (MAPs) that will orchestrate collaboration. Further value will be added by conducting an in-depth investigation of stakeholder needs (surveys and interviews) and capacity-building activities, i.e. cross visits. A questionnaire was created to identify current needs of farmer communities and identify possible knowledge gaps or expertise in carbon farming. Based on the literature review carried out for carbon farming we identified that some carbon farming technologies are in use by a group of farmers between the IES.

A survey of 200 stakeholders and >60 face-to-face interviews involving farmers, advisors, industry, and policy makers will be employed to uncover stakeholder needs and current practices, existing infrastructure, R&I capacities of IES and policy frameworks. Common protocols for surveys and interviews will be developed. The aim of this questionnaire is the participation of stakeholders based on the quadruple helix model of the participating countries, which belong to the widening countries, expecting in this way to lay the foundations of carbon sequestration in agriculture giving added value to the wider region.

Table of Contents

List of Figures

List of Tables

Glossary of terms and abbreviations used

List of Abbreviations and Acronyms	
CO_2	Carbon Dioxide
GHG	Green House gas
SOC	Soil Organic Carbon
NT	No Tilling
CT	Conservation Tillage
SOM	Soil Organic Matter
CA	Conservation Agriculture
DMC	Direct Seeding Mulch-Based Cropping
CAP	Common Agricultural Policy
CFI	Carbon Farming Initiative
DAC	Direct Air Capture
DACCS	Direct Air Carbon Dioxide Capture and Storage
CDR	Carbon Dioxide Removal
VOCs	Volatile Organic Compound
SSLs	Soil Spectral Libraries
LUCAS	Land Used and Coverage Area Frame Survey
RF	Random Forest
DSM	Digital Soil Mapping
INT	Intensive Management
REG	Regenerative Management
MIN	Minimum Impact Management
CERES	Crop Environment Resource Synthesis
SIC	Soil Inorganic Carbon
CF	Carbon Farming
WHO	World Health Organization
IES	Innovative Ecosystems
BGB	Belowground live Biomass
DOM	Dead Organic Matter
EFSA	European Food Safety Authority
EH	Excellence Hub
NGO	Non-Governmental organizations

1 Introduction

This task will involve mapping the current situation of the regional Innovation Ecosystems (IES) in carbon farming in CY, GR, and NMK. Firstly, a systematic mapping of published literature, previous projects, and activities in progress to identify state-of-the-art research and gaps in carbon farming will be conducted. Measurement frameworks and technologies for addressing real-time monitoring requirements will then be examined (i.e., ground measurements at the farm level or EO services). These will lead to the mapping of the current situation of the regional IES in carbon farming in Cyprus, Greece, and North Macedonia.

The term carbon farming indicates several agricultural practices that have as a goal to sequester Carbon Dioxide (CO_2) from the atmosphere and store it in soil and crop roots [1]. The European Commission stated the urgent need for the reduction of greenhouse gasses (GHG) emissions and the goal of climate-neutral continent with zero net GHG emissions by 2050[1]. The European Union (EU) announced economic support through funding to those who will adopt carbon farming practices and contribute to the EU goals. Considering the Green Deal and its 'Farm to Fork' and 'Biodiversity' strategies, the EU aims to find new ways to decrease GHG emissions through the EU Carbon Farming initiative. Farming practices that remove CO_2 from the atmosphere will be rewarded in line with the development of new EU business models[2]. The Carbon farming initiative is a new approach for Europe. Its main objective is to create direct incentives to encourage the agriculture and forestry sectors to take climate and biodiversity action and contribute to the European Green Deal. The initiative concludes that carbon farming can significantly contribute to climate change mitigation. Considering current policy developments such as the European Green Deal and the EU climate action on sustainable carbon cycles, the importance of robust carbon monitoring is likely to increase in the coming years [2], [3].

It is widely acknowledged that the pace of climate change has now reached exceptional levels, with consequences for both the environment and humanity. Climate change-related threats to human life include those of physical and emotional well-being, the environment, food security, and economic development both domestically and globally [4]. However, there is no doubt that a number of environmental impacts caused by climate change are likely to persist into the near future and have a greater impact on people's health. According to Portier et al., 2010 [5], climate change is a driver in the development of four major diseases: cardiovascular disease, malnutrition, diarrhea, and malaria. Additionally, according to the World Health Organization (WHO), in 2000, climate change was directly responsible for 5.5 million disability-adjusted life years (DALYs, one DALY represents the loss of the equivalent of one year of full health) and 166,000 fatalities [5]. One of the worst heat crises was the European heatwave of 2019, which led to 2500 fatalities[3]. The difficulty of predicting changes in the environment and human health and behavior makes it difficult to develop rational policies with different climate change scenarios. One of the main causes of climate change is the effect of GHGs (e.g., NH_4, NO and CO_2) release in the atmosphere. The present literature review concerns the atmospheric CO_2 derived from agriculture and its mitigation. Agriculture is one of the numerous factors that contribute to CO_2 emissions into the environment. More examples are industry, transportation, and energy production.

Carbon sequestration is a naturally occurring process performed in soils. Atmospheric Carbon Dioxide (CO_2) is captured by plants through photosynthesis, during which several physicochemical processes take place for storage in the soil [6]. However, soil disturbance caused by many conventional agricultural practices (e.g., tillage and fertilizers) causes the release of stored soil organic carbon back into the atmosphere in the form of CO_2. Several Carbon Farming techniques such as alternative soil amendments, tillage crop rotation, cover crops, and sustainable water management were proven by literature to increase carbon sequestration. By minimizing soil disturbance, carbon farming practices can collect carbon from

[1] EC Carbon Farming: https://climate.ec.europa.eu/eu-action/sustainable-carbon-cycles/carbon-farming_en
[2] EC Common Agricultural Policy: https://agriculture.ec.europa.eu/common-agricultural-policy_en
[3] Climate-Resilient Europe: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021DC0082

the atmosphere and store it in the soil for extended periods of time, thereby reducing the amount of carbon released back into the atmosphere.

In this task, a literature review (*section 2*) was conducted to determine the significance of CF techniques for carbon sequestration and the countries that have adopted these techniques. Moreover, previous projects and activities are discussed (*section 3*), and measurement frameworks and technologies are identified (*section 4*). The scientific publication libraries used for this review are the Web of Science and Google Scholar. Additionally, the European Commission and Eurostat websites were used for the identification of current challenges and countries' adoption of CF techniques respectively. CORDIS EU research results website was used for the identification of previous and current projects on CF. The main keywords used are ‘Carbon Farming’, ‘Soil organic carbon and matter’, ‘Carbon Sequestration’, ‘Europe’, ‘Worldwide’, ‘Real-time monitoring’ and ‘Legislation framework’. In this review, 115 papers were chosen and analyzed along with 8 funded projects.

2 Global published literature

Over the past 10 years, the multiplication of greenhouse gases (GHGs) in the atmosphere has increased enormously. The global monthly mean of CO_2 elevation grew from 418.42 ppm[4] in April 2022 to 420.54 ppm in April 2023, according to Global Monitoring Laboratory - Carbon Cycle Greenhouse Gasses. Considering the years 2011 and 2012, the total worldwide emission of CO_2 grew from 9.4 billion metric tons of carbon (C) to 9.6 billion metric tons in a year.

The main sources of CO_2 circulating actively in the ecosystems are biomass (generally vegetation), soil organic matter, and the oceans [7]. The carbon cycle in agriculture is the process through which plants uptake CO_2 from the atmosphere via photosynthesis and store it. Roots and some other parts of the plant are converted into soil carbon with the help of microbes when they decompose. Previous studies support the idea that the use of carbon farming techniques can increase soil carbon storage and mitigate the amount of CO_2 emission back into the atmosphere [8]. Agricultural CO_2 emissions are mainly from soil organic carbon (SOC) and crop residues oxidation, respiration of crops and agricultural fossil fuels usage from machines (e.g., water machines, tractors, and harvesters) and non-renewable energy sources usage for the pesticides and fertilizers production and application [9]. Land use shift from forest to agriculture causes high CO_2 release in the atmosphere, triggered by deforestation [10]. Release of carbon caused by the land use change between 1850-1990 was estimated to be 124Pg C [10], [11].

The agriculture sector can be influenced by climate imbalances but can also contribute to climate change mitigation [1]. Soils, forests, and oceans are naturally occurring carbon sinks on earth. In most cases, croplands have low carbon stocks in comparison to forests which are native vegetation [1]. This loss can be reversed via carbon sequestration. Specifically, increased soil organic carbon can have a positive impact on climate change mitigation and CO_2 removal from the atmosphere. It is estimated that EU cropland soils lose about 7.4 million tons of carbon annually[5]. Several techniques have been developed and examined for carbon farming. Some examples are integrated cropping, livestock, and forest, restoring degraded pasture, no-tillage and plantation in the forest [12]. Extensive traditional practices used by farmers (e.g., large-scale tilling and crop residue combustion) have largely increased soil erosion and soil degradation and thus carbon losses [8]. Land use changes and existing agricultural practices have a negative impact on the soil, with losses of approximately 10-59% of SOC [13].

The maximum amount of carbon a soil can attain is referred to as the soil carbon saturation level. The level of carbon in soil cannot increase endlessly because the mechanisms through which SOC is stabilized are limited. SOC content is mainly dependent on the soil mineralogy (content of sand, silt, and clay), the input of organic carbon (e.g., from vegetation and fertilizers) and the soil environment [6] (e.g., oxygenation, water content).

The main challenge in instrumentalizing soils to sequester atmospheric carbon is the implementation of a method that is robust, affordable, and scalable and which is coupled to feasible land-use management advice [14]. The purposeful separation and disposal of CO_2 as a combustion byproduct in non-atmospheric reservoirs is known as carbon sequestration. Carbon sequestration comprises several techniques that aim to reduce CO_2 emissions and CO_2 concentration in the air[7]. Such methods are also called Direct Air Capture (DAC), Direct air carbon dioxide capture and storage (DACCS), and Carbon dioxide removal (CDR).

[4] Global Monthly Mean of CO2: https://gml.noaa.gov/ccgg/trends/global.html?doi=10.15138/9n0h-zh07
[5] Soil health: https://joint-research-centre.ec.europa.eu/jrc-news-and-updates/healthy-soils-necessity-eu-2022-06-09_en
[6] Soil carbon stock: https://soilcastor.com/blog/how-much-carbon-can-soils-store.html
[7] Integrated National Energy and Climate Plan 2021-2030: https://commission.europa.eu/energy-climate-change-environment/implementation-eu-countries/energy-and-climate-governance-and-reporting/national-energy-and-climate-plans_en

Carbon sequestration by agricultural-related products and techniques is under the umbrella of biological CDR methods[8]. These aim to increase carbon storage on land by boosting primary productivity while reducing CO_2 in the atmosphere. The IPCC has placed a high confidence level for carbon sequestration, in secondary forest regrowth, non-forest ecosystems restoration, and improved practices in agriculture and grasslands [15], [16].

Soil organic carbon (as a proxy for soil organic matter) plays two roles as we tackle the challenge of achieving sustainable agroecosystems in the coming decades: i) increasing crop productivity and ii) sequestering atmospheric carbon. The mass balance for carbon (and any material) in the ecosystem can be accounted for by the equation:

$$Input - Output = Storage \qquad \text{(Equation 1)}$$

For carbon, *Equation 1* can be summarized as follows:

- Inputs: Photosynthesis; Soil amendments
- Outputs: Plant and microbial respiration; Emissions of volatile organic compounds (VOCs)
- Storage: Plant and microbial biomass; Soil carbon as SOC and SIC pools.

The agricultural practices that contribute to the achievement of carbon farming goals are diverse, and their success varies according to many factors including climate, soil type, and landscape. Equally important are the varying local economic and cultural conditions that help determine the practices that can be adopted [17]. There are numerous carbon farming agricultural practices [18]. These will be further discussed in this review and can be adopted to increase soil carbon storage in agroecosystems. The practices that are below discussed in detail are:

1. No tillage/Conservation Tillage (Subchapter 2.1)
2. Crop rotations (Subchapter 2.2)
3. Cover crops (Subchapter 2.3)
4. Mulching (Subchapter 2.4)
5. Water management systems (Subchapter 2.5)
6. Organic amendments (Subchapter 2.6)

2.1 No tilling/Conservation Tillage

No tilling (NT) is a promising carbon farming technique that is applied to enhance soil health, increase SOC, increase yield productivity, and ensure long-term carbon storage [19]. NT or reduced tilling is a carbon farming technique that helps soil to sequester carbon [20]. Traditional tilling procedure comprises the soil preparation for cropping, weed control, incorporation of fertilizers or manure and application of crop residues [19]. The usage of traditional tilling was proven to result in heat absorption, soil disturbance, and soil erosion [19]. NT technique is characterized by the principle of zero usage of traditional tilling. NT requires the usage of planting equipment that targets direct cutting of residual mulch, retention of residues that are on the top and can decrease soil erosion, growth of weeds and evaporation, and seeding straight to soil that is covered by mulch residue [21]. The very first movement for NT in agriculture was introduced after World War II [22]. At the very first steps of this movement, this technique was misunderstood due to farmers' hesitation [22]. Farmers believed that this approach would have a negative impact on yield productivity and subsequently low income [22]. An agronomist named George Elvert McKibben supported the idea of NT technique and made it acceptable to farmer associations [22]. Approximately 95 Mha cropland farmers use NT farming globally [22]. High acceptance of NT practices was achieved by many countries such as Brazil, the U.S., Argentina, South America, and Chile. For example, South America uses NT on a continuous basis, while the usage of no-tilling in the Corn Belt of the U.S. is rotational [22]. Generally, NT adoption contributes to the quality of the environment due to its efficacy in regulating soil erosion, controlling runoff, enhancing water uptake, increasing SOM absorption, enriching the biological

[8] Decarbonization: https://www.eurelectric.org/decarbonisation-pathways

activity of the soil, and contributing to energy usage reduction [22]. Incorporation of seeds into untilled soil has a lot of positive outcomes. Specifically, NT helps in soil organic matter (SOM) maintenance, boosts the biological processes of soil, preserves soil structure and porosity, and generally soil health [20].

In Brazil, the technique of NT and reduced tilling or Conservation Tilling (CT) first began in the 1970s, when farmers took the lead [20]. The Chinese government under several GHG mitigation projects urged farmers to start using environmentally friendly approaches to mitigate climate change impact. Promoting the five-year plan (FYP) 2011-2015, China suggested the usage of NT for the reduction of soil disturbance and thus GHG negative input to the atmosphere, increased straw mulching, and limiting the application of fertilizers [8]. The USA is at the top of the ranks of the countries with the highest untilled lands globally [19]. *Figure 1* was taken from the paper written by Chen et al., 2023 and shows the NT map in the USA [19].

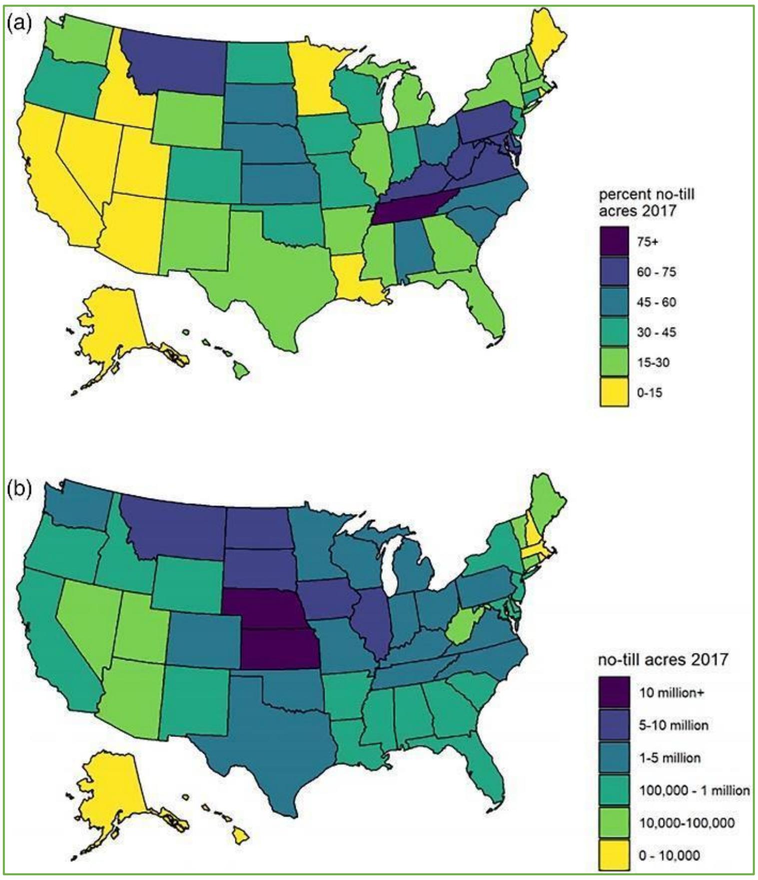

Figure 1. USA no tilling regions [19]

The European Union (EU) has approximately 1.09M km2 of arable lands. In 2016, farmers applied conservation tilling which covered approximately 22.4% of EU arable land and NT farming which covered 4.2 of EU arable land [23]. Between 2010-2016, European countries increased the usage of CT [23]. CT is a tilling method that can either be reduced or NT and requires the retention of crop residues from previously cultivated land. The increase in CT was particularly recorded in France, Portugal, Estonia, and Austria, while low usage of this technique was observed in Greece, Bulgaria, some regions in Italy, and Poland [23]. NT practice was proven to be cost-effective in relation to production costs due to the low need for fuels, employee cost, and fewer agricultural practices needed [24]. EU statistics[9] showed that in Greece in 2016, lands on which NT was practiced were 5,970ha, while CT lands were 233,930ha. In 2016 in Cyprus, lands on which NT was practiced reached 3,190ha, while usage of CT was practiced on 44,170ha (*Table 1*). Both NT and CT can be characterized as Conservation Agriculture practices since both aim for

[9] EuroStat: https://ec.europa.eu/eurostat/databrowser/view/ef_mp_prac/default/table?lang=en

sustainability [20]. CA was adopted by more than 70 countries. Argentina, USA, Brazil, and Australia incorporated CA in most of their cultivated land [20].

Table 1. Statistical analysis of 2016 for arable lands under CT and NT

Countries	CT (Arable land per ha)	NT (Arable land per ha)
Greece	233,930	5,970
Cyprus	44,170	3,190
North Macedonia	40,180	530
France	5,948,190	960,120
Portugal	382,460	15,230
Estonia	182,570	73,900
Austria	395,290	23,250
Bulgaria	1,336,890	4,850
Italy	263,410	231,420
Poland	296,630	226,700
Germany	4,719,290	94,210
Spain	2,020,150	739,130

2.2 Biochar

One of the main suggestions of the EU Green Deal is the reduction of fertilizers that promote GHG emissions. Biochar application is another carbon farming technique that is used for carbon sequestration in the form of a fertilizer [25]. Biochar is a type of charcoal produced by burning biomass (organic material) in a low-oxygen environment. This process, known as pyrolysis, converts the carbon in biomass to a form that resists decay. When the charcoal is buried or added to soil, most of the carbon can remain in the charcoal or soil for decades to centuries, given the right conditions. The pyrolysis process removes carbon dioxide (CO_2) from the atmosphere, as it involves growing plants or collecting waste biomass, converting that biomass to biochar, and adding the biochar to soils. As plants grow, they remove CO_2 from the atmosphere and use it to produce biomass. Carbon biomass is converted into a stable form in biochar, and burying biochar prevents carbon release in the atmosphere for an extended period.

As a result of the above process, the production and burial of biochar can be regarded as a form of carbon removal. The potential and cost of using biochar on a large scale remain somewhat unclear. Estimation of how much CO_2 sequestration was performed,[10] predicting that approximately 0.5-2 billion Gt of CO_2 per annum will occur by 2050. The cost of this process was also mentioned and amounts to 30-120 US dollars per CO_2 tone. Biochar is used as a remedy for soil productivity and plant health since it can result in a positive impact. Previous studies showed that wheat cultivation in combination with biochar application increased yield output and reduced negative emissions [25]. Interactions of soil with biochar is a promising technique that ensures a long period of time carbon sequestration [25]. Mediterranean soils are fragile

[10] https://www.american.edu/sis/centers/carbon-removal/upload/icrlp_fact_sheet_soil_carbon_biochar_181006.pdf

since they come across numerous factors that affect the soil ecosystem. Specifically, soils in the Mediterranean region have a high erosion rate, the levels of SOM are low, and they face salinity issues [25]. Biochar usage enhances the density of nutrients in soil, helps in carbon sequestration, increases water capacity, reduces the need for fertilizers, and improves the microbiota of soils [26]. To date, only the United States and China use biochar as a carbon farming technique [26]. Studies carried out in China proved the reduction of CO_2 emission by 18,479.35-37,457.66 kg after the addition of biochar in maize and rice [27]. Biochar on its own is alkaline and helps acidic soils to increase the pH [26]. Additionally, incorporating biochar in croplands can increase production yield [28]. Biochar has a high potential for CO_2 mitigation since it can reduce more than 10Mg CO_2 equivalent (CO_2-e) per ha-1 per year -1 [28].

2.3 Cover Crops

A promising approach for carbon farming is the intercropping of cover crops [29]. Previous studies proved that the use of cover crops does not cause a loss in yield production or carbon loss [29]. Replacing bare fallows with cultivated cover crops during winter and autumn is a well-established agricultural practice for nitrogen leaching avoidance. Cover crops are a promising approach in relation to the environmental perspective. Scientists propose that cover crops could also be exploited to sequester SOC and thereby mitigate climate change by reducing carbon dioxide (CO_2) concentrations in the atmosphere. Numerous meta-analyses propose the dynamic ability of cover crops to increase SOC concentration in topsoil at a rate of 0.3-0.6 Mg C per ha-1 per year. However, some previous studies illustrated that no significant change was observed during cover cropping, despite its potential to increase SOC. Cover crop models recommend that they can be effective towards greater isolation linking C input from cover crops to SOC dynamics and stability, as they lead to higher biomass generation and thus soil carbon supply. In comparison to natural vegetation, croplands deal with approximately 30-40% SOC depletion under cultivation [29].

In the winter period, cover crops are planted in the uncultivated land and before the cultivation of the main crops, they are tilled as green fertilizers [29]. Cover crops are an effective way to improve biodiversity, limit soil erosion, and mitigate drought. Cover crops approach increases the concentration of SOC, preserves soils, increases soil structure and fertility, and contributes to pest management [9]. SOC sequestration promoted by cover crops is mainly done by the addition of residues derived from crops [9]. Green manure derived from cover crops results in an increase in SOC [29].

Crop cover along with CT was adopted by farmers in Denmark, Spain, Portugal, and Canada and resulted in a more efficient and effective SOC sequestration [30]. This happens because of the minimum soil disturbance of CT that maintains SOC in soil and the cover's crop ability to increase biomass, which in turn increases SOC sequestration. According to the Census of Agriculture, cover crop acres are more than 10 million in the U.S. An increased popularity in cover crops was observed in European countries, Asia, Australia, and New Zealand[11]. This is due to the fact that farmers want to uptake the opportunities and benefits of cover crops for their own lands. Due to the mild winters that occur in Cyprus, Estonia, and Malta, normal winter crops cover the majority of arable lands[12]. In Cyprus and Estonia, arable land farmers use winter cover crops in 68110 ha and 148220 ha respectively[13]. On the other hand, non-arable lands in Finland are covered by normal winter cover crops due to heavy winters. Multi-annual plants cover the greatest shares of arable lands in Latvia and Estonia. Statistical analysis results showed that some European countries with more than a third of arable lands in winter, such as Bulgaria, Croatia, Latvia, Lithuania, Hungary, Poland, Romania, and Slovakia do not use cover crops. Farmers in Germany, Greece, Spain, France, Croatia, Italy, Austria, and Poland use winter cover crops.

[11]Cover Crops: https://shorturl.at/fgloN
[12]Cover crops analysis : https://shorturl.at/fpJS8
[13]EuroStats for cover crops: https://shorturl.at/jHOTW

2.4 Crop Rotation

Crop rotation is another promising carbon sequestration approach that can increase SOC stocks [31]. Crop rotation is one of the first agricultural practices used around the world [32]. It is done by sowing a specific sequence of crops on the same land [31]. Adoption of this approach showed improvement in weed control, prevention of soil depletion, prevention of diseases and pests, increased SOC, and contributed to Nitrogen fixation [31]. Cropping different varieties of crops or inserting perennial grasses proved to be a good SOC sequestration parameter, increasing crop productivity and mitigating environmental impact [31]. Healthy soil ecosystems require that SOC does not increase without Nitrogen content so that balance occurs [33].

China adopted crop rotation practice in agriculture for a long time now [33]. Studies showed that combining the approach of crop rotation with the addition of cover crops improved SOC [33]. Intercropping with legumes showed a decrease in the need for pesticides and fertilizers based on N caused by the ability of legumes for N fixation [34]. Thus, the carbon footprint derived from the N fertilizer production can be reduced significantly [34]. However, the total EU arable land that is under legume-based crop rotation is 3% [34]. The US farmers adopt a short rotation system where extended rotation is used less. The most commonly used rotation system in the US is the corn-soybean cropping rotation [35]. In the Midwest, a region named Corn Belt is the nation’s biggest corn production site [35]. The Corn Belt region includes mainly the states of Minnesota, Illinois, Indiana, Ohio, South Dakota, Lowa, Wisconsin, and Nebraska. In 2010, 83% of the agricultural land was used for corn and soybean crop rotation [35]. According to a 2014 survey, farmers in Lowa used the cropping rotation approach on corn-soybean on 80% of the lands, while they added a third cultivation in the system of crop rotation to only 19% of the lands [35]. In Canada, the replacement of uncultivated land with legumes (e.g., lentils) and red clover was shown to be a successful approach for Carbon storage [9]. Specifically, adopting this approach led to carbon storage rates of 15 ± 11 g C m-2 per year [9]. In Brazil, the most common crop rotation techniques with soybeans used the wheat and maize crops [36].

The combination of crop rotation with NT gives a promising approach in relation to SOC sequestration, increase of SOM maintenance, and reduction of soil erosion [37]. In Sweden, the addition of legumes in the rotation cropping system of cereals showed an increased SOC concentration in soil [38]. The use of remote sensing applications in mapping crop rotation was reported in Germany, China, Argentina, and the US [39]. Crop rotation system was proven to play a significant role in soil health and Carbon depletion from the atmosphere [39]. Moreover, previous studies showed that crop rotation benefits the productivity of soybean, rice, and corn crops [39].

2.5 Mulching

Mulching is another sustainable agricultural practice that can reduce GHG emissions [40]. An example of mulching is residue cropping. This method gives various benefits to soils, including the reduction of soil erosion, the retention of water holding capacity, the regulation of temperature changes, the increase of SOC, the increase of carbon storage, and the restoration of biodiversity [40]. Cultivation of different varieties of crops and the choice of which residue types will be used can affect SOC sequestration [40]. In previous papers, different crop residues were examined, illustrating that crop residue types have different abilities based on carbon sequestration [40]. For instance, maize increases SOC while legumes retain carbon [40]. In Japan, grass mulching has been highly used as an agricultural practice, since the 1900s when fertilizers were introduced in the market [30]. The input of grass was proved to introduce an increased rate in SOC concentration [30]. To date in Japan, farmers use manure along with the use of fertilizers in most of the agricultural lands [30]. Previous studies in China, illustrate that mulching use increases soil OC and mulch type plays an important role in SOC improvement [41]. Mulch types can be either straw, film, sandstone, leaf, compost, or grass [41]. The most commonly used mulching types are straw residues and plastic film [42]. Plastic film mulch is a technique adopted by Chinese farmers to increase crop yield

[43]. Plastic film mulch was initiated at the beginning of the 1950s, and it was used in the production of vegetables [43]. However, this approach was proved through research that can provide high crop productivity, play a role in water retention in soil, and increase temperature in soil [43]. Sun et al., 2020 supported that due to the high temperature that plastic film mulch provides to the soil, it increases microbes' respiration and thus, leads to higher CO_2 release in the atmosphere [43]. Similar studies were carried out in the past to determine whether plastic film mulching can sequester carbon and increase SOC stock. Studies performed in Loess Plateau and Southwest China, showed that the plastic film mulch approach leads to higher carbon stocks in comparison to non-plastic film mulch [44]. Nevertheless, a study performed in China by Li et al., 2015 illustrates that plastic film mulching increased SOC amount in soil layers between 0-30cm [44]. Additionally, the straw mulching approach can reduce CO_2 emissions, increase yield production, and enhance carbon absorption [45]. This was proved by a previous study performed in North China using maize under straw mulching [45].

The system of direct seeding mulch-based cropping (DMC) covers the area of zero disturbance of soil (NT) using machines and the addition of former crop residues and lifeless or alive mulch. As mentioned before, extensive soil disturbance by tilling causes the release of CO_2 in the atmosphere and reduces SOC in soils. The DMC approach offers a significant positive impact on soil health, reduces soil erosion, and increases soil carbon [46]. About 235 agronomists in 1974 adopted the DMC system on their farmland in Parana State of Brazil [46]. However, low evidence at that time about the pros of DMC in the agricultural field lowered these practices in Parana State and Rio Grande do Sul at the end of 1970s [46]. Nevertheless, even if in the beginning the adoption of this technique was limited, at the end of 1980s Brazilian agriculture started to increase the usage of DMC [46]. About 13.3% of cropping land was under the DMC adoption in the cropping period of 1991 and 1992 and is still ongoing [46]. The DMC practice covers 20 million hectares of cropland in Brazil [46].

2.6 Water Management

Irrigation in croplands is of high importance to meet the growing food demand, due to the growth of population. Smart water management practices can enhance carbon sequestration in soils. It includes strategic and efficient irrigation, which can contribute significantly to the reduction of GHG emissions. Groundwater is over-saturated with CO_2, thus pumping water for irrigation releases CO_2. A significant amount of CO_2 is emitted during groundwater pumping, because of both water CO_2 release and CO_2 required for the energy generation for pumping. The energy required for pumping irrigation water is one of the main sources of CO_2 emissions in agriculture and thus, smart irrigation systems in conservation agriculture can contribute to the reduction of CO_2 emissions [9]. A case study performed on an agricultural land in Egypt by El-Gafy and El-Bably (2016) concluded that 1m3 of water pumping emits approximately 690 tonnes of CO_2.

Additionally, the interaction of water with various chemical compounds of soil can result in further CO_2 emissions. More specifically, when an acid source (e.g., soil nitric acid) or a triggered chemical reaction occurs, $CaCO_3$ becomes degraded and releases CO_2 into the atmosphere. The release of GHGs from soils is controlled by many biogeochemical procedures [47]. Biogeochemical processes are largely influenced by ground moisture along with the natural respiration of microbes [47]. CO_2 emissions from soils are driven by the microbial aerobic and anaerobic respiration of organic carbon [47]. Specifically, this process occurs through three biological procedures, i.e. the respiration of microbes in soils, root respiration, and the respiration of faunal [47].

The three processes mentioned above are mainly influenced by the availability of water in the root system of crops [47]. Intensified irrigation that results in soil's high-water conciseness speeds up the microbial respiration of SOM, which in turn increases CO_2 flow [47]. Over the years, irrigation has proven to be a good solution for high yield production [47]. Nevertheless, in recent years farmers have been forced to adopt deficit irrigation practices [47], due to the severe droughts that are more frequent because of the current climate crisis. Low irrigation rates can reduce GHGs by improving the soil's turnover procedures of Nitrogen and Carbon [47]. Previous studies illustrated that limited water for irrigation reduces CO_2 emissions and increases SOC input [21].

Nevertheless, irrigation management approaches and irrigation rates in relation to GHG emissions are not very well understood [47]. Several types of irrigation are used all over the world, some examples are flooding, drip, and sprinkler irrigation. Drip irrigation was described by Andrews et al., 2022, who showed that GHG emissions (e.g., CO_2, N_2O, and NO) were decreased by at least 62% [48]. Irrigation management provides opportunities for CO_2 emissions mitigation since it requires low amounts of water in land use and subsequently provokes the energy reduction derived from fossil fuels and electricity that are needed for water pumping [49]. In recent years, various irrigation approaches have been developed to enhance the efficacy of water and energy usage and CO_2 leakage reduction [50]. Specifically, examples of technical approaches adoption are the replacement of open distribution systems with pressure networks and the improvement of irrigation methods by using more effective water distribution apparatuses such as sprinklers and drippers [50]. Irrigation decision support tools are essential to develop, to optimize the consumption of water and plant output in relation to atmospheric conditions at specific regions and farming methods [50].

2.7 Organic Farming

Increase in SOC can also be achieved through organic farming approaches [38]. Organic farming systems consist of the application of organic fertilizers instead of chemical ones, the use of crop rotation systems, and the addition of cover crops [38]. Organic fertilizers in farming are mainly manure derived from cattle or pigs, and green manure [51]. Additionally, the use of organic agricultural methodologies such as organic fertilizers, reduces the use of chemically made fertilizers, such as herbicides and pesticides with the subsequent outcome of reduced consumption of primary energy [38]. More than 1% of the global cropping lands are under organic farming approaches and more than this percentage is applied in advanced countries [52].

Organic farming is used for climate change mitigation since it requires the use of climate-friendly fertilizers (e.g., manure), increases biodiversity and water quality, and contributes to GHG reduction derived from agriculture [52]. Organic farming requires fewer pesticides and fewer fuels such as gasoline and diesel, and thus the usage of fossil fuels is reduced [52]. Thus, CO_2 derived from the above needs in agriculture with organic farming is mitigated [52]. In the period 2012-2020, it was observed that organic farming approaches were applied in over 50% of agricultural land in the EU. Furthermore, in the EU, organic farming is mainly practiced by young farmers. The crops that are under organic farming are mostly vineyards, olives, fruits, and cereals[14].

The European agricultural lands that are under organic approaches have gained financial support through the Common Agricultural Policy (CAP) since 1992[15]. Spain, France, Italy, and Germany are the main countries where farmers are using organic farming [53]. Spain, France, and Italy use 2.4, 2.2, and 2.0 million hectares under organic farming respectively [53]. Based on statistics, European consumers tend to spend more money on organic products enlarging the market need for organic products or products that are environmentally friendly and are produced without the usage of chemicals [53]. In 2019, statistics illustrated that farmers in Cyprus used 6240 hectares, Greece 528752 hectares, and North Macedonia 3711 hectares under organic agricultural techniques [53]. Many authors compared conventional agricultural practices with organic farming in the past, indicating that organic farming produces less GHG emissions [54].

Table 2. Countries adoption of CF techniques

[14] EC Organic Farming: https://agriculture.ec.europa.eu/farming/organic-farming_en

[15] CAP-Organic Farming: https://shorturl.at/BHO47

Country	**CT/NT**	**Biochar**	**Crop Rotation**	**Cover Crops**	**Mulching**	**Organic Farming**
Cyprus	√			√		√
Greece	√			√		√
North Macedonia	√					√
USA	√	√	√	√		
Brazil	√		√		√	
China		√	√		√	
France						√
Portugal				√		
Estonia	√			√		
Austria	√			√		
Bulgaria	√			√		
Italy				√		√
Poland	√			√		
Germany			√	√		√
Spain				√	√	
Canada			√	√		
Sweden			√			
Argentina			√			
Denmark				√		
Japan					√	

Carbon farming initiatives (CFI) demand agro-environmental policies to incentivize farmers to adopt the best farm management practices. However, it is usually difficult to get farmers involved in such programs mainly because of the complex scheme design and its implementation, or conflicting targets of policymakers and the farmers [55]. Farmers state that they have insufficient access to information regarding available options for carbon farming [56]. Limited educational information about the assets and liabilities of carbon farming keeps farmers uninformed on the topic and sets them to continue practicing conventional practices. CFI's other significant barriers are the lack of approved methods and procedures, higher administrative expenses, and difficulty getting certification as a qualified carbon offset provider [57], [58]. In addition, the capital investment required, and the probable impacts on the ability of farmers to obtain financial assistance from banks or other sources have been identified as significant challenges to carbon farming.

3 Projects and activities

As the magnitude of climate change rises quickly, challenges regarding food supply and security are anticipated to grow dramatically [59]. The increase in the amount of atmospheric CO_2 and high temperatures have a major effect on agricultural development, not only in the European region but worldwide. Furthermore, agricultural yield may be impacted by extreme conditions, such as dry and rainy spells or heat stress [60]. For example, prolonged droughts may cause water shortages and crop development failure, causing market gaps [61]. The evaluation of different possible solutions in the energy, transportation, industrial, and agricultural sectors is necessary for the effective reduction of GHG emissions [61].

Given the enormous quantity of C that can be stored in soils, carbon sequestration in agricultural soils is occasionally considered an appealing possibility to mitigate global warming [62]. In most cases, the loss of soil carbon has been compounded by the fundamental causes of climate change, such as the uneven use of chemical fertilizers and the removal or burning of agricultural leftovers, which decreases the soil's fertility. In addition, drylands make up approximately 40% of the world's ground surface. Sustainable climate change adaptations and greater agricultural ecosystem resilience practices such as the addition of crop residues and the practice of NT, hold the key to improving and minimizing this disaster [62]. As explained above, the use of methods such as minimum tilling, cover cropping, crop rotation, crop diversity, and intercropping, is a possible solution. However, this needs more clarification. In a cropping system used on drylands, even a small increase in soil C concentration can have significant impacts on soil characteristics and crop output, especially when soils lack C. Aditi et al., 2023 stated that the level of resilience created by implementing strategies through management techniques in an agricultural system can be predicted through long-term simulations. Therefore, the results of such simulations may be useful information for farmers and other associations living in the semi-arid tropical drylands, which are the most susceptible areas to future climate change scenarios [62].

The European Union sets various strategies[16] regarding the reduction of the effects of climate change as the severity of this challenge calls for immediate measures [63]. As mentioned above, great importance is given to the issue of carbon sequestration by soil. Considering carbon farming techniques, methods that incentivize the expansion and defense of carbon sinks into soil are under evaluation. It is essential to create practical solutions for the adoption of climate-friendly practices[17] to motivate stakeholders in agriculture and forestry fields to contribute to the European Green Deal[18] and take climate action.

A good number of projects were designed to give a closer look at carbon farming techniques. It is important to give an overview of what has been done and what is being under research in terms of the progress of the projects, their structure, and innovative technologies. In this way, we can clarify gaps that may exist but also address the combination of techniques for sustainable results. All the projects presented in *Table 3* below show a wide range of information on various points in the development of CF structures.

[16] EU Strategy on Adaptation to Climate Change: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2021:82:FIN
[17] EU Adaptation Strategy: https://climate.ec.europa.eu/eu-action/adaptation-climate-change/eu-adaptation-strategy_en
[18] EU Green Deal: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

Table 3. Recent and Previous Projects that contribute to CF research

	Project (Call)	Timeline	Coordinator	Aim	Practices	Countries	EU Contribution	References
1	**MARVIC**[19]: Developing and testing a framework for the design of harmonized, context-specific Monitoring, Reporting and Verification systems for soil Carbon and greenhouse gas balances by Agricultural activities. (HORIZON-MISS-2022-SOIL-01)	1/6/2023 - 31/5/2027	Eigen Vermogen Van Het Instituut Voor Landbouw- En Visserijonderzoek, Belgium	Create and analyze a dependable framework (the "MRV Framework") for the creation of a customized and relevant MRV systems for determining different variations in soil carbon stocks, green manure, and soil GHG emissions. To increase trust in both public and private schemes in Europe, this framework can be relevant for each agricultural land-use practice.	N/A	Belgium Italy Ireland Netherlands Spain Denmark France Finland Estonia Czechia Germany Switzerland	€6,999,965	Reference for the project:[20]
2	**MRV4SOC**[21]: Monitoring, Reporting and Verification of Soil Organic Carbon and Greenhouse Gas Balance. (HORIZON-MISS-2022-SOIL-01)	1/1/2023 - 31/5/2026	Gmv Aerospace and Defence Sa, Spain	To develop a thorough and reliable Tier 3, a strategy that is in line with national GHG reporting regulations and accounts for changes in most C pools as possible. (Create solutions for various spatiotemporal scales and climate change scenarios)	N/A	Belgium Greece Israel Czech Republic Netherlands Italy Germany France	€6,999,966	Reference for the project:[22]

	Project (Call)	Timeline	Coordinator	Aim	Practices	Countries	EU Contribution	References
						Spain Norway		
3	**CIRCASA**[23,24]: Coordination of International Research Cooperation on soil CArbon Sequestration in Agriculture (H2020-SFS-2016-2017)	1/11/2017 - 28/2/2021	Institut National De Recherche Pour L'agriculture, L'alimentation Et L'environnement, France	The project seeks to create not only on European Union-level but global as well, research and knowledge-exchange synergies around carbon sequestration in agricultural soils. With 22 partnerships from 17 different countries. These partners provide a particularly dense network of scientific experience to the project. As to that, the CIRCASA project has created a strategic research agenda to educate broadly applicable priority objectives and actions that are in line with more general European and global aims. It highlights the requirements for research and	To achieve this, the CIRCASA project's SRA is structured in four pillars: Pillar 1: Frontiers research: unlocking the potential of soil carbon. Pillar 2: Soil carbon balance monitoring, reporting, and verification (MRV) system. Pillar 3: Technological and agroecological innovations. Pillar 4: Enabling environment and knowledge co-creation.	France Russia China Australia South Africa Nigeria New Zealand Madagascar Germany Austria Denmark	€2,451,771	[64], [65], [66] Project website: [25]

[19] MARVIC project: https://cordis.europa.eu/project/id/101112942
[20] CORDIS.EUROPA.EU: Developing and testing a framework for the design of harmonized, context-specific Monitoring, Reporting and Verification systems for soil Carbon and greenhouse gas balances by Agricultural activities. https://cordis.europa.eu/project/id/101112942
[21] MRV4SOC project: https://cordis.europa.eu/project/id/101112754
[22] CORDIS.EUROPA.EU: Monitoring, Reporting and Verification of Soil Organic Carbon and Greenhouse Gas Balance. https://cordis.europa.eu/project/id/101112754
[23] CIRCASA project: https://cordis.europa.eu/project/id/774378
[24] CIRCASA project website: https://www.circasa-project.eu/
[25] CIRCASA project. Home page : https://www.circasa-project.eu/

	Project (Call)	Timeline	Coordinator	Aim	Practices	Countries	EU Contribution	References
				innovation and meets the requests made by stakeholders across 10 global regions.		UK USA Colombia Brazil		
4	**Catch C**[26]: Compatibility of Agricultural Management Practices and Types of Farming in the EU to enhance Climate Change Mitigation and Soil Health (FP7-KBBE-2011-5)	1/1/2012 - 31/12/2014	Stichting Wageningen Research, Netherlands	Identify agricultural "Best management practices" (BMPs) to ensure productivity, upgrade soil quality and mitigate GHG emissions, as well as hold the soil carbon. A few BMPs were classified according to their impacts on productivity, greenhouse gas emissions and soil quality were examined.	They showed that there is no key practice (BMPs: cropping scheme, tillage, crop residue management, and nutrient and water management) to ensure all goals. A web-based support tool 'KnowSoil' was developed.	Austria Belgium Germany Spain France Italy Netherlands	€2,960,679	[67], [68], [69]

[26] Catch C project: https://cordis.europa.eu/project/id/289782

	Project (Call)	Timeline	Coordinator	Aim	Practices	Countries	EU Contribution	References
5	**Eurochar**[27]: Biochar for Carbon sequestration and large-scale removal of greenhouse gases (GHG) from the atmosphere (FP7-ENV-2010)	1/1/2011 - 30/6/2014	Consiglio Nazionale Delle Ricerche, Italy	According to the primary source of the biomass as well as the type of treatment, the project found significant variations in the composition of the biochars. Compared to biochar produced by HTC, TC's is more stable and has a higher sequestration capacity.	It was discovered that it can contribute to carbon sequestration which may be equal to 5% of the emissions from EU transportation. Long-term C-sequestration in soils by transforming biomass, and in particular crop residues, into a stable product by using biochar (Biochar - more stable and has higher C sequestration and SOC for long periods of time)	Italy France UK	€2,498,900	Project reference:[28] [70]
6	**DSCATT**[29,30]: Dynamics of Soil Carbon Sequestration in Tropical and	1/4/2019 - 31/3/2023	Institut de Recherche pour le Développement, France	The possibility of cultivated soils can sequestrate carbon was determined while preserving the global sustainability of agricultural systems. Agronomic and financial performance of farms, as well as the effects of various	To find the best practices, they examined if rural household activities were included, can preserve carbon sequestration in farms soils.	Senegal Zimbabwe France Kenya	€1,700,000	Project reference: [31] [32]

[27] Eurochar project: https://cordis.europa.eu/project/id/265179
[28] CORDIS.EUROPA.EU: Biochar for Carbon sequestration and large-scale removal of greenhouse gases (GHG) from the atmosphere https://cordis.europa.eu/project/id/265179
[29] DSCATT project website: https://dscatt.net/index.html
[30] DSCATT project library: https://library.dscatt.net/s/en/page/home
[31] DSCATT – Dynamics of Soil Carbon Sequestration in Agriculture - website: https://dscatt.net/index.html
[32] Libraire DSCATT: https://library.dscatt.net/s/en/page/home

	Project (Call)	Timeline	Coordinator	Aim	Practices	Countries	EU Contribution	References
	Temperate Agricultural systems (Agropolis Fondation)			transformation strategies on soil carbon sequestration, were assessed.				[71], [72], [73]
7	**LIFE CLIMATREE**[33]: A novel approach for accounting & monitoring carbon sequestration of tree crops and their potential as carbon sink areas (LIFE14 CCM/GR/000635)	16/7/2015 - 31/10/2020	Institute of Urban Environment and Human Resources, Panteion University, Greece	The project investigated the CO_2 balance and identified the potential of tree cultivations (Olive, Orange, and Peach trees) contributing to climate change mitigation. A specific algorithm (CO_2RCA Algorithm: CO_2 Removal Capacity Algorithm) was created in the context of the project for calculating the CO_2 annual balance among tree crops regarding CO_2 removals from the atmosphere for the biological life cycle of the tree and the emissions of CO_2 due to the utilized farming techniques.	Parameters: 1. Plantation density. 2. Soil tillage. 3. Irrigation requirements. 4. Fertilization use. 5. Herbicides use. 6. Pesticides use. 2 electronic tools were designed and developed:[34] 1. The CO_2RCCT (CO_2 Removal Capacity Calculation Tool) 2. The dynamic model to investigate the trends of CO_2 balance.	Greece Italy Spain	€1,158,868	Reference of the project's website: [35] [74]

[33] Life CLIMATREE website: https://www.lifeclimatree.eu/english/home/
[34] Climatree CO2 model: https://amimis.shinyapps.io/climatree/
[35] Life CLIMATREE website: https://www.lifeclimatree.eu/english/home/

	Project (Call)	Timeline	Coordinator	Aim	Practices	Countries	EU Contribution	References
8	**Carbon Farming project**[36] (INTERREG VB North Sea 2014 - 2020)	1/9/2018 - 31/8/2022	Zuidelijke Land- en Tuinbouworganisatie (ZLTO), Netherlands	The key objectives of the project were, to increase farmers' understanding of carbon farming, establish business models to motivate farmers to use the CF techniques, and create 15 real-life examples of how farmers may use carbon farming and get credits for it.	N/A	Netherlands Belgium Germany Norway	1,341,544	[75]
9	**Beernem project**: Opportunities for the covenant of mayors (Under Carbon Farming Project Call)	2018-2021	-	The idea of the project was to use the land to compensate for the CO_2 emissions caused using service vehicles of the municipality. The municipality (Municipality of Beernem) was willing to let farmers (12 local farmers) cultivate the available land for one year or one growing season, by dropping the usual rent, on the condition that these farmers would apply CF techniques during the growing season.	Practices under this subproject: 1. Improved grass management 2. Under sowing of grass in maize cultivation 3. Cultivation of grass clover 4. Enriched crop rotation, with winter cereal every third year as alternation with maize and grass. Using those practices: 1. 80 tons of CO_2 emitted each year by the automobile fleet of the municipality of Beernem.	Belgium	Under Carbon Farming Project fund	[76], [77], [78]

[36] Carbon Farming project: https://northsearegion.eu/carbon-farming/

	Project (Call)	Timeline	Coordinator	Aim	Practices	Countries	EU Contribution	References
					2. 22 tons of CO_2 are stored in the soil annually. 3. Approx. 39 tons of CO_2 have been stored in 2021 (2 years into the project using CF techniques).			
10	**Windpark Krammer project:** Upscaling the potential of Carbon Farming with support of an energy cooperative (Under Carbon Farming Project Call)	2018-2021	-	This project includes event organizers and nearby farmers working together for climate-positive results. CO_2 is easily created when an event is organized (transportation, lighting, heating, etc.) This project based its solutions on using CF methods. Local farmers can store the CO_2 produced by events back into the soil. In return, the event coordinator covers the farmer's costs associated with implementing CF techniques. (How much carbon is captured and stored in the soil)	Soil measures: 1. Reduced tillage/No tillage 2. Cover Crops 3. Compost Solid animal manure 4. Permanent grassland 5. Herb-rich grassland 6. Crop residue Above-ground measures: 7. Flower borders 8. Agroforestry	Netherlands	Under Carbon Farming Project fund	[60], [79]
11	**DKG de Keukenfabriek:** Farmers contributing to climate goals of a private company.	2018-2021	-	DKG de Keukenfabriek is the company and organization behind several kitchen brands. DKG utilizes ecological objectives (produces climate-neutral goods - renewable energy savings,	Soil measures: 1. Reduced tillage 2. No-tillage. 3. Improved crop rotation 4. Cover crops	Netherlands	Under Carbon Farming Project fund	[75]

Project (Call)	Timeline	Coordinator	Aim	Practices	Countries	EU Contribution	References
(Under Carbon Farming Project Call)			sustainable transport, and emissions). It also has an ambitious social responsibility policy. As to that, a five-year agreement was established with DKG and two farmers in cooperation with ZLTO. Each farmer uses a minimum of three CF techniques: two for the soil and one for the above-ground surface.	5. Compost Solid -animal manure 6. Permanent grassland 7. Herb-rich grassland 8. Crop residue Above-ground measures: 1. Flower borders 2. Agroforestry 3. Nuts, fruits, or other nutrition trees. 4. Line planting, hedges, and yard trees Using the particular practices, approximately at least 15 tons of CO_2 were saved per farmer every year. Tools for the project: 1. Soil Cooling practical tool ("FarmMap"):[37] determines what is required to generate a specific effect but not an optimization tool			

[37] FarmMap tool: https://slimlandgebruik.nl/

Project (Call)	Timeline	Coordinator	Aim	Practices	Countries	EU Contribution	References
				that gives efficient measures. 2. Measurements for arable farming:[38] monitoring the amount of C for each category and if it's better to plant again or rotate. (Categories measured: Crop residues left behind, agroforestry, bird fields, add animal manure and compost, non-innovation tillage, green manures and catch crops, field margins, improve crop rotation). 3. Smart land use tool: (''CO_2 Soil Clay'[39]' and '' CO_2 Sand''[40]) is divided into 2 parameters and for each parameter, there are other parameters that depend on the following: carbon sequestration, nitrous oxide emissions, soil functions, costs, and benefits.			

[38] Measurements for arable farming: https://slimlandgebruik.nl/maatregelen/akkerbouw
[39] CO2 Soil Clay tool: https://slimlandgebruik.nl/effecten/co2bodem-klei
[40] CO2 Sand tool: https://slimlandgebruik.nl/effecten/co2bodem-zand

	Project (Call)	Timeline	Coordinator	Aim	Practices	Countries	EU Contribution	References
12	**Oat flakes** (Under Carbon Farming Project Call)	2018-2021	-	This showcase (Klims) offers a strategy to compensate farmers financially for implementing CF practices. By using the label, businesses may show their support for the initiative and climate conservation efforts. Based on anticipated C-sequestration levels computed in CO_2, this business model's label fees and farmer finance are determined. Students from a nearby milling school processed grains from the Thünen Institute of Organic Farming's field trials with oats and under-sown clover grass. Climate labels can be used in marketing to bring customers' attention to the product's successful narrative. The label was created by the Klim (Berlin), which also encourages farmers to use regenerative agricultural methods.	1. Cover crops and catch crops. 2. Agroforestry 3. Flowering strips 4. New planted hedges 5. Greening bare fields Using the particular practices: 1. The project contributed to educating farmers about CF practices and potential business models as well as in label marketing and production chain development. 2. Useful link for the app on Klims[41]	Germany	Under Carbon Farming Project fund	[75]

[41] Klim.eco: https://klim.eco/

4 Measurement frameworks and technologies

To be useful at the farm scale, soil indicators must be easy to measure, understandable, meaningful, and cost-effective in terms of monetary costs and workload [80]. Physical and chemical indicators that provide information about soil fertility are commonplace, [81] but there is a striking absence of indicators addressing the effects of agricultural management on the soil biota [82]. The scarcity of soil biodiversity data at the management scale is an important drawback of implementing bioindicator systems useful for policy making [83].

There are methods that assess soil carbon stocks using solely satellite data [84], but they are limited regarding their resolution and their ability to monitor changes over time on field and farm levels. For example, a system providing digital soil mapping information collected from global soil sampling and environmental layers called SoilGrid has a resolution of 250m, which is too coarse for numerous fields to accurately assess carbon stocks for carbon credit certification [85]. An additional drawback of satellite-based global models is that these models are geared toward optimal predictions on a global or national scale, limiting the reliability at the farm level [84]. Studies about SOC prediction from satellites are categorized according to four main groups:

- Using spectral information from satellite imagery only, being mostly optical (SPOT, Landsat TM, Hyperion, Landsat 8, Sentinel-2, Pléiades, ASTER); rarely thermal (ASTER).
- Using spectral information from optical satellite imagery in combination with SAR imagery (e.g., Sentinel-1) or its derived products, such as soil moisture maps.
- Using spectral information from optical satellite imagery in combination with available soil spectral libraries (SSLs) (e.g., open libraries, Land Use and Coverage Area Frame Survey (LUCAS) for the European Union or the GEOCRADLE[42] for some Western Mediterranean and Middle Eastern countries), or a local database.
- Using spectral data from optical satellite imagery in combination with non-spectral datasets, e.g. Digital Elevation Models (DEM).

Machine learning can be used to predict patterns of carbon stocks and reduce the need for additional sampling [86]. Nevertheless, overfitting in machine learning can constrain the versatility of the approaches. When an overfitted model is used, it may be applicable to the region it was trained in, but not to other regions and is therefore not scalable. Random Forest (RF) is a widely used machine learning technique for SOC modeling [87], [88]. According to Diaz-Uriarte and de Andrés [89], the most important advantage of RF, which makes it a quite popular choice, is its resistance to overfitting and the removal of irrelevant features.

Besides the advances in Remote Sensing, analytical methods (Laboratory techniques) and field samples are necessary for SOC measurements as well. Numerous laboratory techniques are reported in literature. Some of the most widely applied techniques are dry combustion, wet oxidation, spectroscopy, UV-visible fluorescence and laser induced breakdown spectroscopy [90], [91], [92], [93], [94].

In the dry combustion method, the collected soil samples are burned at elevated temperatures (900-1000°C or 1400-1600°C) in a pure oxygen atmosphere. All compounds containing carbon are decomposed and converted to carbon oxides, mainly CO_2. The measurement of total carbon is performed by utilizing carbon gas detector and thermal difference between gas columns[43]

The Principal of Wet[44] oxidation (SOC oxidation) requires the usage of potassium dichromate ($K_2Cr_2O_2$) and concentrated sulfuric acid. When the reaction between the two oxidative agents occurs, heat in the

[42] GEOCRADLE project: http://geocradle.eu/en/
[43] Dry combustion: https://www.fao.org/3/ca7781en/ca7781en.pdf
[44] Wet Oxidation: https://shorturl.at/hjoy0

solution increases, inducing substantial oxidation. During the reaction, Cr_2O_2 is reduced. Then, organic carbon can be measured by calculating the remaining unchanged dichromate with the use of back-titration.

The dry combustion method was used for 50% of the studies and **wet oxidation** for 30%, however analytical methods differ from country to country [95]. Historically, one of the most commonly used wet oxidation methods is the Walkley–Black method [96]. This method is still being used in numerous countries, and several modified methods based on the same principles have also been proposed [97].

Moreover, over the past decade, laboratory spectroscopic measurements have been successfully tested to predict SOC contents over the visible near-infrared and shortwave infrared ranges [90], in combination with UV-visible fluorescence measurements [95] or restricted to the visible range only [92], or over the mid-infrared only (4000–400 cm) [93].

Laser-induced breakdown spectroscopy (LIBS) is another emerging technology [94]. LIBS can be used to detect multiple elements, such as inorganic and organic carbon can be detected. LIBS principle involves the usage of high energy laser pulse to focus on the sample surface and cause sample evaporation, atomization, ablation, excitation, and ionization. The above low-cost technologies are good candidates to provide numerous training information for digital soil mapping (DSM).

Relevant literature has shown plenty of approaches leveraging a combination of available satellite data, field soil spectroscopy measurements, and machine learning techniques to generate carbon stock estimates and create efficient sampling protocols. Indicatively a couple of study cases and the techniques that can facilitate carbon stock monitoring are briefly presented below. Those case studies employ the use of a combination of data (Remote Sensing, In situ measurements, and the employment of AI Models) in relevance with Precision Agriculture.

Since the quality of the soil of most Spanish vineyards is strongly eroded, carbon depleted, and in a very poor biodiversity status, Andres et al., 2022 examined the real effect of sustainable management strategies on soil carbon stocks and soil functional biodiversity [83].

After a long-lasting shared history of intensive viticulture, the three examined fields currently undergo contrasting management strategies: intensive management (INT), regenerative management (REG), and minimum impact management (MIN). The system management referred to as “minimum impact” farming concerns the minimum usage of external inputs derived from fossil fuels, mineral fertilization, and agrochemicals, and its goal is to improve the on-farm sources management. “Regenerative agriculture” is a farming approach that seeks to close nutrient cycles and to increase farm biodiversity and resilience, which applies locally tailored combinations of practices that contribute to sequestering carbon, building soil fertility and health, and improving the hydrological cycle [98].

Compared to intensified impacted vineyards, SOC stocks are identified in regenerative and minimally impacted vineyards and measured as 2.3 and 3.4 times higher respectively. Previous research showed that regenerative viticulture compared to intensive practices on vineyards favored the microbiology of soil with an increase of about 26.2 times more protists, nematodes about 3,1 times more, and 29,4 times more microarthropods.

Andres et al., 2022, examined three soil cores of vineyards and sampled 16 points from each vineyard [83]. In their case study, they buried Tea bags near the vineyard's soils for the experimentation of the soil quality using Micro Resp™ test and for the examination of the leaves' decomposition rate. The “Tea Bag” test was used to compare the three sampled vineyards for the effectiveness of their soil in decomposing plant residues. The different decomposition level method concerns the comparison of Camellia Sinensis (Green tea), which has fast-decomposing leaves and Aspalathus Linearis (Rooibos tea), which has slow-decomposing leaves for three months. Among the studied soil physical and chemical properties, such as texture, bulk density, aggregate stability, pH, electric conductivity, cation content, and total and labile organic carbon content were responsive to changes in agricultural management. Texture is often considered an inherent and immutable soil characteristic, but it can be altered by practices causing erosion, due to preferential removal of fine particles by runoff [99]. In agreement with previous works [100], the proportion of fine particles is about twice as high in the soil of the regenerative and minimal impact vineyards than in the soil of the intensive vineyard.

The MicroResp™ [45] is a unique microplate-based respiration system that enables the user to analyze up to 96 soil, sediment, or water samples and test a range of carbon sources and/or replicates in a small compact space. The MicroResp™ test provides information about the ability of soil microbes to exploit carbon sources of varied chemistry and recalcitrance. The microbial community catabolic capacity with regenerative and minimum impact approaches showed well-restored outcomes compared to the intensively managed soils. The results of the study indicate that the intensification of ecological agricultural practices is highly promising to restore degraded agricultural soils under Mediterranean conditions.

Cillis et al., 2018, used the SALUS model to study the evolution of SOC under different soil tillage systems considering field scale variability for the case of the Venice Lagoon District in Italy [101]. SALUS is a process-based model developed to simulate the interactions between soil, climate, crop genotypes, and management strategies on crop growth, water, and nutrient cycles during growing seasons. It evolved from the well-established CERES (Crop Environment Resource Synthesis) model with modifications in the nitrogen cycle, water balance, and tillage [102], [103]. The SALUS model requires information about the soil, climate, genotype characteristics and agronomic management to simulate yield, water, and nutrient fluxes at a daily step *(Figure 2)* [102].

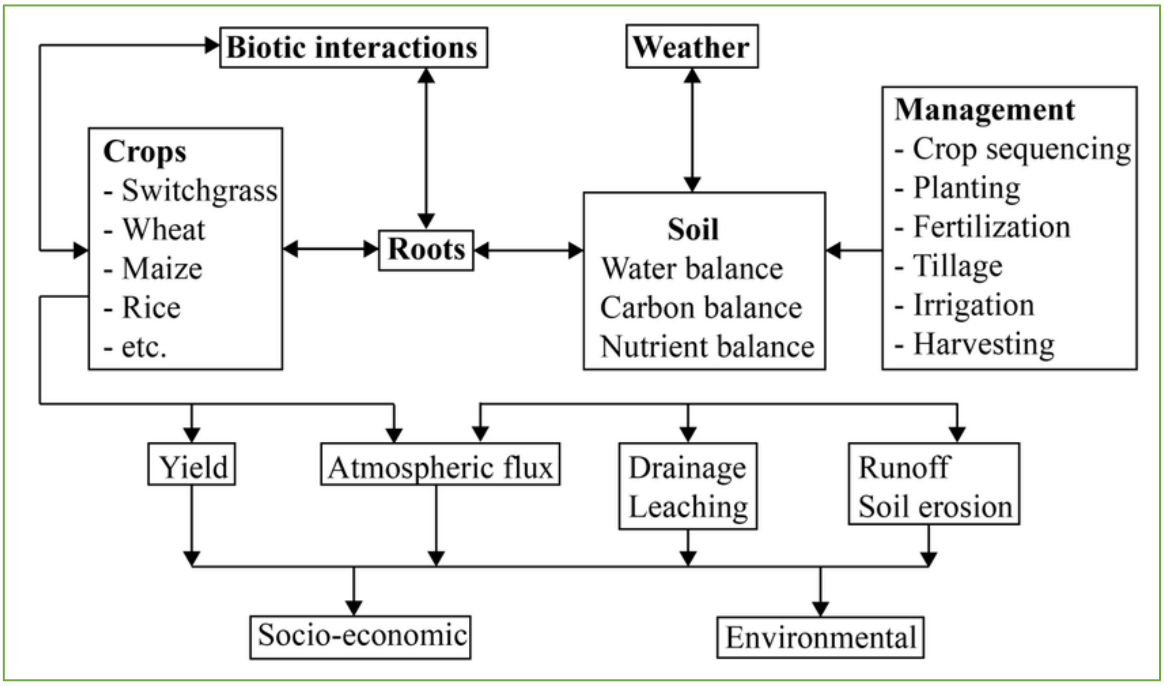

Figure 2 The SALUS model [102]

The study area was managed following the typical farming operation characterized by deep soil tillage and the inversion of the soil layers for five years before starting the experimentation. Successively, three soil tillage systems characterized by varying degrees of soil cultivation intensity were analyzed in the experimentation:

- Conventional tilling (CT): the soil was plowed down to 35 cm deep, leading to the inversion of soil layers. Soil plowing was followed by seedbed preparation using a tine cultivator at 25cm and power-harrow at 10cm.

[45] MicroResp™: https://www.microresp.com/

- Minimum tilling (MT): the initial technique conducted with a tine cultivator at 25cm depth without the inversion of soil layers. Seedbed preparation was carried out during planting operation using a combined power-harrow planter.
- No-tilling (NT): seeds were planted without a working soil surface. Seeding was conducted by planters using special discs that make a narrow trough on the soil surface for seed deposition.

Consequently, each tillage system was accompanied by crop rotation including the most important crops present in the Po Valley: wheat (Triticum aestivum L.), canola (Brassica napus L.), corn (Zea mays L.) and soybean [Glycine max (L.) Merr.]. If not seeded with the main crop, the soil surface was permanently covered by sowing cover crops using conservation tillage techniques. In addition, MT and NT were integrated with PA technologies, consisting of an automatic steering guidance system and control units that allowed automatic section control, and variable rate treatments (VRT). Finally, they identified central test strips managed with fixed rates of input to evaluate the contribution of PA within the different conservation tillage techniques.

The simulation showed a general trend among the treatments characterized by a decrease in SOC stock. However, a significant reduction of 17% and 63% SOC losses were simulated in MT and NT compared to CT respectively. Furthermore, the adoption of conservation tillage techniques decreased carbon emissions related to farming operations, while PA technologies led to an optimization of exhaustible sources such as fossil fuels and fertilizers. Finally, it was demonstrated that the synergy between conservation tillage systems, especially NT, and PA strategies represents a useful tool in terms of carbon emissions mitigation. In fact, with consideration of current climatic conditions and the studied field variability, NTv highlighted a reduction of 56% of total CO_2 as compared to CT.

Dargains and Cabral, 2021 performed the quantification, valuation, and mapping of carbon storage and sequestration of observed (2007–2017) and future LULC (2027) sustainable scenarios at a cattle ranch in Serra da Mantiqueira, in Southeastern Brazil. The aim was to understand how different LULC changes affect the provision of ecosystem service (ES) and contribute to economic opportunities in the farming sector. Under a GIS approach, remote sensing techniques for LULC mapping were employed, Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) for scenario building and carbon assessment, as well as the Sis program are suitable for woodland development and simulation production.

Artificial Intelligence for Ecosystem Services [104], InVEST - Integrated Valuation of Ecosystem Services and Tradeoffs [106], or LUCI - Land Utilization and Capability Indicator [107], are widely used in studies to model the consequences of different management practices on land use and land cover changes (LULCC) and carbon emissions, such as agriculture, forestry, livestock, and the conservation of natural areas [105], [106], [107]. Dargains and Cabral, 2021 used the InVEST[46] Scenario Generator: Proximity Based (version 3.7) *Figure 3*, to create four alternative scenarios for a case study in the district of Bocaina de Minas and Carvalhos, Brazil in 2027.

[46] InVest software: https://naturalcapitalproject.stanford.edu/software/invest

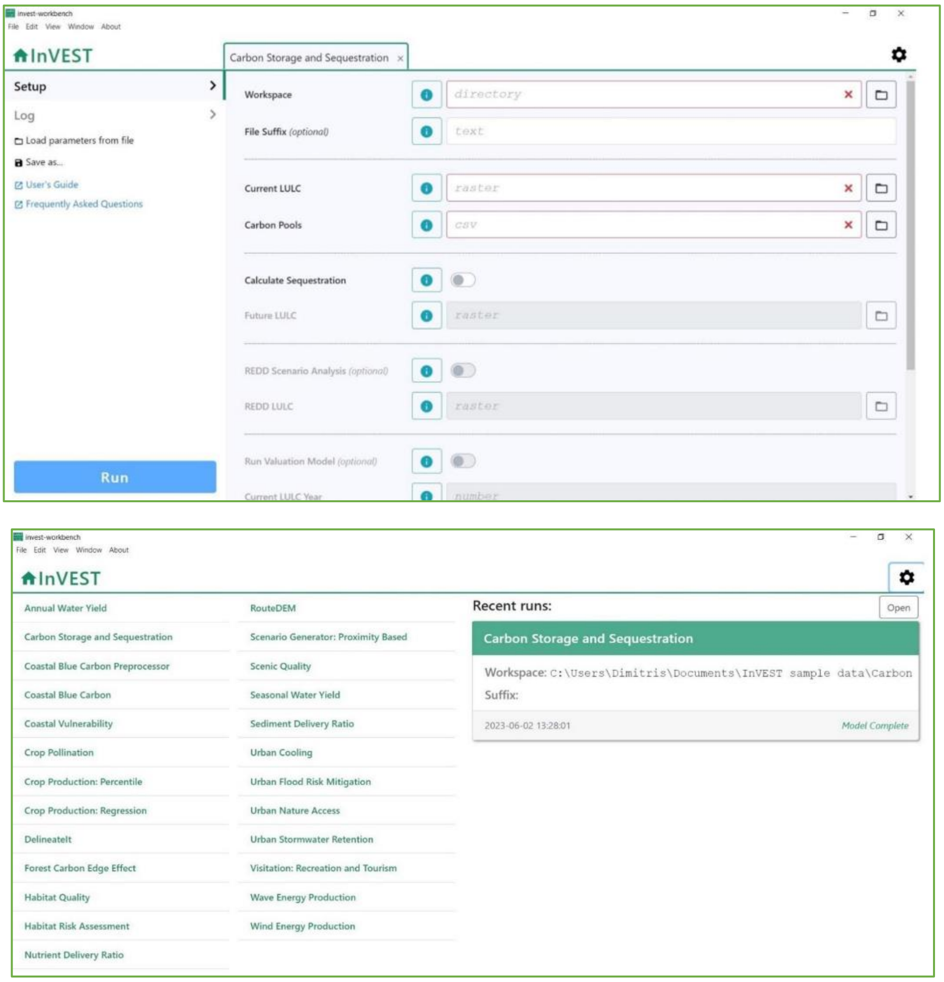

Figure 3. The InVEST interface. Derived from the Standford University website (InVEST, n.d.)

InVEST is a set of models used to quantify, map, and value ecosystem services (ES). InVEST software aims to support decision-makers in exploring the likely results of alternative climate and management scenarios and evaluate trade-offs across sectors and services. InVEST was chosen because it has been widely used, has detailed documentation, comes with useful support tools, and provides sample reference data for each model. Considering future scenarios, 8 classes in total were identified for modeling LULC maps. Four established scenarios were simulated, namely:

- Natural forest regeneration (Scenario 1)
- Recovery of degraded pasture (Scenario 2)
- Forest plantation (Scenario 3)
- Silvopastoral system implementation (Scenario 4)

The InVEST Carbon model (version 3.7) was used to assess the carbon storage and sequestration of the observed (2007 and 2017) and future (2027) scenarios. According to Liang et al., 2017 [106] the carbon storage $C_{m,i,j}$ for a given grid cell (i,j) with land-use type m can be calculated by *Equation 2* as follows:

$$C_{m,i,j} = A \times (Ca_{m,i,j} + Cb_{m,i,j} + Cs_{m,i,j} + Cd_{m,i,j}) \qquad \text{(Equation 2)}$$

where A is the actual area of each grid cell (30 m) and $Ca_{m,i,j}$,$Cb_{m,i,j}$,$Cs_{m,i,j}$, $Cd_{m,i,j}$ represents the densities of the referred carbon pools (Mg C ha^{-1}) for grid cell (i,j) with land-use type m. Thus, carbon storage C and sequestration S across the region can be calculated by *Equation 3* and *Equation 4* respectively, as follows:

$$\Sigma^{n}_{m=1} C_{m,i,j} \qquad \text{(Equation 3)}$$

$$S = C^{T2} - C^{T1} \qquad \text{(Equation 4)}$$

where C^{T2} and C^{T1} indicate static carbon storage at years T2 and T1 (T2 > T1), respectively.

Carbon data required to run the model was obtained for each of these pools through literature research. Carbon storage information for each LULC class was estimated for four pools: above (AGB) and belowground live biomass (BGB), dead organic matter (DOM), and SOC. Reference values for carbon pools are available in InVEST for different land uses.

The forest management software SisEucalipto and SisILPF [108] were used to estimate the average timber volumes per hectare for scenarios 3 and 4, respectively. Brazilian livestock agriculture research company provides a set of free simulation suites, with a software named Sis. They are widely used by farmers and support the management, economic analysis, modeling, growth, and production of planted forests.

According to Feliciano et al., 2018 [108], carbon benefits are greater in agroforestry systems in tropical climates than in those located in other climates and engender the greatest soil carbon sequestration (4.38 Mg C ha^{-1} yr^{-1}) results from the transition of a grassland system to a silvopastoral system. The results of the paper revealed also that a forest management approach mainly directed at natural or commercial reforestation (3 out of the 4 scenarios examined) on a farm level growing trees can store more carbon in changed areas than trying to fix up damaged grasslands (scenario 2).

5 Carbon Footprint

Globally, the measurement of the greenhouse gas intensity of various products, bodies, and processes—expressed as their carbon footprints—occurs in accordance with the maxim that only what is measurable is controllable. There is a continuous involvement in calculation methodologies for carbon footprint determination and it is a vital tool related to carbon footprint management. The notion of carbon footprint has become widely accepted and is currently being marketed in every aspect of life and business. However, the definitions and computations of carbon footprints used in various studies lack coherence. Since carbon footprint is meant to serve as a guide for pertinent emission reductions and verifications, international standardization of the concept is necessary.

Assessment report performed by the Intergovernmental Panel on Climate Change (IPCC) a strong recommendation was reported in reduction of the increase global temperature to avoid the expected ecological issues and economic risks. Extreme weather occurrences and climate change are already signs of the imbalances in natural systems brought on by global warming. Future projections based on natural phenomena changes state that approximately 1-2 billion people will be under water stress, will face crop productivity problems and wildlife and biodiversity will be at stake [109].

Increase in the global temperature caused by the rise of greenhouse gases is a human induced procedure that leads to GHG release into the atmosphere. Not all greenhouse gases (GHGs) have the same ability to induce warming; instead, their potencies vary depending on the radiative forcing they provide and the average amount of time they spend in the atmosphere. Geological and ice core investigations have shown that the rates of increase in GHG concentrations are abnormally high, much above the natural range. The highest contribution to these GHGs release derives from the combustion of fossil fuels in the form of CO_2 [110]. Following CO_2, CH_4 and N_2O are the next highest contribution elements to GHGs release where the major source of those elements derives from the agricultural system [109]. As climate change issues gained prominence on corporate and political agendas, the general population, particularly in industrialized nations, began to recognize their responsibility to take action to combat global warming. Due to these worries and the media, the quantification of the contribution of different activities to global warming, which is typically expressed in terms of carbon footprint, has become extremely popular.

The term "carbon footprint" has its roots in the concept of "ecological footprint," which was first put forth by Wackernagel and Rees, 1998. Ecological footprint states the requirements of human population sustainability derived from the biological productive lands and marine areas measured in world hectares. This idea states that the amount of land needed to absorb all of the CO_2 that humans have ever produced is known as the carbon footprint. Carbon footprint is a notion that has been around for a few decades, although it is also referred to as global warming potential or life cycle impact category indicator.

Quantification of carbon footprint is an important parameter to express GHG emissions and helps in the establishment evaluation and management strategies towards mitigation frameworks. Quantifying and measuring the emissions is an important asset for determining specific areas with high emissions and prioritizing them for reduction. Cost savings and environmental efficiencies are made possible by this. It is necessary to report carbon footprints to third parties or make them public in order to comply with legal obligations, participate in carbon trading, uphold corporate social responsibility, or enhance brand perception. Numerous steps have been taken over time where legislative actions for quantification and carbon footprint reduction took place in cities and corporations. This plays a crucial role in policy making.

USA as a leading country around the world, registration forms related to emissions was set as a mandatory rule for firms and companies. Legal bindings related to aviation emission were also formulated by the EU aiming in emissions reduction. California imposed a ban on the import of non-conventional vehicle fuels unless their carbon footprint was lower than that of fuel sourced from petroleum and minimize the GHG releases from large companies. Through a plan created by the UK government named Low Carbon Transition Plan, citizens households are encouraged to contribute to this cause. It has been noted that the majority of businesses and nearly all individual carbon footprint initiatives focus on cutting emissions or offsetting footprints through the purchase of carbon credits or other control measures.

5.1 Carbon footprint calculation

The quantity of GHGs released, removed, or incorporated into the product's life cycle must be estimated and summed in order to calculate the carbon footprint of the product. Life cycle refers to the manufactured product life cycle that includes all the procedures from the starting point (raw material) until the end point (packaging) including the distribution, consumption and use and the product disposal [111]. When it comes to the production of air pollutants, water use and wastewater generation, energy consumption, greenhouse gas emissions, or any other similar parameter of interest and cost-benefit measures, life cycle assessment (LCA) provides a comprehensive picture of inputs and outputs. In order to calculate a product's carbon footprint, life cycle assessment, or LCA for short, calculates the GHGs emitted or embodied at each stage of the product's life cycle.

GHG accounting standards and guidance are available in many resources [109].

1. World Resource Institute (WRI) GHG protocol / World Business Council on Sustainable Developments contains two standard procedures to be followed. It takes into account the product LCA and Corporate Reporting and Accounting Standard: Value Chain Guidelines. It deals with the estimation of GHG reductions resulting from the use of mitigation strategies in its Project protocol and offers both general and sector-specific calculation tools. It serves as the foundation for the majority of GHG accounting rules, such as ISO 14064. ISO 14064 offers an international standard for establishing limits, measuring greenhouse gas emissions, and eliminating them. Additionally, it offers guidelines for creating GHG mitigation programs [112].

2. Standard for carrying out LCA is the ISO 14025.

3. Under development products carbon footprint follows a standard from the ISO 14067.

4. British Standard Institution guidance for publicly available specifications-2050 that the aim is the requirement specifications for GHG LCA of goods and services.
5. Guidelines for National Greenhouse Gas Inventories from the Intergovernmental Panel on Climate Change (IPCC): The four sectors that comprise the IPCC's classification of anthropogenic sources of greenhouse gas emissions are energy, industrial process and product use, agriculture, forestry, and other land use and waste [112].

The Environmental Protection Agency (EPA) in the USA and the Department of Food and Rural Affairs (DEFRA) and Carbon Trust in the UK are two examples of nations that have created their own GHG accounting criteria. Nearly all of these recently created standards and guidelines, known as comprehensive LCAs, require direct accounting for the GHGs released during the production, use, and disposal of the product, entity, or event.

6 Regional IES Carbon Farming

Current CF situation and techniques used in Cyprus, Greece, and North Macedonia are hardly found in the literature. However, statistics published by the European Union mention some[47]. Furthermore, regional governmental and non-governmental organizations highlight the significance of agriculture's role in reducing greenhouse gas emissions.

6.1 Carbon Farming in Cyprus

The European Food Safety Authority (EFSA), the European Commission, and their partners in the Member States of the European Union launched the #PlantHealth4Life campaign. Cyprus participates in this campaign with the Department of Agriculture of the Ministry of Agriculture, Rural Development and Environment having coordination as the Competent Authority for Plant Health matters (National Plant Protection Organization). The campaign aims to raise public awareness of plant health and its connection to our daily lives. **"The flora of our country is an integral part of our Cypriot cultural identity. Ensuring the health of the forests of Cyprus, the urban greenery, our agriculture, is not just a responsibility but a duty of all of us,"** said Dr. Anthemis Melifronidou - Pantelidou, Senior Product Inspection Officer and responsible for Plant Health issues at the Department of Agriculture[34].

Cyprus submitted its first proposal for a Common Agricultural Policy Strategic Plan on 30 December 2021, after consultation with stakeholders. On 16 November 2022, Cyprus submitted a revised proposal, addressing the Commission's observations on the first draft. The Commission approved this proposal on 2 December 2022 leading to the CAP Strategic Plan 2023-2027. The Strategic Plan 2023-2017 aims to create foundations that will help farmers respect the environment and produce products in a way that will ensure natural resources for future generations. According to the obligation to comply with GAEC 7, farmers who own arable land are obliged to implement one of the following:

- The main crop must not be cultivated in the same field for more than one year (except in the case of perennial crops, grass and other herbaceous forage plants and fallow land).
- Cultivation of a main and a secondary plantation (duration of at least two months) with a genus different from the main one, within the same year is required. The Cyprus CAP emphasizes that in the period 2023-2027, the main crop should be rotated after 3 years.
- As an alternative to the above, farmers who own arable land with plots of seed production according to the Seed Law of 1998, spring potatoes, melons, and watermelons, are obliged to rotate the main crop after 3 years.

Through the CAP,[48] actions such as the ecological program for soil organic matter and soil quality improvement were set. The actions will be carried out by the farmers every year during the months of April and May with annual commitment. They include the removal of the trees from the previous year's plantation, the removal by pruning of the old leaves of the trees of the existing plantation and the depositing of these plant residues on the ground between the lines. Additionally, the farmers should keep proper records throughout their commitment, including the main cultivation cares and the dates they were carried out.

Additionally, they should apply green fertilization with ground cover plants between the tree planting lines on at least 30% of the agricultural area. Ground cover plants are not harvested or grazed, but they are cut before the sporulation of the plants and either remain on the soil or are incorporated into it. The use of nitrogenous fertilizers or manure in areas of green fertilization is banned. Cover the soil with organic materials (except compost) in the tree basins can be used. The current situation in Cyprus shows that

[47]EuroStat databases: https://ec.europa.eu/eurostat/web/main/data/database
[48] Cyprus Common Agricultural Policy (CAP) 2023-2027: https://agriculture.ec.europa.eu/cap-my-country/cap-strategic-plans/cyprus_en

Cyprus wants to contribute to sustainable agriculture and acts towards climate change mitigation through the EU incentives.

As previously discussed, carbon farming techniques known as CT and NT offer numerous advantages in terms of soil fertility and carbon sequestration. For the years 2010 and 2016, Eurostat provides statistics regarding the arable lands under these techniques in Greece, Cyprus, and North Macedonia. As Figure 4 shows, these techniques have been used less frequently over time.

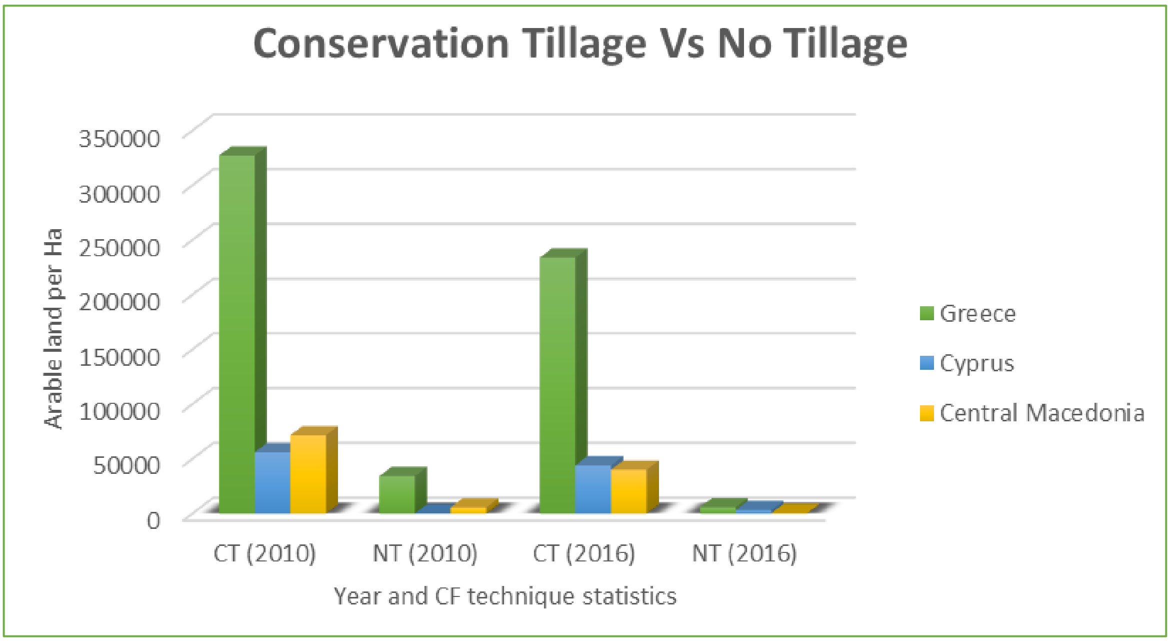

Figure 4. Conservation Tillage and No Tillage practices evolution during 2010-2016. (The statistical data derived from the Eurostat website: https://shorturl.at/mrKP5)

Furthermore, the Office of the Commissioner[49] of the Environment of the Republic of Cyprus organized several conferences with the theme of "Green Transition in Agriculture," covering a range of subjects such as the significance of the CAP, the EU's "Farm to Fork" strategic plan, and the circular economy. These conferences point out the value of sustainability along with the reduction of GHG emissions.

The Cyprus Ministry of Agriculture, Rural Development and Environment announced the invitation for participation in a public consultation on ''The on-Plant Protection Products''. The topic of the consultation is the use and management of pesticides. The Plant Protection Products (Amendment) Law of 2021 (I20/7) has been passed by the House of Representatives and published on 26.04.2021 in the Official Gazette of the Republic. In the context of the general effort made to further increase the level of safety of Cypriot agricultural products, a series of actions are being taken, including the amendment of the relevant legislation, to implement the goal of producing safe products for the consumer and to ensure the full compliance of our farmers with the Legislation concerning Plant Protection Products. The Cyprus Ministry of Agriculture, Rural Development and Environment[50] supports research in relation to pest management and alternative ways for plant protection such as biocides.

The economic value of viticulture and winemaking of the Mediterranean regions is an important parameter for the rural area's sustainability. The Life Cycle Assessment (LCA) method was used by Litskas et al., 2020 with system boundaries from vineyard to market to calculate the CF for wine. Twenty vineyards on the island of Cyprus, where the native Xynisteri variety is grown, and a small-to-medium-sized winery that uses the grapes to make wine provided the input data [113]. For every 76,000 bottles produced, the

[49] Office of the Commissioner of the Environment: http://www.environmentalcommissioner.gov.cy
[50] Cyprus Ministry of Agriculture: https://www.moa.gov.cy/moa/da/da.nsf/home_en/home_en?OpenForm

winery's Carbon Footprint was 99,586 kg CO_2-eq (1.31 kilogram/0.75 L bottle) [113]. 46% of the energy came from electricity, 18% from packing, and 16% from grapevine. 10% of the Carbon Footprint came from fuel such as heating and transportation and waste management such as solid and wastewater. By switching to lighter bottles instead of heavier ones, utilizing less energy, and repurposing some of the solid waste as fertilizer, the CF may be lessened. In order to support sustainable wine production, it is imperative that research be done on eco-innovation in viticulture and winemaking [113].

The highest share in the global wine manufacture held by the EU holding the 62.9% followed by the USA, Argentina, and Australia. Approximately 3 million hectares are planted with vines in the EU, and the wine trade balance was approximately +12 billion euros in 2018. However, like other Mediterranean regions, winemaking and viticulture is an important element that contributes to the rural development and economy of Cyprus [113]. In total, 5,313 ha of Cyprus lands are planted with wine grapes where the annual grapes yield is 20,508 tons. An estimated amount of GHG emissions in Cyprus derived from the agricultural sector was 550,000 tons CO_2-eq. In Litskas et al., 2020 research, estimation of carbon footprint was performed giving that Xynisteri wine emit 1.31kg CO_2-eq/0,75 L bottle. The emissions in the vineyards (19 ha) were estimated to be 16,305 kg CO_2-eq or 858 kg CO_2-eq/ha based on the data. They estimated the wine Carbon Footprint for the winery to be between 19,195- and 22,685-tons CO_2-eq/year (vineyard and winery included 1.745 CO2-eq/L) for the production of the 11–13 million L of wine on the island [113].

EU Agricultural sector accounts for the 470.6MT of CO_2-eq emissions witch this represents the one tenth of the overall emissions. A bottle of wine production of wine has a substantial role in emissions of approximately 1.85kg CO_2eq. About 12 MT of CO_2-equivalent or 30% of the Product Carbon Footprint for wine is contributed by viticulture annually. Litskas et al., 2017 research aim was to identify carbon emissions for Cyprus local grapes variety (Xynisteri, Cabernet Sauvignon and Thomson seedless (Soultanina)) [114]. During this research he identified that Soultanina had the highest product carbon footprint (0.846 kg CO_2-eq per kg of grapes), followed by Cabernet Sauvignon and Xynisteri that had 0.556 and 0.283 kg CO_2-eq per kg of grapes respectively. In addition, creation of a model was performed with a scenario related to carbon footprint reduction showing that product carbon footprint can be reduced by 40-67% with the manure application and tillage reduction [114].

The management of carbon pools, flows, and greenhouse gas (GHG) fluxes at the farm level with the aim of mitigating climate change is known as "C farming," and it is connected to the Carbon Footprint. Apart from the CF, there is still work to be done to balance agricultural output with biodiversity conservation, despite the fact that historically there has always been a mutualistic link between the two. Litskas et al., 2022 used a Cool Farm Tool (CFT) to calculate GHG emissions as well as removals connected to an agricultural product's production [115]. In this study the CFT was evaluated afterwords of the monitored management practices on a Xynisteri grape cultivar. Several management practices considered during this research including tillage, pesticides application, fertilizers, energy use etc.). The emissions associated with inputs, such as gasoline, fertilizer, and pesticides, amounted to 29294 kg CO_2 equivalent per hectare (emissions related to fossil fuels). Reducing fertilizer use by 30%, cutting tillage frequency (from three to two times) to save fuel consumption by 10%, preserving natural vegetation in the field margins, and ceasing to burn pruning material instead of incorporating it into the soil for the vineyard's life cycle are all potential ways to store carbon in the vineyard [115].

6.2 Carbon Farming in Greece

According to the "National Inventory Report of Greece for Greenhouse and Other Gases for the Years 1990-2021," published in 2023[51], the trends in greenhouse gas (GHG) emissions, including CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6, from 1990 to 2021 are detailed in Table 4. The report estimates that Greece's GHG emissions in the base year of the UNFCCC (1990), including Land Use, Land-Use Change, and Forestry (LULUCF), were approximately 101.74 million tonnes of CO_2 equivalent. In 2021, greenhouse gas (GHG) emissions, excluding land use, land-use change, and forestry (LULUCF), reached 77.50 million tonnes of CO_2 equivalent, marking a 25.48% reduction from the levels observed in 1990. Including the impacts of LULUCF, this reduction expands to 29.22%. Specifically, carbon dioxide was the major contributor, making up 74.28% of the total GHG emissions in 2021 (excluding LULUCF) and experiencing a 25.48% decrease from 1990. Methane emissions, constituting 14.61% of the total, fell by 9.61% since 1990, while nitrous oxide emissions, representing 4.93%, dropped by 44.32%. Conversely, emissions of fluorinated gases (f-gases) increased by 35.06% from 1995, accounting for 6.03% of the total GHG emissions in 2021.

Table 4.Total GHG emissions in Greece (in kt CO_2 eq) for the period 1990-2021

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
A. GHG emissions per gas (excluding LULUCF)															
CO_2	83,438.04	83,407.50	84,975.65	84,284.96	86,430.26	86,963.20	89,114.95	93,801.56	98,621.79	97,934.81	102,973.17	105,361.86	105,000.51	109,066.73	109,485.28
CH_4	12,526.76	12,513.86	12,588.58	12,639.36	12,714.41	12,913.15	13,093.06	13,041.52	13,279.72	13,237.90	13,244.46	12,469.81	12,565.23	12,680.88	12,707.47
N_2O	6,855.77	6,736.87	6,588.65	6,095.98	5,973.97	6,157.05	6,308.90	6,166.36	6,091.67	6,047.55	5,867.17	5,740.05	5,694.40	5,624.06	5,628.87
HFC	991.01	1,173.04	962.74	1,702.86	2,272.32	3,487.68	4,046.99	4,344.36	4,856.97	5,667.03	4,460.65	4,079.50	4,375.21	4,112.54	4,309.68
PFC	171.09	171.93	168.83	101.56	63.23	56.52	48.32	113.00	139.86	94.78	110.09	75.81	79.64	80.61	79.37
SF_6	3.02	3.11	3.21	3.30	3.39	3.53	3.62	3.67	3.71	3.81	3.92	4.00	4.18	4.18	4.39
Total	**103,985.69**	**104,006.31**	**105,287.66**	**104,828.03**	**107,457.58**	**109,581.12**	**112,615.84**	**117,470.46**	**122,993.73**	**122,985.87**	**126,659.45**	**127,731.03**	**127,719.17**	**131,569.00**	**132,215.07**
B. GHG emissions/removals from LULUCF															
CO_2	-2,323.53	-2,411.98	-2,682.71	-3,155.04	-2,881.77	-3,097.63	-2,461.35	-2,240.31	-2,426.98	-2,721.77	-2,784.57	-2,670.27	-2,976.49	-2,729.13	-2,722.20
CH_4	70.20	34.83	102.83	91.78	85.59	48.58	29.35	64.73	176.54	13.44	232.99	31.29	4.26	5.99	15.16
N_2O	5.75	4.38	9.48	9.54	9.64	7.74	7.17	10.23	18.14	8.18	23.60	11.70	10.63	11.43	12.87
Total	**-2,247.59**	**-2,372.78**	**-2,570.40**	**-3,053.72**	**-2,786.54**	**-3,041.31**	**-2,424.82**	**-2,165.35**	**-2,232.30**	**-2,700.15**	**-2,527.98**	**-2,627.28**	**-2,961.60**	**-2,711.71**	**-2,694.18**
C. GHG Emissions from International Transport															
CO_2	14,136.62	14,932.09	15,294.12	15,460.88	15,753.14	16,084.99	16,535.05	17,236.86	18,998.77	19,311.12	18,364.24	19,227.92	19,553.34	20,628.46	21,024.82
CH_4	123.66	124.88	123.58	124.92	124.62	125.99	126.47	128.78	133.36	136.92	137.72	141.31	139.52	138.49	139.75
N_2O	242.36	255.57	272.47	298.66	318.79	329.67	324.14	350.38	418.17	429.38	308.58	343.43	341.55	337.60	349.19
Total	**14,502.64**	**15,312.54**	**15,690.17**	**15,884.46**	**16,196.55**	**16,540.64**	**16,985.66**	**17,716.01**	**19,550.30**	**19,877.42**	**18,810.54**	**19,712.66**	**20,034.41**	**21,104.54**	**21,513.76**

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
A. GHG emissions per gas (excluding LULUCF)																	
CO_2	113,888.97	112,419.54	114,545.69	111,080.37	104,319.84	97,354.15	94,505.23	91,392.59	81,713.26	78,636.45	74,927.63	71,361.00	74,843.44	71,780.90	65,759.48	55,619.77	57,556.33
CH_4	12,799.11	12,883.79	12,749.22	12,607.04	12,186.91	12,431.60	12,266.77	12,086.36	11,812.45	11,597.59	11,378.56	10,988.67	11,324.03	11,463.06	11,210.53	10,959.05	11,323.42
N_2O	5,467.73	5,311.31	5,399.06	5,184.78	4,860.91	5,035.28	4,821.51	4,441.49	4,171.65	3,971.17	3,904.13	3,952.87	4,017.64	3,926.58	3,917.48	3,930.76	3,817.43
HFC	4,503.29	2,568.97	3,058.38	3,494.70	3,805.73	4,215.53	4,480.25	4,864.48	5,403.54	5,505.32	5,641.71	5,844.57	5,806.45	5,559.42	5,137.08	4,816.27	4,675.45
PFC	82.70	78.87	93.29	107.64	82.83	117.35	100.08	133.83	156.13	121.65	108.05	122.05	113.58	122.07	123.63	133.54	111.18
SF_6	6.35	8.23	9.75	7.40	5.17	6.04	5.29	5.20	5.31	5.07	5.22	5.36	5.16	5.09	5.07	5.09	5.03
Total	**136,748.14**	**133,270.71**	**135,855.39**	**132,481.94**	**125,261.39**	**119,159.95**	**116,179.12**	**112,923.95**	**103,262.34**	**99,837.26**	**95,965.29**	**92,274.52**	**96,110.32**	**92,857.12**	**86,153.27**	**75,464.49**	**77,488.83**
B. GHG emissions/removals from LULUCF																	
CO_2	-3,553.80	-3,629.67	-2,689.16	-3,389.06	-3,497.52	-3,427.33	-3,534.26	-3,609.93	-2,055.01	-631.89	-4,279.18	-4,123.21	-4,145.35	-4,981.22	-5,506.26	-5,451.26	-5,653.65
CH_4	11.80	23.48	359.82	48.78	51.70	18.38	19.95	48.95	17.92	10.52	12.11	35.47	20.78	21.75	87.00	20.96	153.68
N_2O	13.12	14.62	37.45	17.90	18.50	15.56	15.06	17.21	14.72	13.89	13.80	15.08	13.99	14.24	18.54	14.13	23.74
Total	**-3,528.88**	**-3,591.58**	**-2,291.89**	**-3,322.39**	**-3,427.32**	**-3,393.38**	**-3,499.25**	**-3,543.77**	**-2,022.36**	**-607.47**	**-4,253.27**	**-4,072.66**	**-4,110.58**	**-4,945.23**	**-5,400.73**	**-5,416.18**	**-5,476.23**
C. GHG Emissions from International Transport																	
CO_2	21,333.01	22,004.63	22,639.51	21,938.64	24,796.63	22,045.52	19,771.67	16,465.15	16,246.67	16,267.32	16,801.61	17,129.16	16,901.36	17,129.03	17,540.52	15,096.29	16,478.75
CH_4	136.69	134.34	128.34	120.41	114.73	121.33	105.59	79.91	89.94	88.07	89.35	81.69	82.22	79.59	77.87	66.06	72.16
N_2O	351.01	374.27	363.07	355.02	319.70	280.80	216.54	178.59	165.97	176.04	191.34	207.55	211.29	216.27	218.73	178.57	200.81
Total	**21,820.72**	**22,513.24**	**23,130.92**	**22,414.08**	**25,231.06**	**22,447.65**	**20,093.80**	**16,723.65**	**16,502.58**	**16,531.42**	**17,082.30**	**17,418.41**	**17,194.88**	**17,424.89**	**17,837.12**	**15,340.92**	**16,751.72**

51 https://ypen.gov.gr/wp-content/uploads/2023/05/2023_NIR_Greece.pdf

The report further delves into sector specific GHG emissions trends from 1990 to 2021 (Table 5), highlighting the energy sector, which, in 2021, was responsible for 69.17% of the total GHG emissions (excluding LULUCF), showing a decrease of about 33.02% compared to 1990. This reduction is attributed to improved living standards, significant growth in the service sector, and the integration of natural gas into Greece's energy mix. A notable reduction of 34.97% in emissions from 2008 to 2019 was driven by the economic downturn and a shift towards renewable energy sources and natural gas, alongside enhancements in energy efficiency. The stark reduction in 2020, compared to 2019, was largely due to a decrease in lignite power plant operations, replaced by a higher share of natural gas and renewables, and COVID-19-related restrictions in the transport sector. Greece's National Energy and Climate Plan outlines a strategy for phasing out all but one lignite plant by 2023, with the remaining plant slated for conversion to natural gas by 2028.

The improvement in living standards has led to increased energy and electricity consumption, particularly in residential and tertiary sectors, as well as higher passenger car ownership and transportation activities. The shift towards electricity consumption not only raised direct emissions from electricity generation but also led to increased methane emissions from lignite mining. However, the introduction of natural gas and renewable energy sources (RES) into the electricity system has lowered the CO_2 emissions per unit of electricity produced, with hydropower availability playing a significant role in this trend.

In 2021, the majority of GHG emissions (48.47%) originated from energy industries, with the transport, manufacturing, construction, and other sectors contributing 31.42%, 9.11%, and 10.93%, respectively. Transport was the only sector where emissions increased since 1990, by 13.49%. Emissions from other sectors have seen significant declines, with fugitive emissions from fuels dropping by 99.71% between 1990 and 2021.

Industrial processes and product use (IPPU) accounted for 12.89% of total emissions (excluding LULUCF) in 2021, decreasing by 7.09% since 1990, despite fluctuations over the period. Agriculture's share was 10.38%, with emissions decreasing by approximately 22.60% due to reduced nitrous oxide emissions from agricultural soils, attributed to less synthetic nitrogen fertilizer use and a decline in animal populations. Advances in organic farming, high fertilizer costs, and initiatives promoting efficient fertilizer use contributed to this trend.

Emissions from the waste sector, comprising 7.55% of total emissions (excluding LULUCF), increased by about 1.93% since 1990, driven by higher waste generation. However, enhanced recycling efforts and biogas utilization have mitigated methane emissions increases, while wastewater treatment emissions have significantly declined due to improved aerobic treatment facilities.

Lastly, the LULUCF sector acted as a net sink for GHGs between 1990 and 2021, with its capacity to absorb CO_2 fluctuating, largely due to enhanced absorption by forests and croplands.

Table 5.Total GHG emissions (in kt CO_2 eq) by sector for the period 1990-2021 (1) Emissions / removals from Land Use, Land Use Change and Forestry are not included in national totals (2) Land Use, Land Use Change and Forestry is not included

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Energy	77,133.43	77,246.16	79,228.42	78,870.98	81,109.57	81,174.63	83,395.36	87,928.58	92,652.89	92,091.99	96,890.77	99,346.16	99,208.74	103,085.36	103,538.52
IPPU	10,933.61	10,855.34	10,322.43	10,642.69	11,130.85	12,818.40	13,470.93	13,908.41	14,550.71	15,245.63	14,281.96	13,797.29	13,972.48	13,832.39	13,989.37
Agriculture	10,534.68	10,548.85	10,271.49	9,791.13	9,524.15	9,887.56	9,938.03	9,865.49	9,822.21	9,734.57	9,563.76	9,536.74	9,537.18	9,512.85	9,541.09
Waste	5,383.97	5,355.96	5,465.31	5,523.23	5,693.00	5,700.53	5,811.52	5,767.99	5,967.92	5,913.69	5,922.97	5,050.84	5,000.78	5,138.40	5,146.09
Total [1)]	**103,985.69**	**104,006.31**	**105,287.66**	**104,828.03**	**107,457.58**	**109,581.12**	**112,615.84**	**117,470.46**	**122,993.73**	**122,985.87**	**126,659.45**	**127,731.03**	**127,719.17**	**131,569.00**	**132,215.07**
LULUCF	**-2,247.59**	**-2,372.78**	**-2,570.40**	**-3,053.72**	**-2,786.54**	**-3,041.31**	**-2,424.82**	**-2,165.35**	**-2,232.30**	**-2,700.15**	**-2,527.98**	**-2,627.28**	**-2,961.60**	**-2,711.71**	**-2,694.18**
Index per sector															
Energy	100.00	100.15	102.72	102.25	105.15	105.24	108.12	114.00	120.12	119.39	125.61	128.80	128.62	133.65	134.23
IPPU	100.00	99.28	94.41	97.34	101.80	117.24	123.21	127.21	133.08	139.44	130.62	126.19	127.79	126.51	127.95
Agriculture	100.00	100.13	97.50	92.94	90.41	93.86	94.34	93.65	93.24	92.40	90.78	90.53	90.53	90.30	90.57
Waste	100.00	99.48	101.51	102.59	105.74	105.88	107.94	107.13	110.85	109.84	110.01	93.81	92.88	95.44	95.58
Total [2)]	**100.00**	**100.02**	**101.25**	**100.81**	**103.34**	**105.38**	**108.30**	**112.97**	**118.28**	**118.27**	**121.80**	**122.84**	**122.82**	**126.53**	**127.15**

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Energy	107,379.67	106,056.84	108,314.44	105,412.56	100,450.70	93,261.20	92,161.13	88,474.05	78,070.49	74,618.33	71,306.03	67,047.12	70,354.84	67,394.99	61,325.47	51,663.76	53,598.90
IPPU	14,774.73	12,522.41	12,924.49	12,712.42	10,977.42	11,433.79	10,044.05	10,855.79	11,571.55	11,938.38	11,580.37	12,088.79	12,383.89	11,994.43	11,346.95	10,158.91	9,991.75
Agriculture	9,337.32	9,244.70	9,368.95	9,092.01	8,881.73	9,198.69	8,965.32	8,839.48	8,754.65	8,347.14	8,165.96	8,157.39	8,189.34	8,121.04	8,100.53	8,153.85	8,045.99
Waste	5,256.42	5,446.76	5,247.51	5,264.95	4,951.54	5,266.27	5,008.62	4,754.63	4,865.65	4,933.42	4,912.93	4,981.21	5,182.25	5,346.66	5,380.33	5,487.96	5,852.19
Total [1)]	**136,748.14**	**133,270.71**	**135,855.39**	**132,481.94**	**125,261.39**	**119,159.95**	**116,179.12**	**112,923.95**	**103,262.34**	**99,837.26**	**95,965.29**	**92,274.52**	**96,110.32**	**92,857.12**	**86,153.27**	**75,464.49**	**77,488.83**
LULUCF	**-3,528.88**	**-3,591.58**	**-2,291.89**	**-3,322.39**	**-3,427.32**	**-3,393.38**	**-3,499.25**	**-3,543.77**	**-2,022.36**	**-607.47**	**-4,253.27**	**-4,072.66**	**-4,110.58**	**-4,945.23**	**-5,400.73**	**-5,416.18**	**-5,476.23**
Index per sector																	
Energy	139.21	137.50	140.42	136.66	130.23	120.91	119.48	114.70	101.21	96.74	92.45	86.92	91.21	87.37	79.51	66.98	69.49
IPPU	135.13	114.53	118.21	116.27	100.40	104.57	91.86	99.29	105.83	109.19	105.92	110.57	113.26	109.70	103.78	92.91	91.39
Agriculture	88.63	87.75	88.93	86.31	84.31	87.32	85.10	83.91	83.10	79.23	77.52	77.43	77.74	77.09	76.89	77.40	76.38
Waste	97.63	101.17	97.47	97.79	91.97	97.81	93.03	88.31	90.37	91.63	91.25	92.52	96.25	99.31	99.93	101.93	108.70
Total [2)]	**131.51**	**128.16**	**130.65**	**127.40**	**120.46**	**114.59**	**111.73**	**108.60**	**99.30**	**96.01**	**92.29**	**88.74**	**92.43**	**89.30**	**82.85**	**72.57**	**74.52**

I. Agriculture sector

Between 1990 and 2021, greenhouse gas emissions from agriculture experienced a significant decline of 23.6% (as shown in Table 6), with an average annual reduction rate of 0.76%. This pronounced dip, particularly evident in 1993 and 1994 (Figure 5), can be attributed to the reduction in government subsidies for synthetic fertilizers. The period also witnessed notable volatility in agricultural emissions, especially with regard to N_2O emissions from soil, driven by the yearly changes in agricultural output and the quantities of synthetic fertilizers used. The data on agricultural production was sourced from the Hellenic Statistical Authority (ELSTAT), while information regarding the application of synthetic fertilizers on soils was, for the first time, provided by the Pan-Hellenic Association of Professional Fertilizer Producers & Dealers (PHAPFPD), marking a significant development in tracking agricultural practices.

Table 6.GHG emissions (in kt CO_2 eq) per gas from Agriculture

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CO_2	60	58	56	44	41	45	46	44	44	42	38
CH_4	5664	5659	5576	5582	5451	5620	5632	5644	5614	5610	5551
N_2O	4811	4831	4640	4165	4032	4222	4260	4178	4165	4082	3974
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
CO_2	37	36	35	36	32	30	34	29	25	30	26
CH_4	5575	5619	5656	5625	5612	5623	5622	5525	5490	5602	5562
N_2O	3924	3882	3821	3879	3693	3592	3714	3538	3366	3566	3377
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	
CO_2	25	26	24	23	26	34	33	35	37	33	
CH_4	5494	5395	5212	5101	5009	4989	5023	4964	4943	4947	
N_2O	3321	3334	3111	3042	3122	3166	3065	3102	3174	3066	

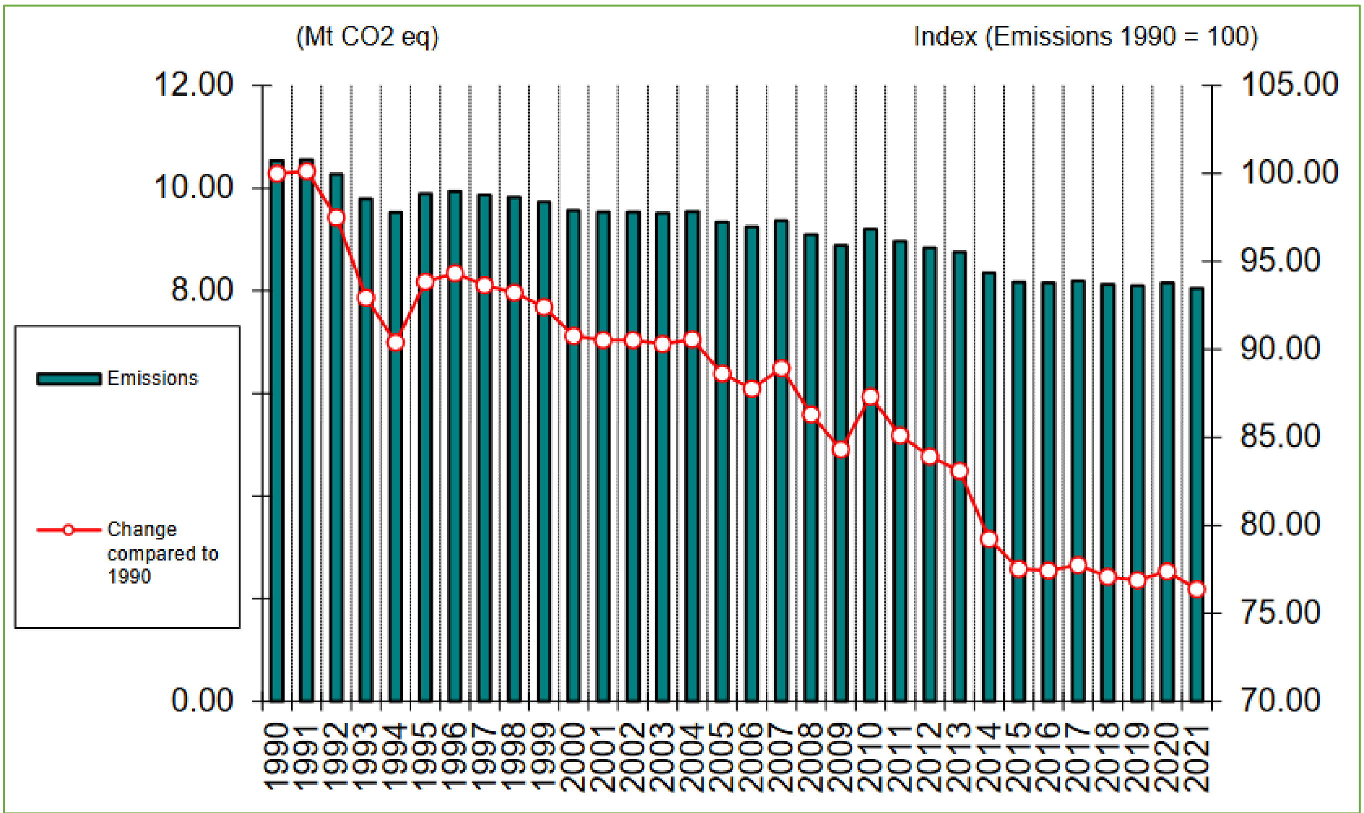

Figure 5. GHG emissions (in kt CO_2 eq) from Agriculture per source category

Agriculture contributes significantly to the emissions of methane and nitrous oxide, key greenhouse gases (GHGs). Detailed breakdowns of these emissions by gas are provided in Table 6, highlighting that methane is the predominant GHG emitted by the agricultural sector, accounting for 53.7% to 62.5% of its total GHG emissions. Notably, methane emissions in 2021 saw a reduction of 12.7% from levels recorded in 1990, with an annual average decline estimated at 0.41%. The primary source of methane emissions within agriculture is enteric fermentation, as depicted in Figure 6, which represents between 43.7% and 51.3% of the sector's total emissions.

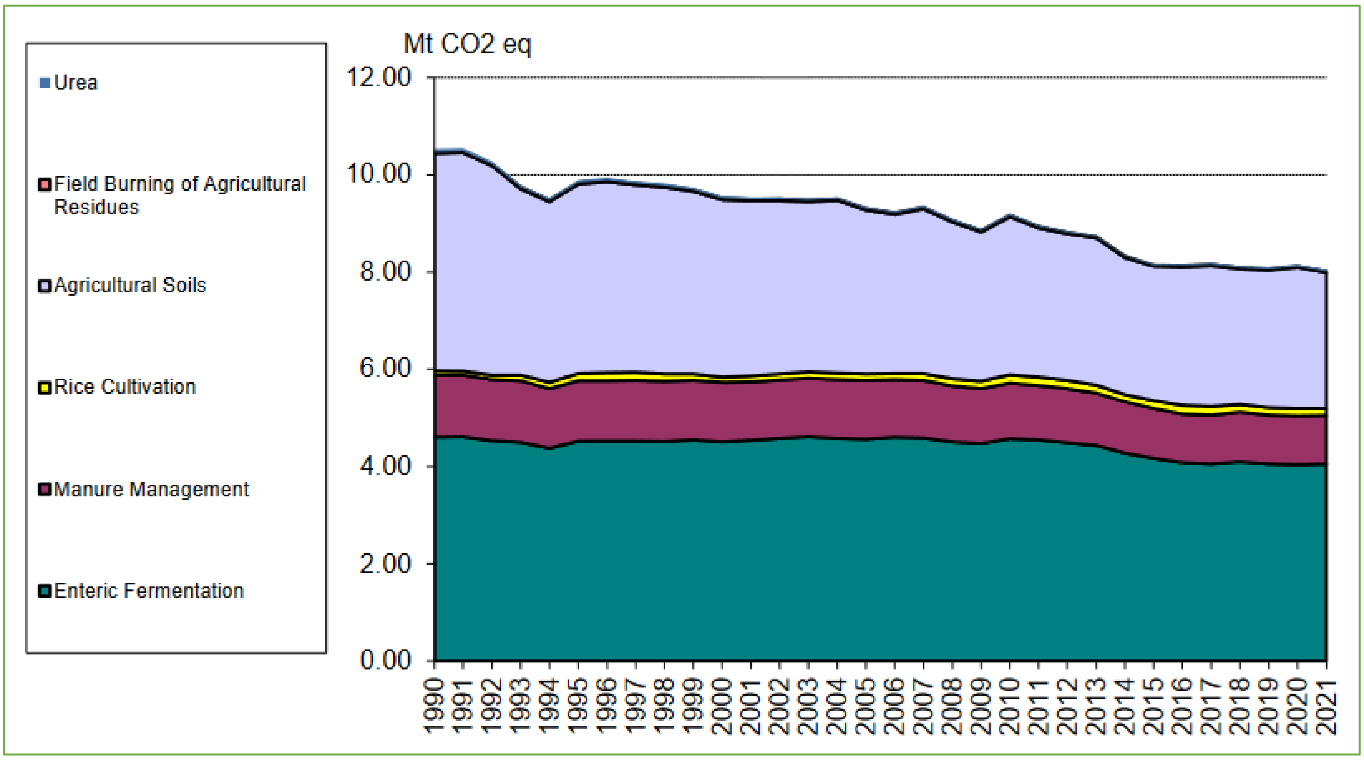

Figure 6.GHG emissions (in kt CO_2 eq) from Agriculture per source category

II. Land Use, Land Use Change and Forestry

From 1990 to 2021, the Land Use, Land-Use Change, and Forestry (LULUCF) sector consistently served as a net sink for greenhouse gases, absorbing more carbon than it emitted. The absorption capacity of this sector varied significantly, ranging from -0.61 Mt of CO_2 eq to -5.48 Mt CO_2 eq, but it displayed a notable upward trend over time. This increase can be largely attributed to the enhanced absorption capabilities of both forest lands and croplands.

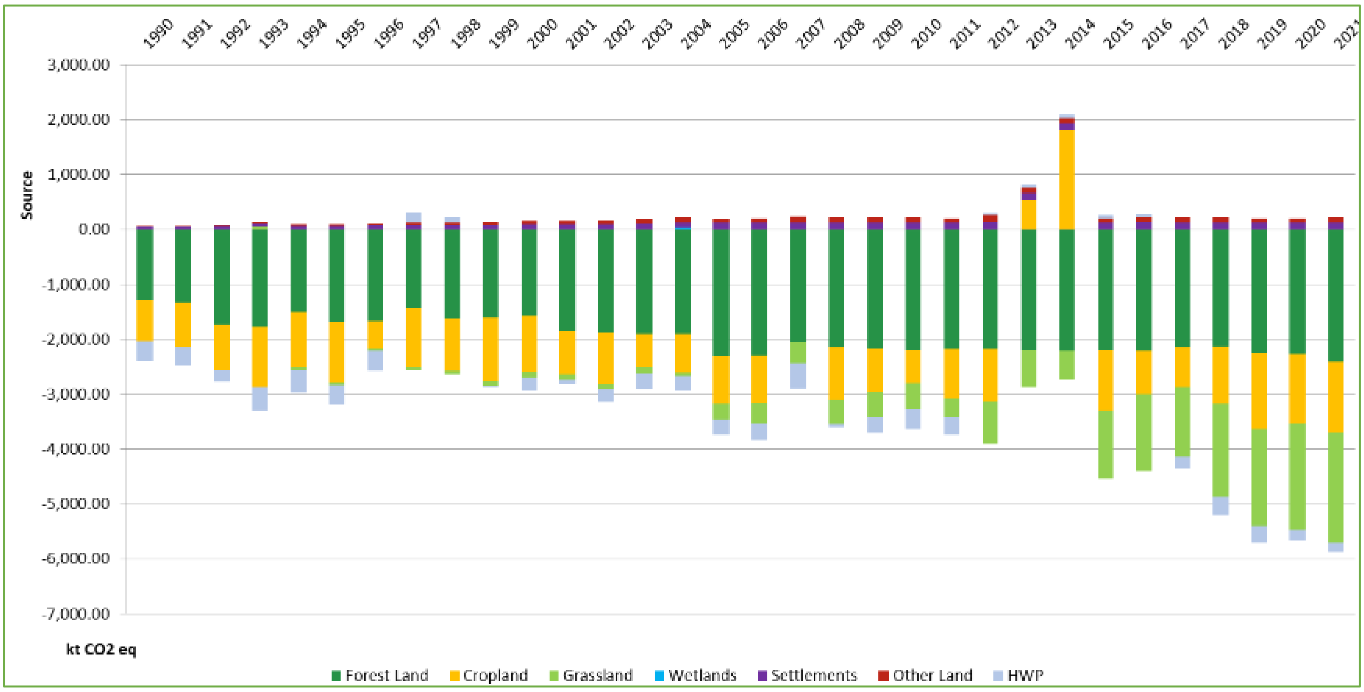

Figure 7.Net GHG emissions / removals (in kt CO_2 eq) from the Land Use, Land Use Change and Forestry sector by category for the period 1990 – 2021

Carbon dioxide (CO_2) is the principal greenhouse gas involved in the addition and removal of carbon from the atmosphere, linked to changes in carbon stocks across various pools. Although CO_2 dominates, other greenhouse gases such as methane (CH_4) and nitrous oxide (N_2O), along with indirect gases like nitrogen oxides (NO_x) and carbon monoxide (CO), are released in smaller quantities during biomass burning.

As illustrated in Figure 7, forest lands have consistently acted as net carbon sinks from 1990 to 2021, absorbing more carbon than they emit. This net absorption results mainly from the increase in biomass due to forest growth and, to a lesser extent, losses from logging and wildfires. The net removal of carbon by forest lands has shown a positive trajectory, primarily owing to decreased logging activities. Specifically, the absorption capacity of forest land improved from -1.23 Mt CO_2 eq in 1990 to -2.26 Mt CO_2 eq in 2021.

Croplands have also seen fluctuating levels of carbon removal, ranging from -0.01 to -1.37 Mt CO_2 eq per year, except in 2013 and 2014 when they temporarily contributed to emissions. The grassland category has acted as a carbon sink since 1994, largely due to the transformation of croplands into grasslands. However, emissions from grasslands have primarily stemmed from converting forest lands to grasslands, changes in vegetation type, and wildfires.

The conversion of forest lands and grasslands into wetlands, settlements, and other land categories has led to minor CO_2 emissions. Detailed emissions and removals by gas and category within the LULUCF sector are summarized in Table 7. This comprehensive analysis highlights the critical role of land use and forestry in mitigating greenhouse gas emissions, emphasizing the importance of managing these areas effectively to enhance their carbon sink capabilities.

Table 7. GHG emissions/removals (in kt) from the Land Use, Land Use Change and Forestry sector by category and gas for the period 1990-2021

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Net CO_2 emissions / removals (in kt)																	
A. Forest Land	-1288.88	-1332.52	-1724.89	-1783.15	-1496.24	-1684.01	-1674.44	-1420.44	-1630.38	-1609.65	-1572.77	-1847.06	-1881.43	-1897.00	-1899.43	-2310.97	-2292.56
B. Cropland	-755.39	-815.55	-827.04	-1078.68	-1019.01	-1111.81	-486.05	-1086.82	-946.88	-1146.23	-1011.10	-786.04	-939.84	-618.83	-707.22	-859.42	-857.28
C. Grassland	0.22	0.20	1.49	54.87	-44.49	-42.76	-48.26	-47.73	-64.87	-88.45	-109.12	-109.13	-91.20	-106.83	-59.52	-287.22	-375.40
D. Wetlands	NE.NO	NE.NO	0.04	0.70	0.26	0.08	0.20	0.57	2.16	0.33	2.51	0.74	2.37	1.37	26.30	3.10	4.23
E. Settlements	49.74	54.76	55.07	58.80	62.90	64.24	77.95	72.54	75.52	81.96	89.96	89.58	94.25	111.79	106.05	115.06	115.37
F. Other Land	19.79	12.68	29.99	23.60	26.41	27.89	39.44	44.87	46.20	51.52	59.15	64.23	69.89	69.09	77.69	69.91	82.51
G. HWPs	-349.00	-331.55	-217.37	-431.18	-411.32	-350.83	-369.93	198.06	96.05	-10.87	-235.05	-81.70	-230.45	-288.58	-265.64	-283.87	-305.35
CH_4 emissions (in kt)																	
A. Forest Land	1.88	0.71	2.06	2.15	1.88	1.24	0.51	1.50	4.72	0.30	5.84	0.62	0.06	0.09	0.23	0.20	0.58
B. Cropland	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
C. Grassland	0.63	0.53	1.61	1.13	1.18	0.50	0.54	0.81	1.59	0.18	2.48	0.50	0.09	0.13	0.31	0.23	0.25
D. Wetlands	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
E. Settlements	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
F. Other Land	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
G. HWPs																	
N_2O emissions (in kt)																	
A. Forest Land	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.03	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00
B. Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
C. Grassland	0.00	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.00
D. Wetlands	NO	NO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E. Settlements	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02
F. Other Land	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02
G. HWPs																	
TOTAL LULUCF (kt CO2 eq)	-2107.91	-2305.10	-2388.77	-2848.77	-2586.52	-2872.37	-2295.07	-1946.29	-1758.29	-2538.91	-1941.35	-2412.11	-2771.89	-2504.41	-2461.12	-3282.91	-3300.98

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Net CO_2 emissions / removals (in kt)															
A. Forest Land	-2051.96	-2145.65	-2159.80	-2194.05	-2182.38	-2176.86	-2197.12	-2208.18	-2185.80	-2200.00	-2141.58	-2135.90	-2254.56	-2266.56	-2413.22
B. Cropland	-5.13	-943.35	-800.78	-613.96	-900.69	-956.24	542.27	1820.13	-1108.83	-808.92	-726.24	-1033.73	-1375.76	-1261.93	-1277.54
C. Grassland	-378.79	-444.78	-457.88	-464.69	-333.55	-773.60	-670.40	-512.62	-1250.63	-1392.83	-1276.18	-1711.81	-1770.62	-1944.13	-2011.39
D. Wetlands	3.58	2.82	2.82	2.61	2.59	2.85	2.52	0.09	0.07	0.03	0.01	0.21	1.57	0.94	2.22
E. Settlements	119.25	121.08	122.24	121.34	119.89	131.89	121.00	118.99	120.37	133.56	131.49	131.71	125.95	124.65	124.63
F. Other Land	107.50	99.33	89.72	86.45	84.33	128.23	82.43	82.47	80.15	81.38	83.76	79.02	75.65	74.13	94.32
G. HWPs	-468.00	-76.06	-291.14	-363.89	-323.96	35.61	64.44	67.31	65.78	64.33	-216.34	-310.60	-308.21	-178.08	-172.66
CH_4 emissions (in kt)															
A. Forest Land	7.71	1.20	1.31	0.55	0.24	0.88	0.07	0.04	0.17	0.49	0.22	0.16	0.83	0.33	5.09
B. Cropland	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
C. Grassland	5.14	0.54	0.54	0.10	0.48	0.87	0.57	0.33	0.26	0.78	0.52	0.62	2.28	0.42	0.40
D. Wetlands	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
E. Settlements	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
F. Other Land	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
G. HWPs															
N_2O emissions (in kt)															
A. Forest Land	0.05	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.03
B. Cropland	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C. Grassland	0.04	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.00	0.00
D. Wetlands	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E. Settlements	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
F. Other Land	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
G. HWPs															
TOTAL LULUCF (kt CO2 eq)	-2291.89	-3322.39	-3427.32	-3393.38	-3499.25	-3543.77	-2022.36	-607.47	-4253.27	-4072.66	-4110.58	-4945.23	-5400.73	-5416.18	-5476.23

Note: Negative (-) sign denotes GHG removals and positive sign (+) GHG emissions

III. Cropland Category description

This report outlines the estimation and documentation of carbon stock variations within Cropland that remains under cultivation and Land that has been transformed into Cropland. Specifically, the alterations in carbon stocks within living biomass and soil on lands continuously cultivated are attributed to modifications in management approaches and crop types. Methane (CH_4) and Nitrous Oxide (N_2O) emissions from these areas were assessed as a segment of agricultural activities. The net carbon dioxide (CO_2) emissions or removals for each distinct subcategory are detailed in Table 8. Drawing from the

Agricultural Statistics provided by the Hellenic Statistical Authority of Greece, there has been a notable shift in agricultural patterns over the past four decades. Tree crops have nearly doubled in extent, primarily at the expense of cereal crops. This significant shift in agricultural cultivation has led to the formation of a carbon sink in the expanding biomass stocks, where carbon is being progressively sequestered. The scale of this carbon sink ranges from -0.01 to -1.37 Mt of CO_2 equivalents per year from 1990 to 2021, except 2013 and 2014, when the category served as a carbon source. The change in carbon stocks within mineral soils can be traced back to time-evolving practices or management strategies. Given the absence of diverse datasets indicating successive management changes during the examined period, the alterations in carbon stocks in mineral soils were presumed to be negligible. Conversely, the cultivation of organic soils has consistently resulted in net emissions amounting to 244 kt of CO_2 annually throughout the same timeframe.

Table 8. Net GHG emissions/removals (in kt) from Cropland by subcategory for the period 1990 – 2021

IPCC categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Cropland remaining cropland											
CO_2	-807.67	-874.01	-839.44	-1091.29	-1031.36	-1124.28	-498.52	-1099.15	-959.27	-1158.70	-1086.36
CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N_2O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Land converted to cropland											
CO_2	52.28	58.46	12.39	12.61	12.35	12.47	12.47	12.34	12.39	12.48	75.26
CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Total (kt CO_2 eq)	-754.93	-814.62	-826.12	-1077.75	-1018.08	-1110.87	-485.11	-1085.89	-945.95	-1145.29	-1009.61

IPCC categories	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Cropland remaining cropland											
CO_2	-874.97	-967.76	-646.81	-735.25	-887.26	-885.16	-33.12	-971.22	-828.69	-636.05	-916.47
CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N_2O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Land converted to cropland											
CO_2	88.93	27.92	27.98	28.02	27.84	27.88	27.99	27.87	27.92	22.09	15.78
CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N_2O	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
Total (kt CO_2 eq)	-783.94	-937.73	-616.73	-705.12	-857.32	-855.17	-3.02	-941.24	-798.67	-612.31	-899.50

IPCC categories	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Cropland remaining cropland										
CO_2	-971.97	526.49	1804.06	-1124.59	-824.85	-742.18	-1049.74	-1392.04	-1278.49	-1294.72
CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N_2O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Land converted to cropland										
CO_2	15.73	15.78	16.07	15.76	15.93	15.94	16.01	16.28	16.56	17.18
CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total (kt CO_2 eq)	-955.06	543.46	1821.32	-1107.64	-807.73	-725.05	-1032.53	-1374.56	-1260.73	-1276.30

NO: Not Occurring; NA: Not Applicable; NE: Not Estimated

6.3 Carbon Farming in North Macedonia

In the Republic of North Macedonia in 2020 agriculture participated with 9.2% in the total GHG emissions with a decline of 25.7% compared to 1990 as a result of livestock reduction. The main cause of these emissions is livestock production participating with 77.6%. Synthetic fertilizers and on-farm energy use are other significant emission sources [52]. Arable soils are characterized with low levels of organic carbon with an average of 1.5 % in the range from 0.5 - 3.2 %. Soils under perennial crops show a higher content of organic carbon or an average of 2.66% in the range from 1.0 - 4.7% compared to soils under different crops. Agricultural soils are losing more carbon than they store which results in losses of soil organic matter. The main cause is narrow crop rotation and mono-cropping (in the case of tobacco) and insufficient application of manure, as well as intensive soil tillage, irrational use of mineral fertilizers and insufficient application of organic fertilizers. Currently, carbon farming practices are not commonly utilized in the country, but experts are very optimistic that these practices could contribute to increasing the soil organic matter content in Macedonian agricultural soils. According to research, under North Macedonian conditions, the application of cover crops alone could sequester around 1.5 tons per hectare in a year. Planting fast-growing crops (annual legumes, mustard, Sudan grass, other grasses, and fodder cultures) can produce substantial amounts of biomass in a short period of time and can be incorporated in the soil to increase its organic matter [53].

There is a connection between carbon farming and organic farming that lies in their shared commitment to sustainable agricultural practices, with both approaches emphasizing soil health, carbon sequestration, and reduced emissions to promote environmentally friendly and resilient farming systems. Organic farming is slowly evolving in the country. The dominating organically produced crops are fodder cultures, cereals, orchards, aromatic and medicinal plants, and horticulture. At the same time there is a notable growth in interest in raising organic cattle, sheep, goats, and beehives. The supply of processed organic products at the moment is very limited and there is a gap between organic farmers and the food processing industry[51].

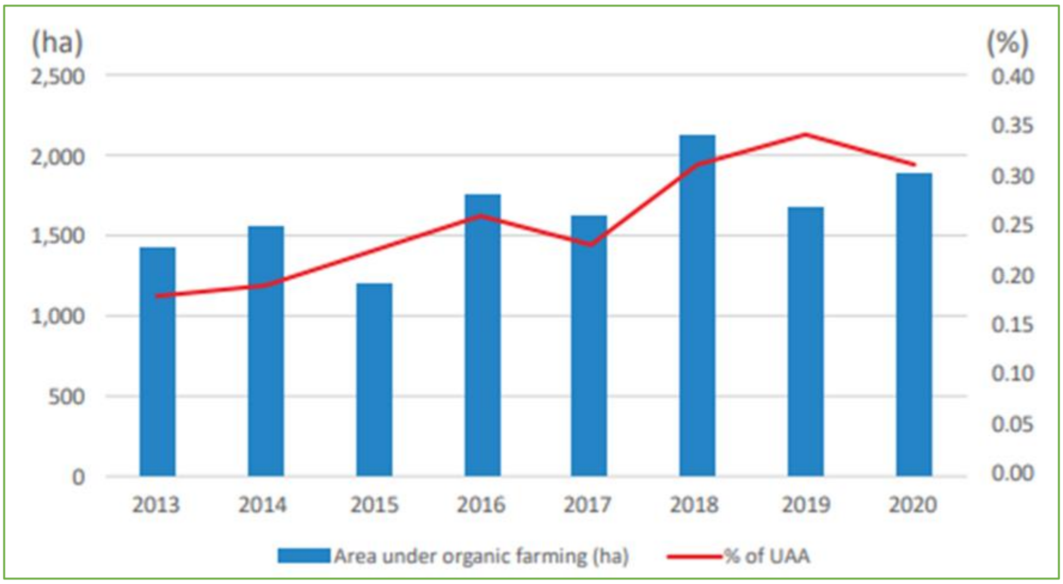

Figure 8. Area under organic farming, North Macedonia[51]

[52] World Bank, Green Growth in North Macedonia's Agriculture Sector, 2022
https://openknowledge.worldbank.org/server/api/core/bitstreams/68656c4b-15a1-4cd7-92ed-7dff1b297b58/content

[53] Rapid assessment of the water food-energy nexus in North Macedonia,2022
https://api.klimatskipromeni.mk/data/rest/file/download/c64c8932c032bca28381f359a36c2180465c6c5a3a82e7721e9caba57486b8cc.pdf

The Republic of North Macedonia, as a party to the United Nations Framework Convention on Climate Change (UNFCCC), signed (2015) and ratified (2017) the Paris Agreement, nationally determined its contribution (NDC) to the global efforts for GHG emissions reduction [54]. The country is also dedicated to effectuating the European Union`s Green Deal expected outcomes. However, the current situation indicates that North Macedonia is behind the green growth ambitions emerging from the European Green Deal, the Farm to Fork Strategy and the Biodiversity Strategy. In 2020, organic farming equals 0.36% of the total farmland while the European Green Deal Target is 25% for 2030. Also, since 2018, the area fully converted to organic farming has declined. The percentage of fallow land in the total utilized agricultural area (UAA) was 2.4% in 2016 (compared to 3% in 2013) while the European Green Deal target is 10%. The annual use of pesticides declined by 16.3% in 2018-2019 compared to the average levels of 2012-2014 against the EU target of at least 20% reduction by 2030. The implementation of climate change adaptation policies in agriculture is restricted by the dependence on smallholders in the sector, insufficient awareness of relevant stakeholders concerning the negative effects of climate change and the limited support for farmers. The most important barriers are the shortages in farm infrastructure investments, the need for new technology adoption, and the lack of technical capacity which would enable farmers to pursue adaptation actions [51].

The different aspects of implementation of carbon farming practices and technologies are addressed within the scope of the following national policies:

- National Strategy for Agriculture and Rural Development of the Ministry of Agriculture, Forestry and Water Economy of the Republic of North Macedonia for the period of 2021-2027 - policies for natural resources management and mitigation of the effects from climate change [55]
- Long-term strategy for climate action and action plan of the Ministry of Environment and Physical Planning of 2021 – specific objective to reduce GHG emissions by 34% in the agriculture sector by 2050 compared to 1990 [56].

National Strategy for Sustainable Development for the period of 2009-2030 of the Ministry of Environment and Physical Planning – action plans and strategies for sustainable development in all sectors including agriculture [57]

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[54] Ministry of Environment and Physical Planning of the Republic of North Macedonia, 2021, Enhanced Nationally Determined Contribution. https://unfccc.int/sites/default/files/NDC/202206/Macedonian%20enhanced%20NDC%20%28002%29.pdf

[55] Ministry of Agriculture, Forestry and Water Economy of the Republic of North Macedonia, 2021, National Strategy for Agriculture and Rural Development for the period of 2021-2027. https://www.mzsv.gov.mk/CMS/Upload/strateski%20dokumenti/ns_16_2021.pdf

[56] Ministry of Environment and Physical Planning of the Republic of North Macedonia, 2021, Long-term strategy for climate action and action plan. https://api.klimatskipromeni.mk/data/rest/file/download/2ba0633b4385d2538862b16572bff16d13ad0895665ee2729d24e177022ace27.pdf

[57] Ministry of Environment and Physical Planning of the Republic of North Macedonia, 2010, National Strategy for Sustainable Development for the period of 2009-2030. https://www.moepp.gov.mk/wpcontent/uploads/2014/12/Nacionalna-Strategija-za-Odrzliv-Razvoj-vo-RM-NSSD-Del-1.pdf

7 Survey details

The questionnaire was activated from 06/12/2023 until 02/02/2024. **Totally, 313 people from the quadruple helix answered the form from all the three ecosystems (CY, GR and NMK). Specifically, 159 answers derived from North Macedonia, 99 responses from Greece and 55 answers from Cyprus**.

Common needs between the three countries participating in this survey were identified. Participation in this survey indicates a clear agreement on GHG mitigation using carbon farming approaches. Additionally, participants showed a strong interest in research and innovation in relation to climatic change mitigation in the agricultural sector. Uncertainties about profit and regulations were also set on table with high voting rate by participants. Individuals who responded to this survey appear to be prepared for a shift toward more environmentally friendly farming methods and the accomplishment of the EU's zero-net goal.

The survey was conducted within the Carbonica project framework in order to identify the current gaps in the agricultural sector as well as the farmers' needs. The survey was composed of 23 questions regarding carbon farming, knowledge in specific fields, current issues farmers face and possible interest in collaboration with Carbonica project.

Some of the questions were also related to EU policies and fundings and how this affects them in total. Economic uncertainty is one of the most important issues that farmers face according to this survey.

One of the aims of the Carbonica project is to provide knowledge exchange and field training to farmers in order to promote sustainability and eco-friendly solutions that possibly will be beneficiary in relation to productivity and soil health. By promoting carbon farming in agriculture based on literature will provide a lot of benefits including profit.

The documents representing the current analysis emphasize the collaboration of Carbonica partnership with people from the Quadruple helix for achieving the zero-net outcome and carbon farming solutions.

The results presented in the current report illustrate the responds to certain questions related to Carbonica objectives as well as the discussion held during the one-by-one interviews of the selected participants. Each country held its own interviews on a country level and reviewed in the current report.

The sources of all the information and statistical figures shown below are the results derived from 313 survey responses.

7.1 Categories involved in the current questionnaire

This survey was originally chosen to be applied in the frameworks of Carbonica project and was designed to be answered by specific countries involving Cyprus (CY), Greece (GR) and North Macedonia (NMK). The aim of this questionnaire is to identify challenges concerning the agricultural sector and how Carbonica can find solutions towards sustainability and carbon farming.

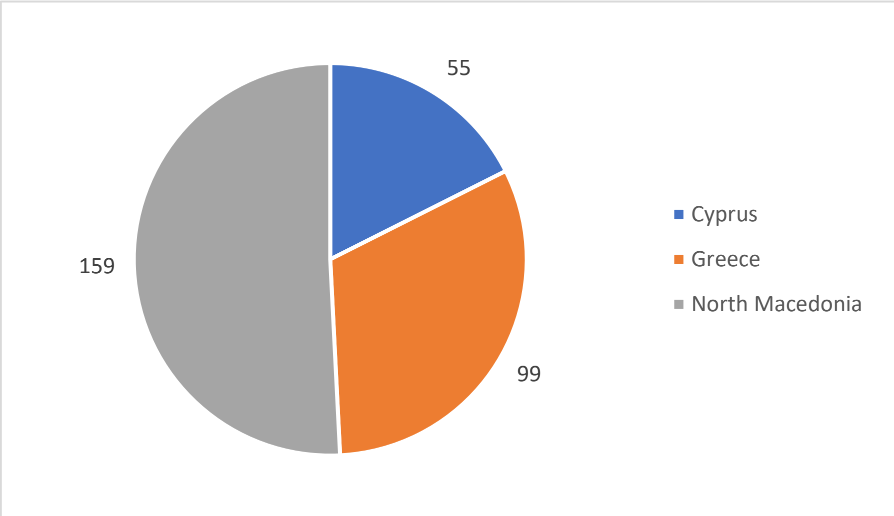

Figure 9. Number of responses per ecosystem

- Respondents are based on the chosen countries involved in the Carbonica project.
- More than half of the responses on the current survey derived from NMK driven by their interest in support and some to involve in the Carbonica project's aims.
- The second most answers derived from Greece followed by Cyprus with 55 responses. Cyprus due to its size as a country has the lowest number of responses.

The categories responded to the current questionnaire are representatives from all the quadrants of the quadruple helix derived from academic communities, farmers, industry, non-governmental organizations, citizens, policy makers, and other categories (e.g., agronomists, veterinarian etc.). The figure below illustrates each category amount of people answering this survey from the three countries.

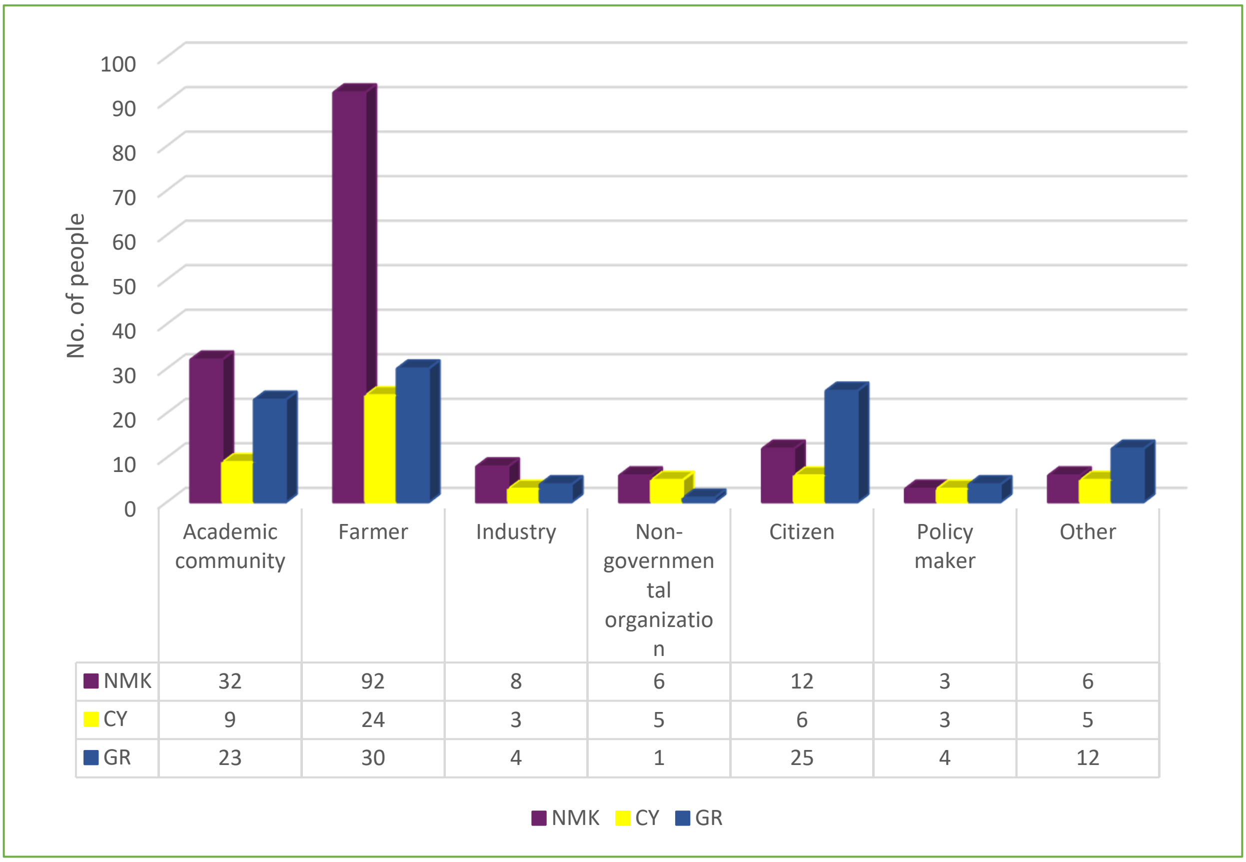

Figure 10. Categories of respondents to the current questionnaire

- The depicted figure above indicates that the majority of respondents to this questionnaire belong to farming communities. This is because the topic concerns them the most as it will give them an insight into new and innovative solutions on a farm level.
- Academic communities are the second in row of most attendance since they can benefit from this project.
- A surprise observation appeared from Greece since many citizens appeared answering this questionnaire.
- An almost equal responses derived from other categories between the three countries.

7.2 Participation to the current survey

Answers derived from the three countries showed a mutual preference in collaboration and knowledge exchange with other stakeholders regarding their contribution to CARBONICA project. Cyprus with 40% and Greece with 27% primary motivation for participating on this questionnaire was the sustainability promotion on agricultural sector while North Macedonia with 36% was for the development of innovative agricultural solutions.

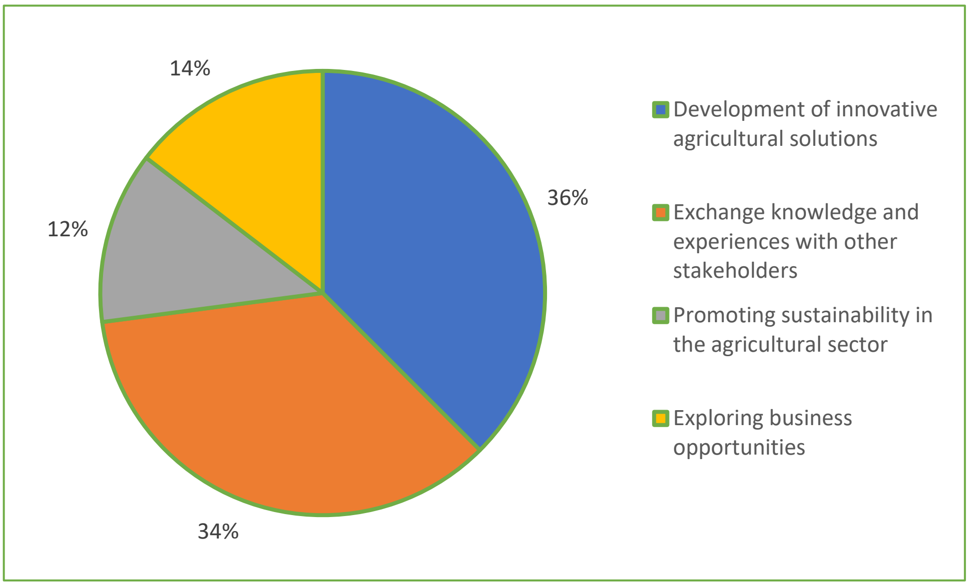

Figure 11.Primary motivation for participating in this questionnaire (NMK

- The second most selected option as the driven force for NMK participants for contributing to this survey is the exchange of knowledge and experiences with other stakeholders. This shows that knowledge exchange is an important asset for achieving certain goals.

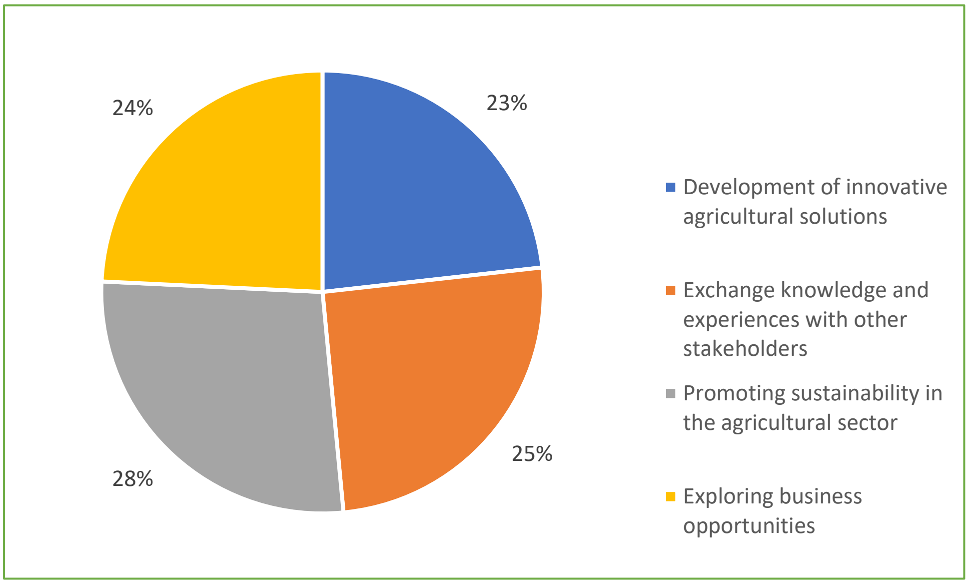

Figure 12. Primary motivation for participating in this questionnaire (GR)

- No significant numerical difference appears by Greece answers about the motivation for answering this questionnaire.
- The highest percentage, 28%, attended this survey in order to promote sustainability in the agricultural sector.
- The other driven reason for participation is the promotion of innovation in agriculture, the exchange of knowledge and experiences with other stakeholders and the exploitation of business opportunities.

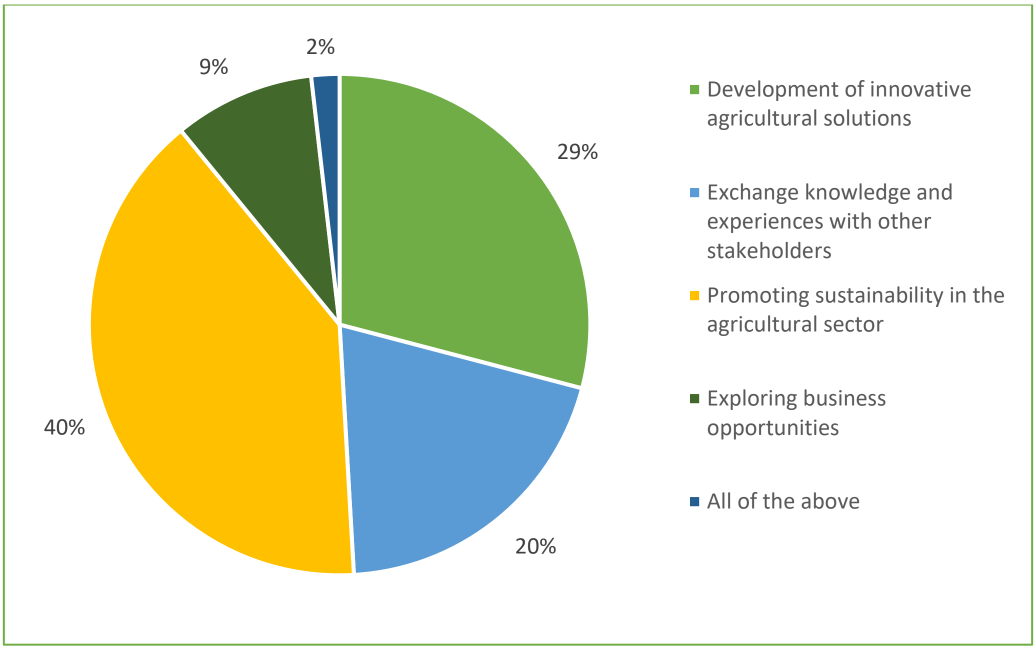

Figure 13. Primary motivation for participating in this questionnaire (CY)

- 40% of Cypriot respondents' motivation for completing this questionnaire aligns with that of Greece, particularly regarding the promotion of sustainability in agriculture.
- 29% of the people's motivation to answer this survey is the development of innovative agricultural solutions.

7.3 Collaboration challenges and needs in agricultural sector

The most believed collaboration obstacles among various stakeholders by Greek and Cypriot community were the establishment of common goals and cooperation with 29% and 34% respectively. Most of North Macedonian participants (33%) voted that the primary obstacles regarding collaboration between stakeholders is the communication and information exchange. The question about participants thought on collaboration with other stakeholders' involvement in Multi Actor Platform (MAP) of the Carbonica project, CY with 43%, GR with 48% and NMK with 49% shares the same priority, that collaboration is an important asset for ideas and experiences enhancement.

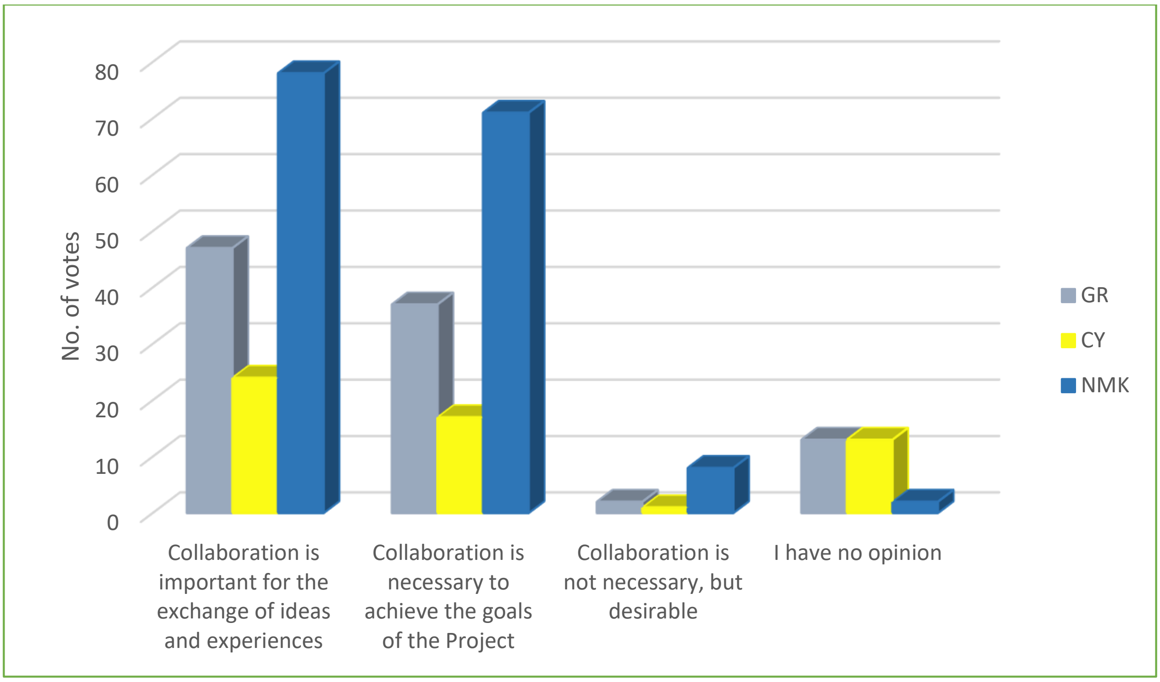

Figure 14. Thoughts on collaborating with other stakeholders that participate to the Multi Actor Platforms (MAP) of Carbonica Project

A variety of different opinions and needs from each country derived from the question about the importance in relation to the agricultural sector. The most important priority derived commonly from each country is about the financial profits and market expansion. Specifically, 15, 32 and 64 people from CY, GR and NMK respectively voted this answer as the most important. This is very reasonable since the agricultural sector is treated as a minority but at the same time is the primary source of food. However, the second most important parameter in the agricultural sector differs for each country revealing the different needs of each of them on a country level.

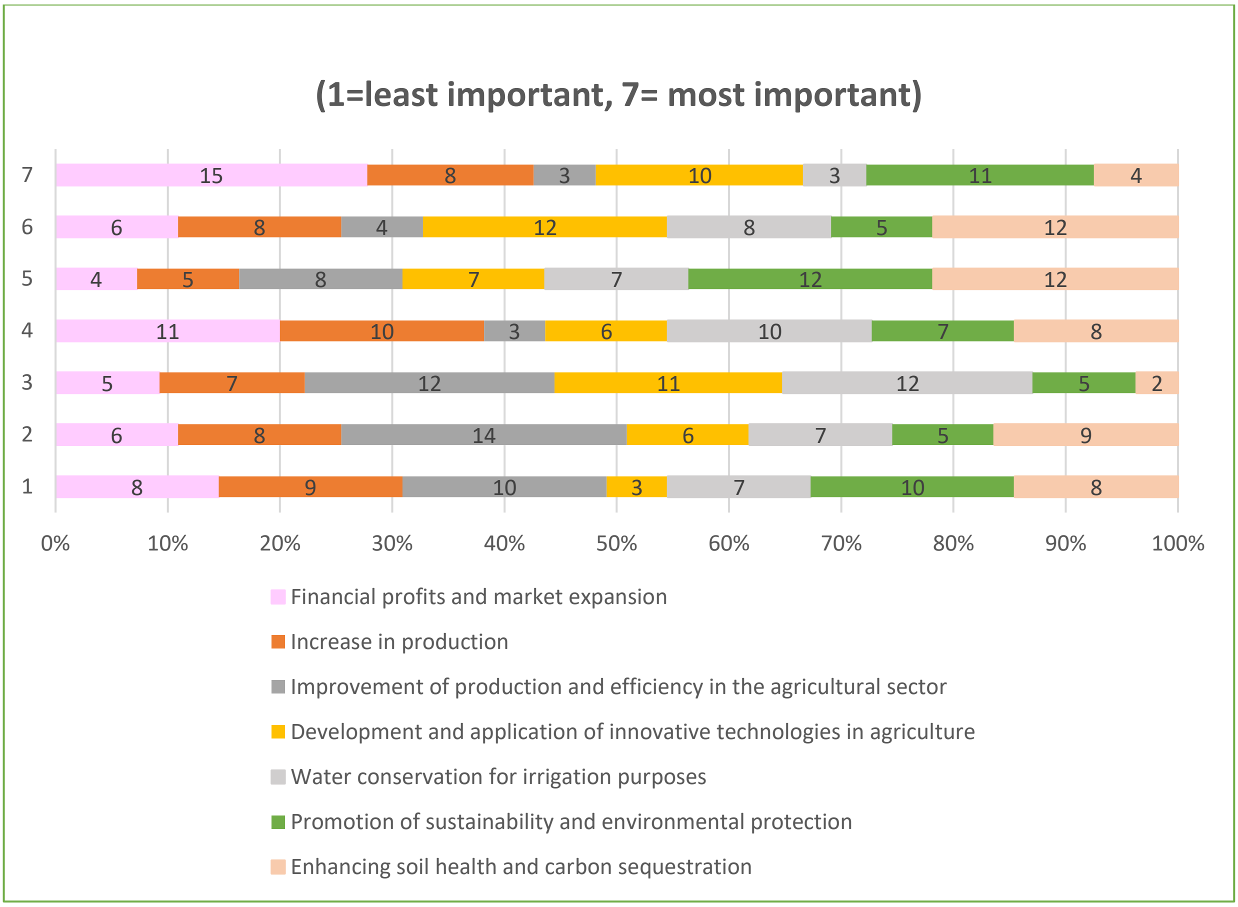

Figure 15. Ranking of the goals based on participants experience (CY)

- An equal amount of people from CY (12 individuals) believes that the second most important thing in agriculture is the development and application of innovative technologies and the soil enhancement and efficiency in agricultural sector.
- An equal interest appears as the third most important goal in the agricultural sector between participants. More specifically, 12 individuals for each option support the enhancements of soil health and carbon sequestration and sustainability promotion and environmental protection.
- A noteworthy finding was made regarding the ranking of the increase in production as the fourth most important objective to accomplish.

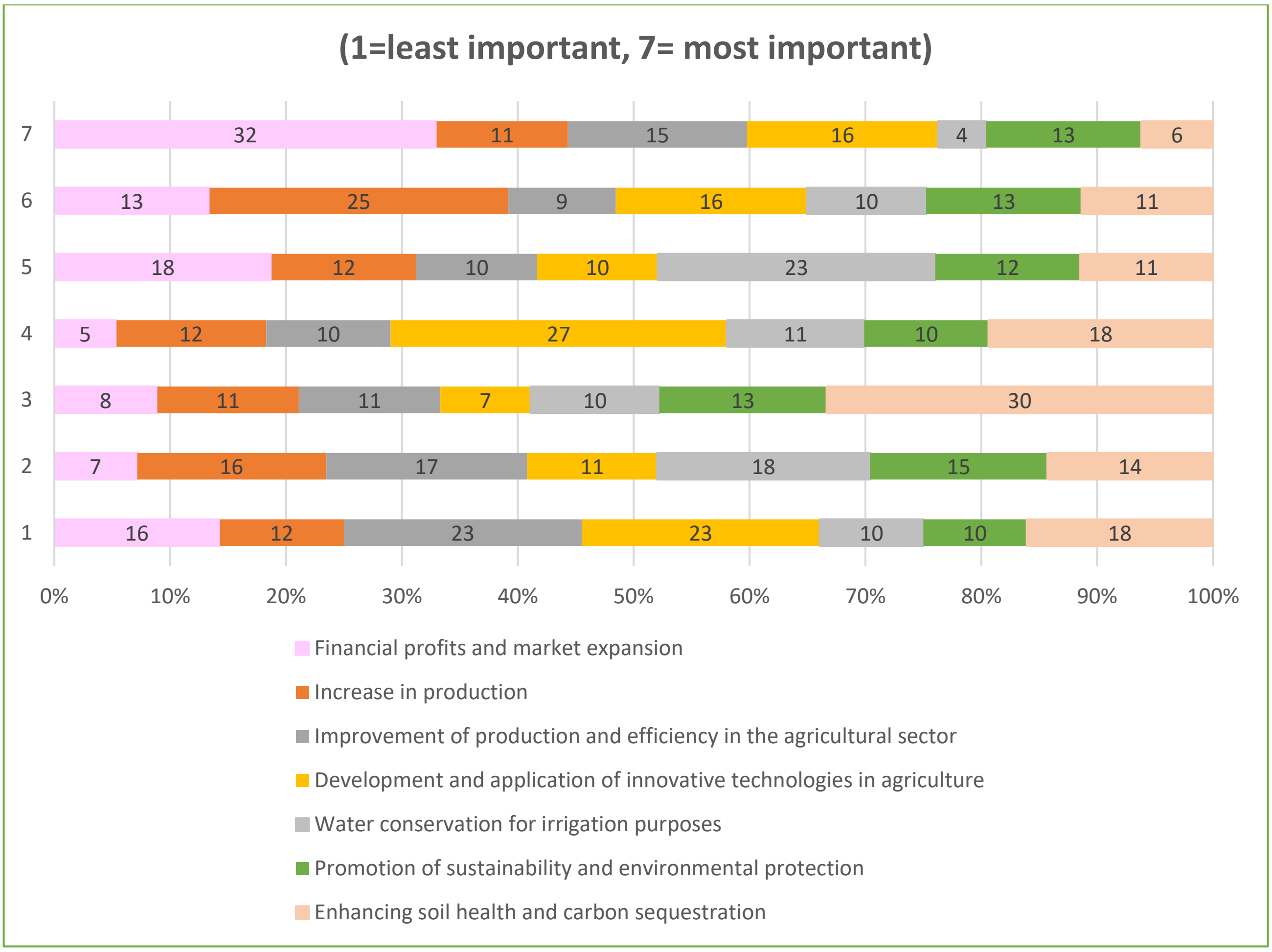

Figure 16. Ranking of the goals based on participants experience (GR)

- In Greece the second most important thing voted by 25 individuals that must be considered is productivity enhancement. With this most chosen choice as the second most important goal reveals the need for production increase.
- However, the third place as the most preferable goal to accomplish Greek people answered this questionnaire is the water conservation for irrigation purposes. This reveals the weakness in irrigation management on a country level.

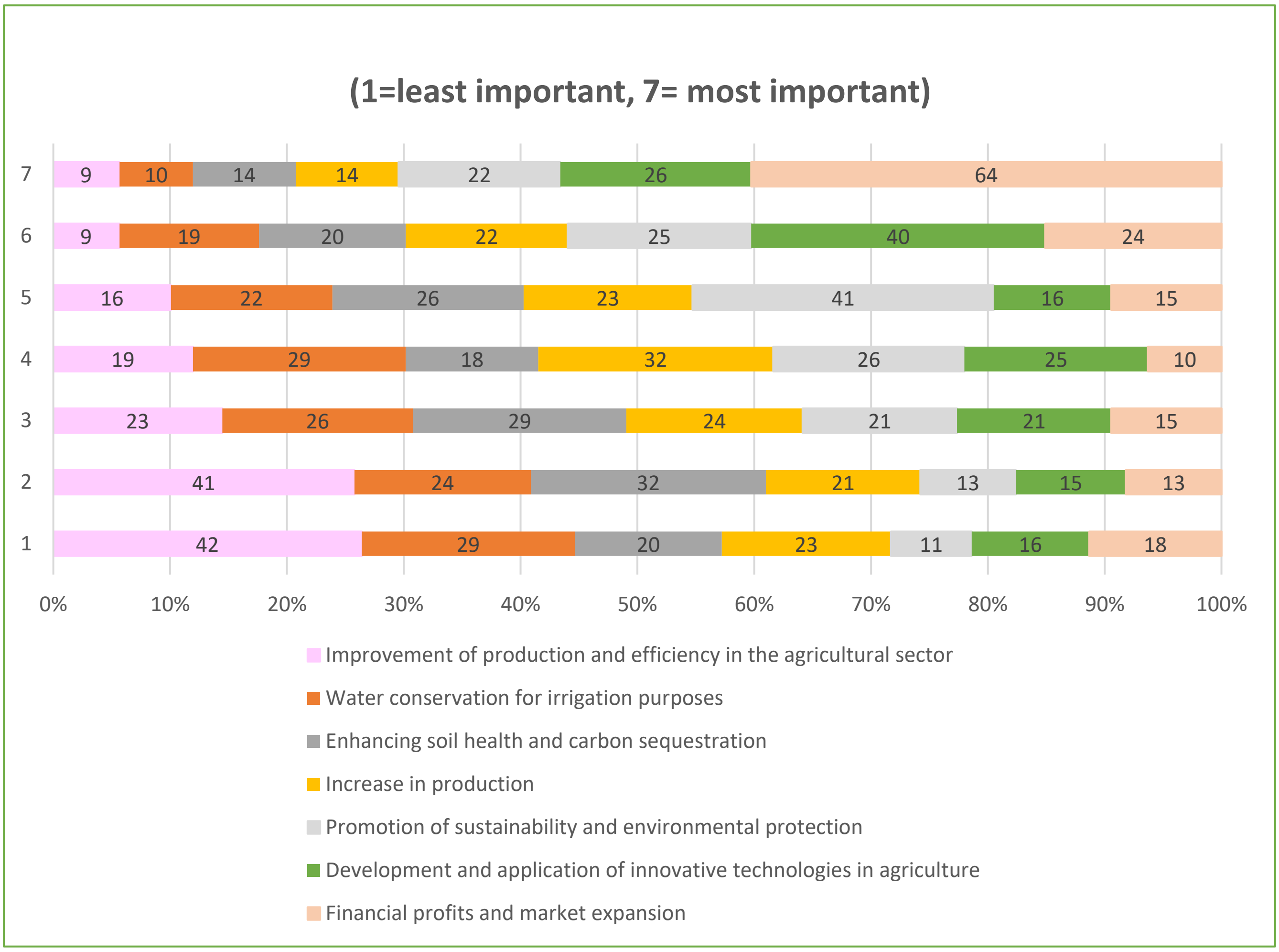

Figure 17. Ranking of the goals based on participants experience (NMK)

- The second most important thing for NMK, with 40 individuals stating it is the development of innovative technologies in the agricultural sector.
- Environmental sustainability and environment protection comes in third place of popularity among the questions with 41 individuals supporting it.
- Same as CY, NMK results showed the increase in production fourth in the ranking as the most important objective to be accomplished.

There is a common opinion between the three countries' attendees that the least important goal to accomplish is the production and efficacy improvement in the agricultural sector. With the above responses we identified the common concerns from each of the three countries regarding profit and market expansion.

7.4 Challenges of the EU affecting agriculture

This section concerns only answers derived from the questions set for European Union (EU) actions. In this survey, individuals were tasked with identifying the challenges they perceive the EU to encounter in the agricultural sector.

- The replies provide an indication related to current challenges that EU faced in agricultural sector.
- It also shows that the least voted answers might mean that the EU does not face the particular challenge on a large scale as the ones with the most votes.

A wide range of answers derived from this question showing that there is more than one challenge. The highest answered challenge derived from GR with 44% is the adaptation to climate change and promotion of sustainability in agriculture. An equal percentage of 21% for each option given for an answer is the lack of ensuring sustainable income for farmers and rural development enhancement and promotion of rural employment. The thing that people voted the less challenge faced by EU is the food safety and product quality and promotion of competitiveness with 12% and 2% respectively. With these answers is very comprehensive that people face serious problems regarding climate adaptation through the lack of frameworks and protocols as well as income issues and stability.

Almost half of the votes from CY (47%) participants believe that the primary challenge that EU confronts is the sustainable income for farmers. This causes serious issues to their business each year and causes stability issues to the owners. The second most voted answer with 29% is the lack in strengthening the rural development and promotion of rural employment. Climate change adaptation and sustainable agriculture is the third most voted answer with 18%. Similar as Greece, Cyprus attendees believe that the least challenge for EU is the food security and promotion of competitiveness with 4% and 2% respectively. However, a conclusion derived from these answers showed that farmers feel insecure in relation to income and rural development enhancement.

The answers most voted by NMK with 33% believes that the primary challenge that EU faces is the adaptation to climate change and sustainability in agricultural sector. The second most voted answer with 24% is the stability of sustainable income for farmers. The third most cited challenge, representing 20% of responses, is the lack of strengthening and promotion of rural development. Like GR and CY, NMK attendees believe that less challenge comes to promotion of competitiveness and food safety and production quality with 5% and 16% respectively.

Additional important feedback concerning European policies, Common Agricultural Policy (CAP) was set as a question to define opinions deriving by the three countries.

- This question answered by the participants provides an opinion of CAP necessity and possible feedback on things that should be considered further.

CAP is an important regulation from the EU concerning the agricultural sector. Its main goal is to support farmers through fundings for productivity improvements and to ensure consistent provision of affordable food supply. An additional aim is to sustain the vitality of rural economies by advocating for employment opportunities in farming, agri-food industries, and related sectors.

Number of choices were set as an option for participants to choose and are summarized below:

- CAP is necessary for farmers' support and promotion of sustainable development.
- Revision of CAP needed to be fairer and sustainable.
- Subsidies reduction and more focus should be given to environmental sustainability.
- No opinion for CAP.
- No knowledge at all of CAP actions.

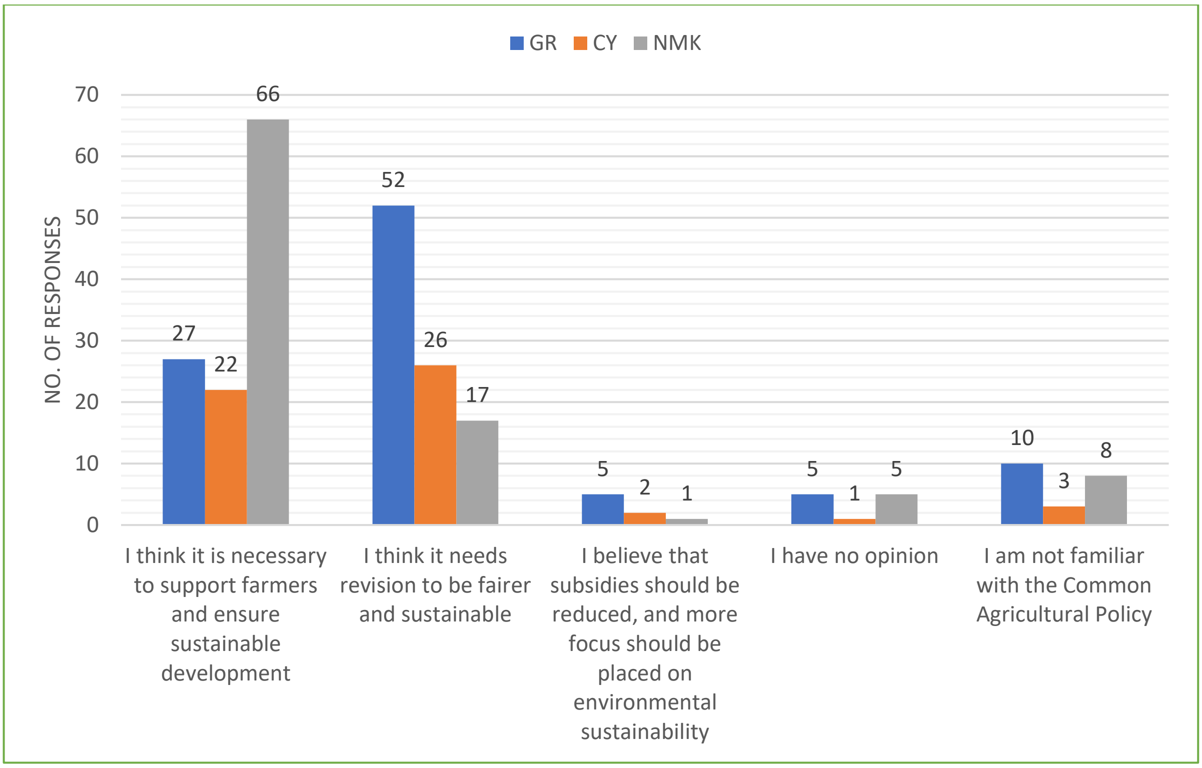

Figure 18. Opinion on CAP

- Most of the people from NMK (66 participants) support the idea that it is necessary for farmers support and ensure the sustainable development of agricultural sector.
- CY and GR commonly support the idea that CAP need revision to be fairer and sustainable with 26 and 52 participants voting for this answer respectively.
- Some people answered that are not familiar with CAP and thus do not have knowledge of its action and possible benefits that can provide in the agricultural sector.

7.5 CAP at a glance

On this subsection more specific information were asked for CAP and it takes into consideration only answers derived from it. On this questionnaire people asked what challenges are facing due to agricultural policies derived from EU and the CAP. More than one option was selected by each person, showing that there is more than one challenge faced in the agricultural sector. The data provided describes numerous difficulties faced by farmers due to agricultural policies. It lists the specific issues raised by the respondents, such as growing production costs and competition from imports, unstable markets, funding constraints for innovation and investment, difficulties implementing environmentally friendly practices, and the administrative strain brought on by rules and regulations. All things considered, the account sheds light on the various challenges faced by farmers in the agricultural industry, representing the various ways that policy choices affect various agricultural stakeholders.

Most of the answers derived from NMK (30%) support that the main challenge is facing is the cost production rise and the competition derived from external imports. However, a close percentage of attendees, 26%, show their uncertainties about the future of the market and prices. This shows that people working in the agricultural sector do not feel safe regarding future and income stability. People also believe that there is bureaucratic burden of rules and regulations that make their job harder, gaining 19% of votes from NMK. The lower votes with percentage of 13 and 10 were about challenges regarding funds earning for investments and innovation and challenges in adopting green practices respectively.

Same as NMK, Greece with the 34% of votes supports that the main challenges faced in agriculture from policies is the production cost elevation and the competition from imports. Additional worries with 22% of votes are the uncertainty about the future of the market and the prices since elevation of them the current year are obvious to the public. Similar percentage of votes concerns the green practices adoption for GHG reduction and climate change contribution, the funding difficulties for investments and innovation as well as the bureaucratic burden of rules and regulation with 18%, 13% and 13% respectively on each choice. Similar percentages appear from GR and NMK for each answer showing that both countries believe that current policies are not very promising for their sustainability and future expansion of their businesses.

CY, like the two other countries with the highest percentage of 38% supports that there is a challenge regarding production cost elevation and competition derived from imports. However, the second most voted answer differs from NMK and GR since 20% votes that they are challenged from bureaucratic burden of rules and regulations. Similar percentages of 16%, 14% and 12% for each answer concern the uncertainty of the future market and products prices, the difficulties for sustainable practices and the challenge of getting funds for investment and innovation respectively.

7.6 Interest in carbon farming

This chapter concerns only carbon farming application and analyses based on attendees' responses. It contains information in relation to:

- Carbon farming interest and applications
- Carbon farming knowledge by the respondents

Carbon farming is somewhat a new approach for CO_2 emission reduction through carbon sequestration in soils. It mainly concerns the agricultural sector by employing carbon farming practices to achieve the purpose of GHG reduction and the zero-net goal of EU. People on this questionnaire asked if they are interested in a particular cause, giving a positive reaction in general. Almost half of NMK attendees, with 47% voted that are somewhat interested in carbon farming. This gives an insight into the way that the country is seeking new approaches in farm practicing and is open to new ideas for the purpose of contribution in GHG emission reduction.

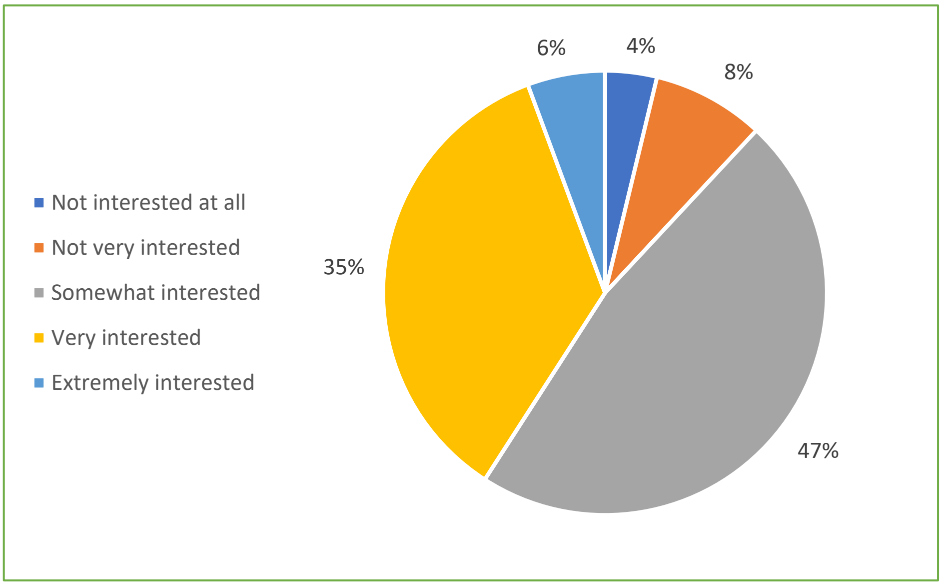

Figure 19. Respondents interest in carbon farming (NMK)

- However, a good percentage of 35% of people answered this questionnaire are very interested in carbon farming.
- The lowest percentage of 4% responded that are not interested at all in carbon farming.

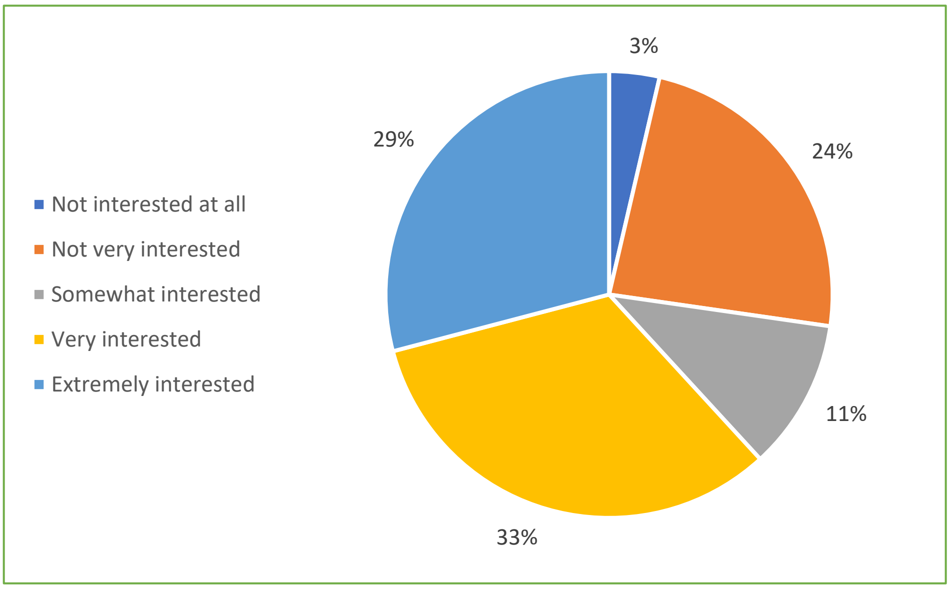

Figure 20. Respondents interest in carbon farming (CY)

- Cyprus respondents on the other hand are very interested in carbon farming with 33% voting for it.
- The second in row in the rank of interest with 29% of votes is the extremely interested. Cyprus seems to be very interested in carbon farming and the development of new innovative approaches for carbon sequestration.
- Not very interested appeared to be chosen by 24% of the attendees.

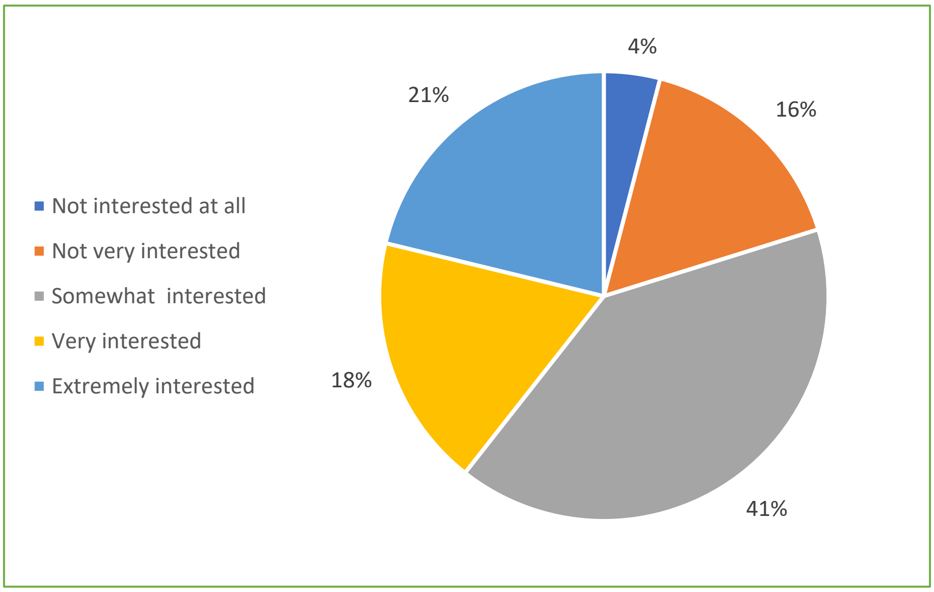

Figure 21. Respondents interest in carbon farming (GR)

Similar to NMK, attendees from Greece answered with the highest percentage (41%) from all the answers that are somewhat interested in carbon farming. This shows like the other countries that people from the agricultural sector are open to new suggestions that could be beneficial for them.

- 21% of individuals voted that are extremely interested in the carbon farming approach.
- Not very different in percentage of people voted that are very interested in carbon farming while others not very interested with 18% and 16% respectively.

With an overall look from the three countries, it is clear that people are somehow interested in carbon farming. People need more information regarding this approach of farm practicing for them to be clear if they are interested. Knowledge gaps and fear of the unknown might be one reason for not choosing directly the extremely interest. However, after that people asked if they are familiar with carbon farming in order to identify knowledge between the participants.

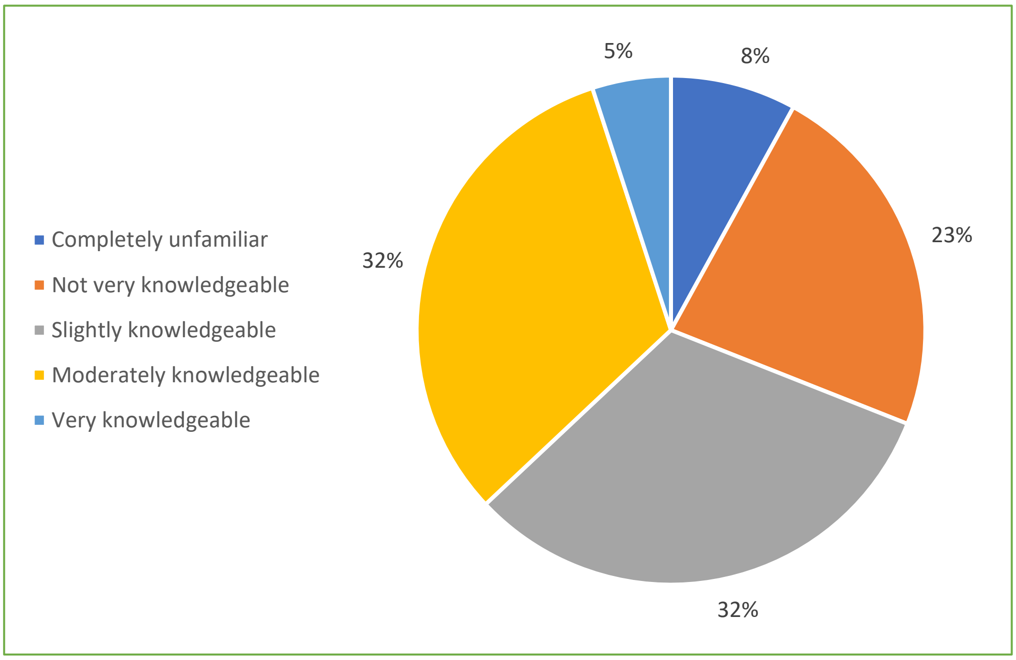

Figure 22. Knowledge in Carbon Farming (NMK)

- An equal amount of 32% of group of participants from NMK answered that have slightly and moderate knowledge in carbon farming. This reports that people are advanced in the field searching for new approaches.
- 23% of attendees are not very familiar with carbon farming while the 8% are completely unfamiliar with carbon farming.
- The lower percentage of 5% expressed that are very knowledgeable.

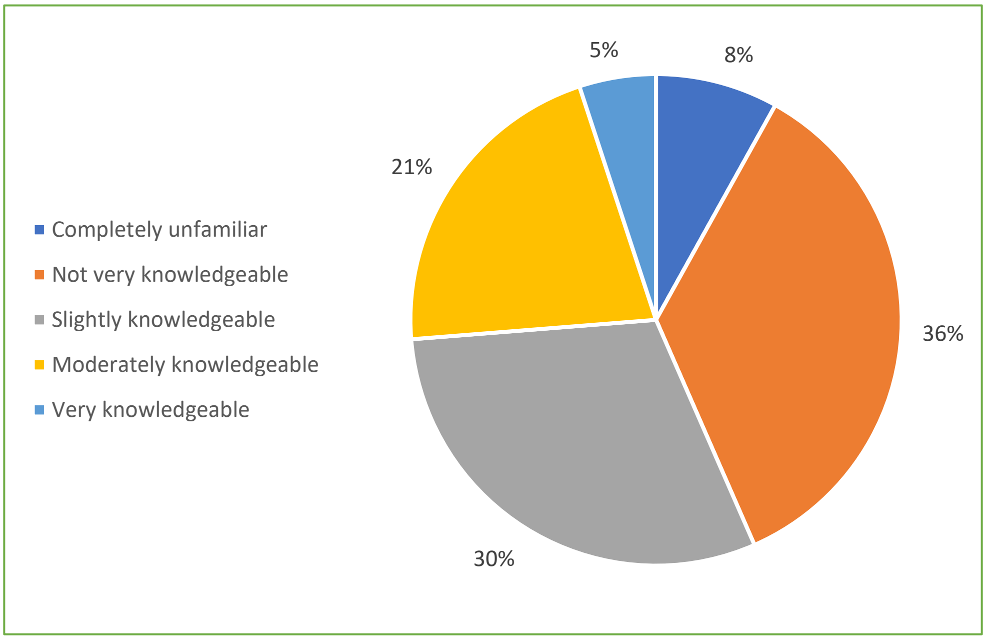

Figure 23. Knowledge in Carbon Farming (GR)

- In contrast with NMK, the highest percentage 36% of GR attendees voted that are not very knowledgeable in carbon farming.
- However, the second in row with the highest percentage of 30% seems that they have slight knowledge in carbon farming.
- Moderate knowledge was selected by 21% of people who answered this questionnaire.
- The lowest percentage was observed in the very knowledgeable group of people and the completely unfamiliar group of people with 5% and 8% respectively.

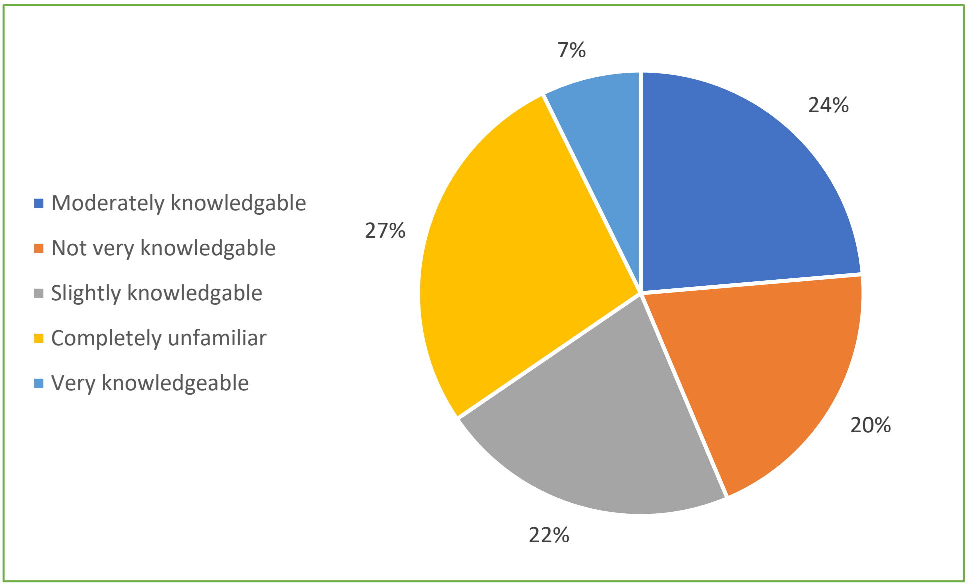

Figure 24. Knowledge in Carbon Farming (CY)

- The highest percentage of the participants, holding the 27%, responded that are completely unfamiliar with carbon farming.
- However, a promising 24% of the participants showed that were moderately informed about carbon farming and its application.
- The third highest percentage of 22% appeared that people from CY have slightly knowledge in carbon farming.
- A minimum percentage of 7% responded that are very knowledgeable about carbon farming. This shows that CY needs informative activities to raise knowledge about carbon farming and its benefits.

The importance of new innovative ideas for ground-based monitoring in agriculture is an essential tool towards sustainability and real time data and monitoring. However, remote sensing (RS) is a promising candidate for such activities since it can provide a lot of information about soil and crop health. On this questionnaire people asked if they are interested in using satellite and ground-based data in agriculture providing a positive outcome. The highest group of people, 47%, are very interested in using satellite and ground-based data in agriculture. 39% of NMK responded that are somewhat interested on these technologies. This might happen because they are not very familiar with it but show the willingness to learn. A very positive response comes with the extreme interest of some people (7%) in using these technologies. Least interest comes with the 6% answering that are not interested and 1% that are not interested at all.

A positive outcome observed also from Greece with the 36% showed that are very interested in using satellite and ground-based data in agriculture. 28% are somewhat interested in this activity. The third place of interest expressed with the 24% extremely interested in using satellite and ground-based data. The 8% showed that are not very interested in this while the lowest percentage of 4% are not interested at all. Cyprus also showed its interest with the highest percentage of 33% to be somewhat interested in using satellite and ground-based data in agriculture. The second in row with 24% voted that are extremely interested in this activity. 20% of attendees are not very interested while the 15% are very interested. The lowest percentage of 8% voted that are not interested at all.

8 Previous experiences in satellite technologies and ground-based data

An emerging application of Remote Sensing (RS) gives an insight in monitoring and prediction of several phenomena one of them concerns the agricultural sector. RS comprises of several applications using satellite imagery along with ground-based data for answering a lot of questions arise. People asked whether they have experience on satellite and ground-based data in agriculture. A variety of responses about people’s skills regarding these two options were observed.

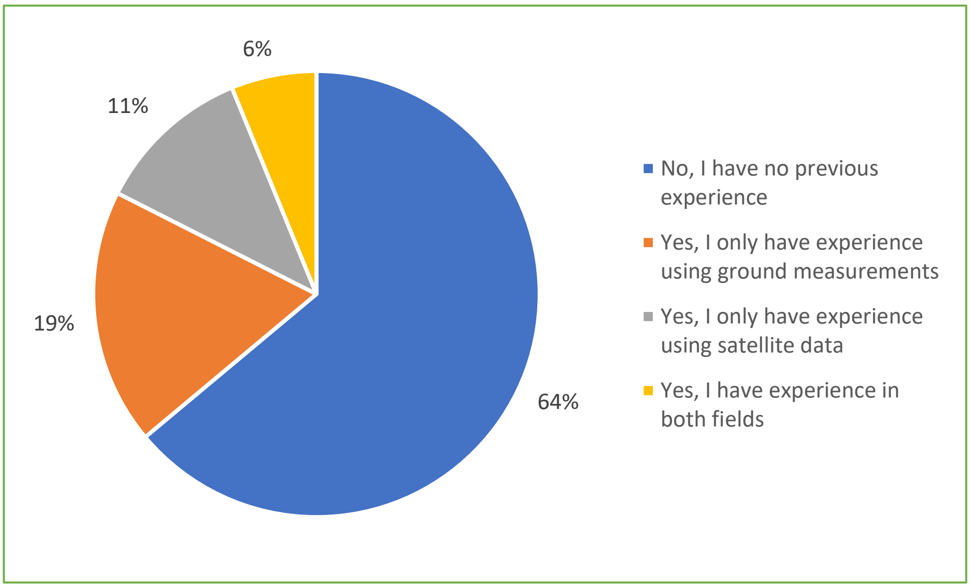

Figure 25. Experience in the use of satellite and ground-based data in agriculture (NMK)

- More than half of the respondents have no previous experience in these technologies from NMK.
- 19% of the people from NMK have experience in ground-based measurements.
- 11% have experience using satellite data while the lower percentage of 6% have experience in both fields.

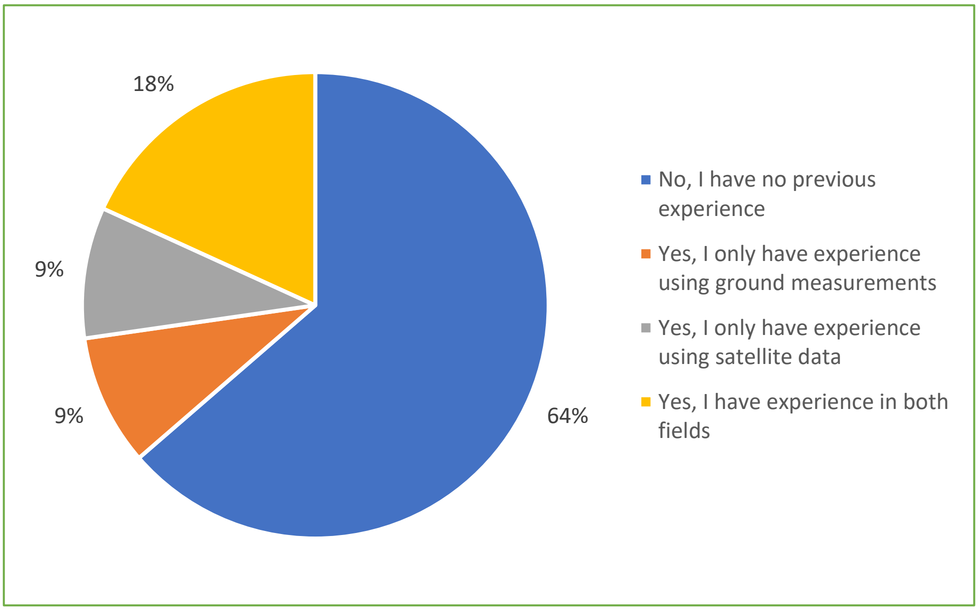

Figure 26. Experience in the use of satellite and ground-based data in agriculture (CY)

- Similar to NMK, CY 64% of the people answered this forum do not have previous experience using satellite or ground-based data.
- However, the second highest percentage of 18% shared that have an experience in both fields.
- An equal amount of 9% of attendees have either ground-based or satellite experience.

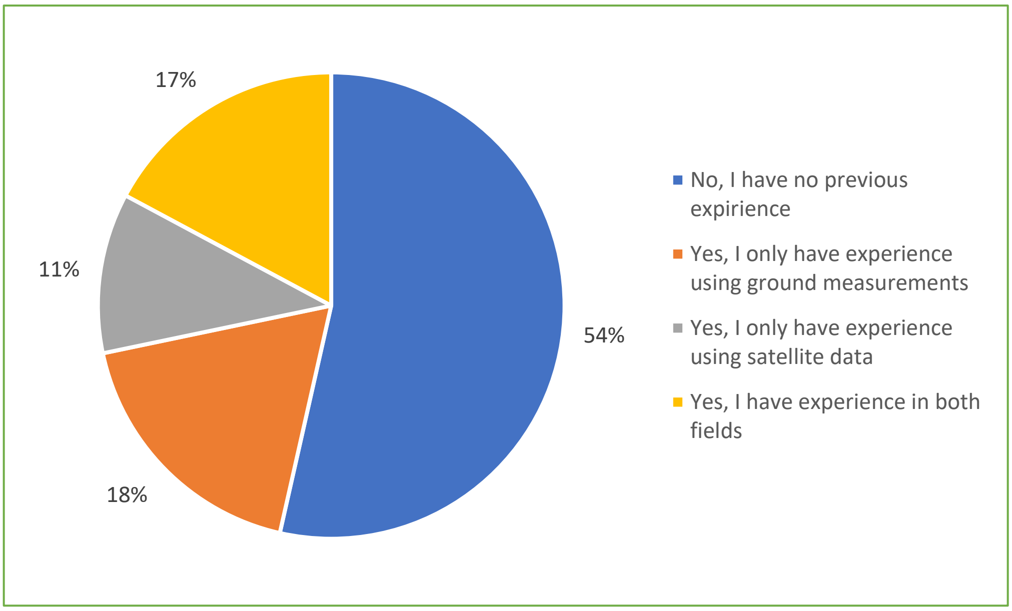

Figure 27. Experience in the use of satellite and ground-based data in agriculture (GR)

- Similar to the other countries, more than half of GR attendees do not have previous experience in both fields.
- 18% of people have experience in ground-based measurements while 17% of people have experience in both fields.
- The least percentage (11%) voted that they have only experience in satellite data.

In summary, the highest percentage of both three countries do not have previous knowledge in ground-based measurements or satellite data analysis. Some people on the other hand showed that they either have in both fields experience or in one of them.

9 Carbon farming development

The presented information describes the answers to important questions about how to advance carbon farming in agriculture. It highlights several factors that respondents believe are critical to advancing carbon farming application.

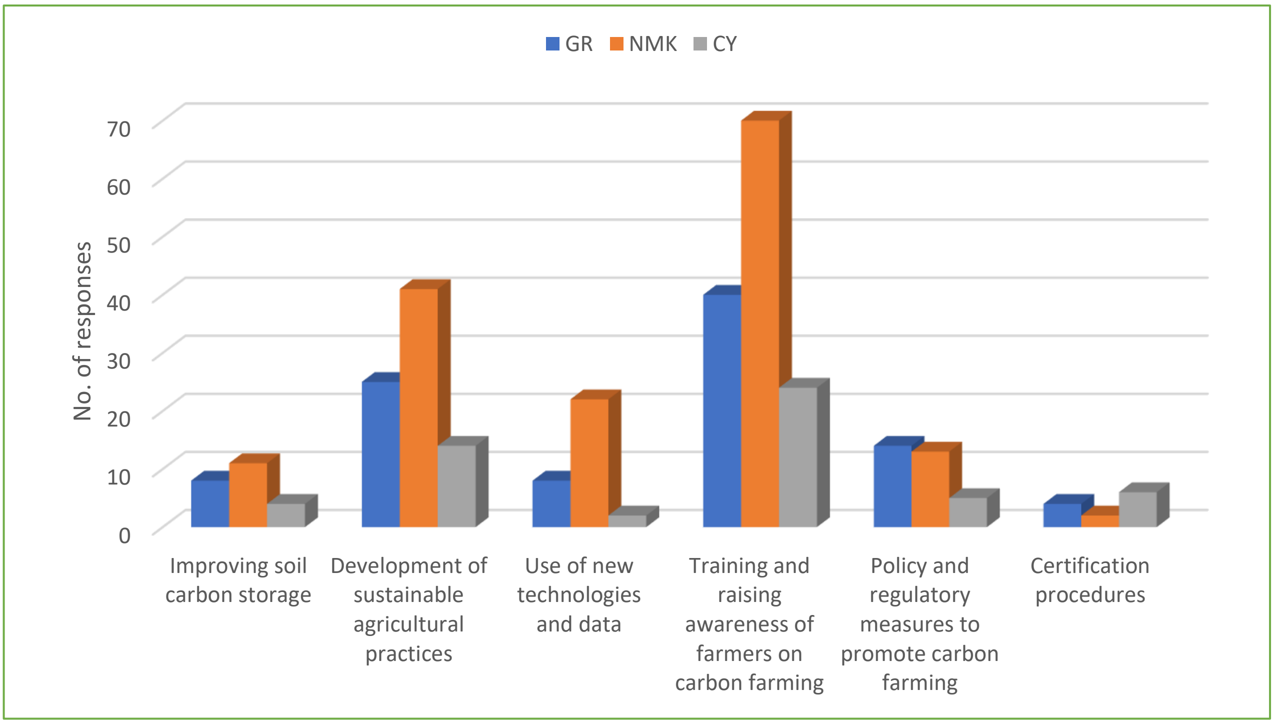

Figure 28. Areas considered crucial for advancing carbon farming in agriculture

Almost half of NMK responses (44%) support that the main thing that is crucial for carbon farming advancement in agriculture is the training and awareness raising of farmers regarding carbon farming. The second most voted answer that people consider crucial with 25% is the development of sustainable agricultural practices. Plenty of votes are also in using new technology and data, the policy, and regulatory measures to promote carbon farming, the critical challenge to improve soil carbon storage and the certification procedure. Like NMK, GR highest percentage (41%) lies on training and raising awareness of farmers in relation to carbon farming. However, the second most selected answer with 25% considered by the attendees of GR as crucial thing for advancing carbon farming in agriculture is the development of sustainable agricultural practices. CY like the NMK and GR the primary crucial area for advancing carbon farming voted the most (44%) is the training and raising awareness of farmers in carbon farming. The second most voted answer derived from CY with 25% like the previous countries is the development of sustainable agricultural practices. The outcome derived from this question is that both countries share somehow similar ideology regarding what areas they consider crucial for carbon farming advancement in agriculture.

10 Participation in Carbonica project

More than half of NMK participants (77%) voted that that they would like to participate in Carbonica project while the rest voted that they are not interested to participate. 75% of GR participants voted that they would like to be part of the Carbonica project where the rest do not want to be involved in it. From CY 69% want to be part of Carbonica project while the rest do not want to participate. An equal contribution from each country observed regarding participating in the Carbonica project showing that they would like knowledge exchange and find new solutions to improve their business and contribute to climate change mitigation. People also asked what kind of activities would like to participate within the frames of Carbonica project showing a variety of interests. Most NMK participants (43%) would like to participate in training activities so that they can improve their skills and knowledge. 30% voted that they would like to participate in agricultural experiments while the rest are more interested in field activities. Participants from GR like NMK most preferably with 43% voting for it is the training activities. 31% of attendees would like to participate in agricultural experiments. The rest 26% most preferably want to attend field activities. Teining activities gain the most with 42% from CY voting for it. 37% voted that they would like to join in agricultural experiments while the rest chose field activities.

People also questioned what they believe is more important technology or method that is linked to farming adoption. The responses provided indicate the preferred technologies or tools for agricultural monitoring and management. More than one of the answers were voted on by the participants showing that is not the only thing that can consider most important. The highest voted answer from all the three countries participating on this questionnaire is smart irrigation/harvesting/ fertilization system voted by NMK, CY and GR with 108, 40, and 71 votes respectively. This indicates an appreciation for smart agricultural systems that optimize water usage, harvesting processes, and fertilization practices through automation and data-driven decision-making. Smart sensors are the second most voted answer for NMK and GR with 54 and 43 responses respectively highlighting the recognition of smart sensor technology for real-time data collection and monitoring in agricultural settings, such as soil moisture. However, the second most voted answer regarding of what is the most important technology to farming adoption linkage by CY in the geographic information systems (GIS) with 17 votes indicating an acknowledgment of the importance of GIS technology for spatial data analysis and mapping in agriculture, including soil mapping, precision agriculture, and resource management. The third most answered option with 50 and 42 votes from NMK and GR is GIS technology. However, for CY the third most voted option are smart sensors voted by 13 people. An equal fourth most voted option by CY, GR and NMK are satellite data with 10, 2 and 38 votes respectively. This suggests a recognition of the value of satellite imagery for agricultural monitoring and assessment, such as crop health monitoring, land use analysis, and environmental monitoring.

Another question with vital importance asked on this questionnaire is about people's opinion of what role they believe that research organizations and academic institutions have in carbon farming. Multiple answers chosen by the people completed this questionnaire with answers ranging from conducting research projects and case studies, development and certification of new technologies, provision of counselling and training to the interest parties and collaboration with businesses for the development of new innovative solutions.

NMK highest in percentage of 37% believes that the main role is the counselling provision and training of farmers. This might be because research organizations through their funds can contact research on specific fields seeking solution to a current issue and then pass the knowledge with interested parties. The second in row with 25% of votes believes that research organization and academic institutes role is to conduct research projects and case studies. With this people interested in the agricultural sector can benefit from the results making their business viable. A similar percentage of 18% and 17% believes that their role can be for development and certification of new technologies and collaboration with businesses to develop innovative solutions respectively.

Similar results derive from CY with the highest percentage of 30% supporting that the main role of research organizations and academic institution is to provide counselling and training to farmers. Almost equal responses presented for all the options showing that CY attendees believe that all the answers given for a choice are the role of these organizations. More specifically 28% voted that collaboration with businesses for the development of innovation solution is one of their roles while 24% answered option is the conduction of research projects and case studies. Lower in rank of votes with 18% is the development and certification of new technologies.

GR highest in percentage option with 29% like NMK and CY is the support provision and training of farmers. The second highest percentage with 25% is the development and certification of new technologies. However, equal in percentage options is the collaboration with businesses for the development of innovative solutions and the employment of research projects and case studies with 23% on each. A similar mind set between the three countries can be identified on this question with the primary role of research organization and academic institutions according to a group of people to be support and training to farmers.

Fundings is of major importance for a lot of businesses as it plays a significant role in their grow and development as well as solution making. Nevertheless, people on this questionnaire asked to answer their thoughts on what should be the main source of fundings for the development of carbon farming. Multiple sources of funding were selected by everyone since funding can derive from several sources.

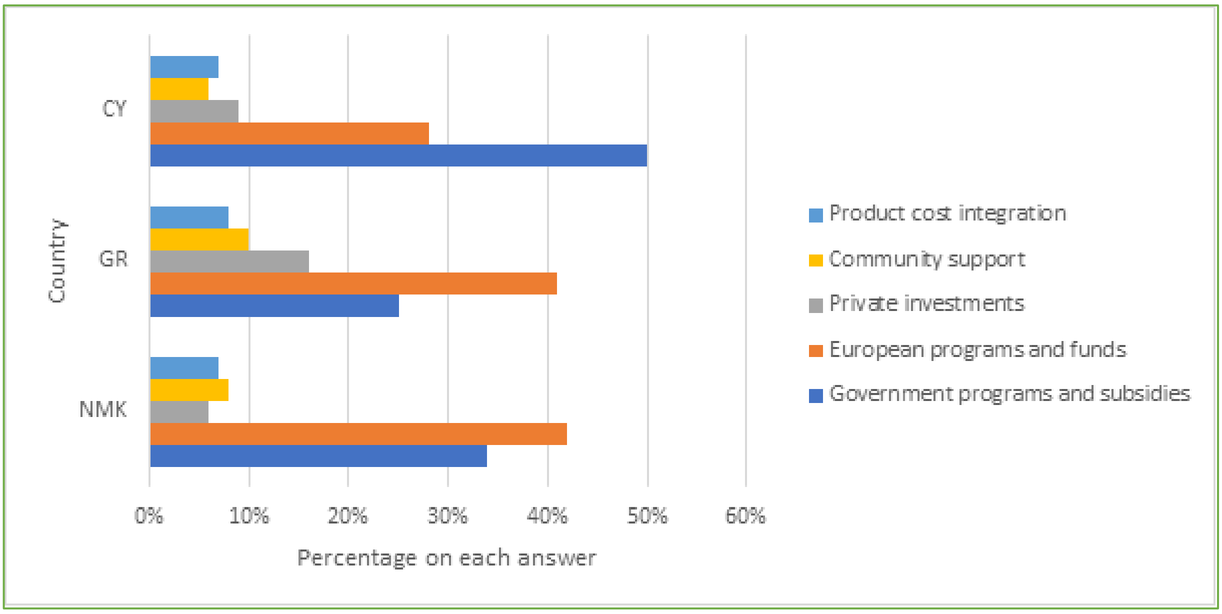

Figure 29. Primary source of funds based on the three countries opinion

Nearly half, accounting for 42% of North Macedonia participants, advocate for European programs and funds to serve as the primary source of funding, while 32% predominantly favor government programs and subsidies, according to the survey results. A small proportion, specifically 8%, 7%, and 6%, respectively, expressed support for community assistance, integrating product costs, and private investments. Similarly to North Macedonia, Greek participants largely voted European programs and funds as the primary source of funding, with 41% of respondents supporting this option. The second in row most answered option with 25% hold that government programs and subsidies should contribute financially. Also, GR, with a notable percentage of 16%, believes that funds should also come from private investments. The top choice among respondents from Cyprus, with 50% of the vote, is in favor of deriving the primary source of funding from European programs and funds. The second most chosen answer holding 28% is the governmental programs and subsidies.

A question on who should provide training to the farmers was set for answer. A variety of answers derived from it with an overall look that all the countries somehow agree with each other.

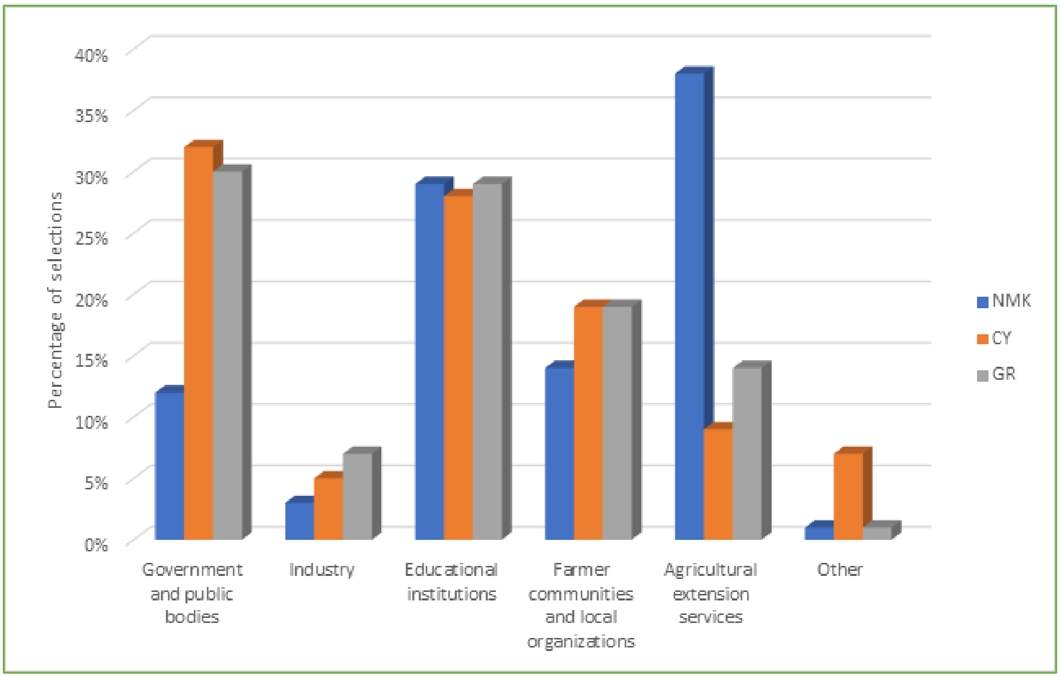

Figure 30. Opinion on who should train the farmers

According to the survey's results:

- Most voted option with 38% represents NMK supporting that agricultural extension services should provide the trainings to farmers.
- The second most selected option by NMK participants with 19% supports that training bust be held by educational institutions.
- An obviously high percentage of 32% of GR participants support that the training can be held by government and public bodies while the second in row option with the most votes (28%) supports educational institutions.
- CY participants with close in percentage of the most voted answers 30% and 29% support that the training should be held by government and public bodies and educational institution accordingly.

Carbon farming through research has been proved to provide a lot of benefits to soil health and improves water holding capacity. People asked to answer how important do they believe that carbon farming is for soil and water protection in agriculture. Almost half of NMK answers with 43% believing that is especially important will the second most chosen answer with 38% said that is important. In GR, 46% of participants in this review believe that is important while the 40% supports that is particularly important. 43% of participants from CY believe that carbon farming is important for soil and water. Second in row with high percentage, 38% believes that is important. An outcome derives from these results showed that in NMK people believe that carbon farming is especially important for soil and water health showing that the promotion of carbon farming on a country level might be more distributed. However, both GR and CY believe that is important to give an insight to willingness on carbon farming practices for soil and water protection.

11 Categories preferences per country

On this chapter each category and their responses are recorded based on selected questions to identify if there are mutual interests for this cause. Each country is analyzed differently by each category.

11.1 Greece

Industry:

The main motivation derived from industrial bodies to attend this survey is mainly for exploitation of new business opportunities along with some response related to knowledge and experience exchange between stakeholders. Opinions also recorded from people in industry in relation to what they believe of collaborating with other stakeholders that participate to the MAP of Carbonica's project receiving an equal response that collaboration is not necessary for goals achievements. Industry opinion on CAP is that it needs revision to be fairer and sustainable. Industry shows a great interest in carbon farming with most of them showing an interest in satellite technologies and ground-based measurements. A mutual response from all the people from the industry showed that they would like to participate in the CARBONICA project.

Academia:

The main reason for academic community participating in this survey vary between the participants. The answers derived from them are for promotion of sustainability in agricultural sector, development of innovative agricultural solutions, exploitation of business opportunities and exchange of knowledge and ideas with other stakeholders. Opinions were also recorded from people in academia in relation to what they believe of collaborating with other stakeholders that participate in the MAP of Carbonica's project receiving different opinions but positive in collaboration. Opinions also recorded for CAP lie on revision to be fairer and sustainable, and people believe that is necessary for farmers' support and sustainable development. A small portion of people are not familiar with CAP. Academia like Industry also shows a great interest in carbon farming solutions with the highest percentage to be interested in satellite technologies and ground-based measurements with a small portion to interest a little on it. Out of twenty-two responses, nineteen people are interested in participating in the Carbonica project while the rest are not interested in participation.

Farmers:

Similar to Industry and Academia, farmers' motivation in participating in this questionnaire varies. Some chose as a motivation the development of new innovative solutions in agriculture, some the promotion of sustainability in agriculture, some the exploitation of business opportunities and exchange of ideas and knowledge with other stakeholders. Additionally, on the question about what their opinion in collaboration with other stakeholders that participate in the MAP of Carbonica project most of the answers showed that it is important while a small number does not have an opinion on this subject. Concerning the opinion about CAP, eighteen respondents believe that it needs revision to be fairer and sustainable and some (9 respondents) believe that it is necessary for farmers support and security for sustainable development. People asked about the level of their interest in carbon farming receiving positive responses in relation to interest while the minority supports that are not very much interested. However, when farmers asked about their interest in using satellites and ground-based measurements they showed a mutual interest. A high interest by twenty people for participating in Carbonica project recorded while nine people are not interested in this project.

Policy makers:

Policy makers respondents' main motivation for participating in this questionnaire was to investigate new business opportunities and development of new innovative agricultural solutions. Their opinion about collaboration among stakeholders on MAP of the Carbonica project was positive since they believe it is important for knowledge exchange and goal achievements. One of the answers derived from this question does not have an opinion on this subject. Respondents answer on CAP opinion suggests that it needs revision to be fairer and sustainable while one of the respondents is not familiar with CAP. An interest appears in carbon farming from the respondents while one of them is interested a little. Additionally, interest appeared around the satellite and ground-based measurements while one of the respondents was interested a little. Participation in the Carbonica project received positive results from the three out of four policy makers category.

Public:
Out of 25, for 6 responses, the main motivation for completing this survey was the exploitation of new business opportunities while the thirteen responses were about knowledge and experience exchange with other stakeholders. Three responses showed that their motivation was the development of new innovative agricultural solutions while the rest three responses were about the promotion of sustainability in the agricultural sector. The highest number of responses showed that the collaboration between the stakeholders involved in the MAP of Carbonica project is important while a small portion showed that they have no opinion on this topic. The prevailing viewpoint among respondents regarding the Common Agricultural Policy suggests a need for revision to enhance fairness and sustainability, although some argue its necessity as it stands. In addition, e great interest appeared from the substantial portion of respondents in carbon farming and carbon sequestration. Interest has been expressed in utilizing both satellite and ground-based measurements by the public, with a small minority showing disinterest. The public expressed its interest in participating in the activities conducted by the Carbonica project.

Non-governmental organization:
Only one participant from GR belongs to a non-governmental organization. However, the answers derived from this scope are of high importance for this survey and will be analyzed. The main reason of the participant for participating in this questionnaire is the provision of sustainability in the agricultural sector. The participant believes that collaborations derived from Carbonica, and the MAP are important for knowledge and expertise enchantments. The participant is not familiar with the CAP so there is no feedback in relation to whether there are issues. The participants showed a great interest in carbon farming along with satellite use and ground-based measurement. Finally, a positive response occurred in participation in the Carbonica project.

11.2 Cyprus

Industry:
The driven motivation of industry in CY to complete this survey shares diverse needs. Thus, the motivations lie in the development of new innovative agricultural solutions, exchange of knowledge and experiences with other stakeholders and promotion of sustainability in the agricultural sector. However, when they asked about their opinion about the collaboration between the stakeholders of MAP of the Carbonica project all the responds derive from industry responded that they do not have an opinion for this part. When they asked about the CAP all the participants responded that it is necessary for farmers' support and security of sustainable growth in the agricultural sector. This, however, differs from the responses collected from the industrial part of GR since the largest portion believes that it needs revision. Two out of three respondents coming from industry showed a high interest in carbon farming and carbon sequestration along with satellite usage and ground-based measurements while one expressed only minor interest in both fields. Only one out of three expressed interests in participating in Carbonica's project activities while the other two responded that they prefer not.

Academia:
The motivation derived from academic community varies with different points of view. The main motivation of group of people is the development of new innovative ideas, some is the promotion of sustainability in agricultural sector, some for exchange of knowledge and idea with other stakeholders and some for investigation of new business opportunity. Most of the participants from academia support the idea that collaboration with other stakeholders from the MAPs for the Carbonica project is important for the achievement of certain goals. Out of nine responds, four believe that the CAP need revision to be fairer and sustainable. Two of them believe that is necessary as it is for farmers' support while the rest are not familiar with CAP. One of the comments received from a respondent for this question expressed below:

"The biggest problem in my view is that it is designed for large farms and cannot be effectively implemented by small farmers, who make up the largest portion of Cypriot farmers. Also, the administrative cost of implementation is huge and finally the design of the subsidies is susceptible to external pressures."

The outcome derived from this comment is that reversion for CAP is needed that will cover at all scales all the interested bodies. Carbon farming and carbon sequestration seems that is an interesting topic for academia since the responses from all participants from this sector showed their interest. In addition, all the participants showed an interest in the use of satellite and ground-based measurements in agriculture with one showed that is not particularly interested in these fields. Seven out of nine participants responded that they are interested in participation in Carbonica's project activities while the rest are not.

Farmers:
24 farmers from CY responded to this survey and their motivation to do so differs from each other. More specific, most important motivation from the largest portion was the promotion of sustainability in agriculture, a medium response rate was the development of new innovative agricultural solutions while the smallest portion responded the exploitation of business opportunities and exchange of knowledge and ideas with other stakeholders. Opinions on the collaboration between stakeholders from the MAP of the Carbonica project were incredibly positive since most of the participants believe that is important to achieve goals. Different opinions appear between farmers for CAP since the highest amount of people believe that it needs revision to be fairer and sustainable while the rest believes that is necessary for farmers support and sustainable development. Out of 24 responses, 13 people are interested in carbon farming and carbon sequestration while the rest are either not interested at all or interested a little in this subject. The positive part derived from this is that the largest portion have positive response to the subject of carbon farming to help their own business as well as the environment. Additionally, the largest portion of respondents are interested in the use of satellite and ground-based measurements while the rest are either not interested or slightly interested. Positive responses were observed based on the attendees' interest in participating in the Carbonica project with the majority voting yes.

Policy makers:
Policy makers' main motivation to participate in this survey varies from promotion of sustainability in agricultural sector, exchange of knowledge and ideas with other stakeholders and development of innovative agricultural solutions. The highest percentage of participants responded that collaboration with other stakeholders from the MAP of the Carbonica project is necessary to achieve certain goals. Out of three derive from policy makers positions believes that CAP is necessary for farmers support and ensuring sustainable development while the other one believes that it needs revision. All the participants have a high interest in carbon farming in addition to the usage of satellite and ground-based measurements. However, two out of three participants from this domain do not want to be part of the Carbonica project while the rest showed an interest to be partis on its activities.

Public:
High participation from the public was observed during this survey. Their main motivation to participate in this questionnaire differs by everyone. The highest number of people participated to develop innovative agricultural solutions and exchange knowledge and experiences with other stakeholders. The minority's main motivation is to promote sustainability in the agricultural domain. Half of the participants believes that collaboration with other stakeholders from the MAP is important to achieve goals and knowledge exchange while the other half expressed that they do not have an opinion on this subject. The highest percentage of public bodies support the idea that CAP requires revision to be more sustainable and fairer for all while the rest believes that is necessary as it is. Half of the participants have a high interest in carbon farming and carbon sequestration while the rest expressed that they have little interest. The level of interest in

using satellite and ground-based measurements half are interested in while the rest are either not interested at all or have a little interest in this topic. Impressive responses appear regarding participation in Carbonica's activities where only one individual out of seven from this group of people expressed their interest while the rest are not interested.

Non-governmental organization:
The main motivation from non-governmental organizations to participate on this survey was the promotion of sustainability in agricultural sector while the rest was the development of innovative agricultural solutions and exchange of knowledge and experiences with other stakeholders. All the participants from non-governmental bodies support the idea that collaboration with other stakeholders from the MAP of Carbonica's project is important to achieve goals and exchange experiences and ideas. The highest portion of the participants responded that CAP is necessary as it is to help and support farmers while the rest believe that it needs revision to be fairer and more sustainable. All participants showed a great interest in carbon farming and carbon sequestration in addition to the usage of satellite and ground-based measurements in the agricultural sector. Out of five participants from this sector, four are interested in participation in the Carbonica project where only one does not want any involvement.

11.3 North Macedonia

Industry:
Main motivation from people from industry for participation in this survey varies. An equal option selected for each answer as the main motivation of the development of innovative agricultural solutions and exchange of knowledge and experiences with other stakeholders. The minority's main motivation is the exploitation of new business opportunities and promotion of sustainability in the agricultural sector. Opinion in relation to collaborations between stakeholders from the MAP of the Carbonica project participants from industry believe that in either important or necessary for goal achievement and sharing of expertise and ideas. Out of eight participants from industry seven believe that CAP is necessary as it is to support farmers and ensure sustainable development while the remaining one suggests that it needs revision to be fairer and sustainable. Most of the participants are interested in carbon farming and the promotion of these ideas for a more sustainable future while the rest are somewhat interested or not very interested. However, on the question about their interest in using satellite and ground-based measurements only one participant is somewhat interested while the rest are very interested in this field. Surprisingly all the participants from industry are interested in participation in activities within the Carbonica project with zero negative results.

Academia:
NMK academic community's main motivation for participating in this survey vary with 32 responses. 14 participants shared a common motivation regarding the development of innovative agricultural solutions while 11 participants main motivation is the exchange of knowledge and experiences with another stakeholders. The rest of the participants' main motivation is the promotion of sustainability in the agricultural sector.

''From the answers observed from the academic community it seems that one of them is a legal expert providing feedback that the motivation of participation is mainly for legal research and analysis. ''

An equal opinion from all the participants derived from the question about collaboration with other stakeholders from the MAP of the Carbonica project where all believe either that is necessary or important to achieve goals and exchange of knowledge and ideas towards a better future. Nine out of 32 participants believe that CAP requires revision to achieve an equal share for all the interested parties and be mor fair while the highest share of 19 participants believes that CAP is necessary to support farmers and ensure sustainable development on its original form without a change. The rest amount remain are either not familiar with CAP or do not have an opinion on this field. Most of the participants find carbon farming and carbon sequestration an important field while the rest are somewhat interested while the minority are not very interested. Additionally, the highest percentage showed that are very interested in using satellite and ground-based measurements while the rest are either not very interested or somewhat interested in this field. Out of 32 participations only four participants chose that they do not want to be part in the Carbonica's project activities where the rest representing the highest amount are positive in participation to this project.

Farmers:
92 participations from farmers occur from NMK. Their main motivation for participation varies. Out of 92 participants, 34 respondents' main motivation for completing this survey is the development of new innovative agricultural solutions. 36 participants participated in order to exchange knowledge and experience with other stakeholders. 15 participants' main motivation for participation is the research of new business opportunities while the rest 6 concern the promotion of sustainability in the agricultural sector. A comment came from one of the farmers about the main motivation for participating was "to gain some knowledge about the current state of gases".

This can show a concern from the specific participant about the current state of GHGs emissions and may further gain knowledge on how we can reduce them. More than half of the participants believe that collaboration with other stakeholders from the MAP of the Carbonica project is important to achieve goals and exchange of ideas and experiences. There is a 7% that suggests that cooperation is not mandatory, but it is desirable. Here we identified a different opinion from a group of people believing that collaboration is not necessary that we did not see from the other two countries (CY & GR). 65% of responses about opinion for CAP suggests that it is necessary to support farmers and ensure sustainable development meaning that the form that it is now does need any change for further advances. However, a small portion of 15% supports that CAP requires revision to make it fairer for all and more sustainable. Something that we did not take responses about from CY and GR participants is the subsidies reduction and that greater emphasis should be given on environmental sustainability. However, 3% of NMK participants suggest that subsidies reduction should take place while a great emphasis must be given to environmental sustainability. A small percentage of participants are not familiar with CAP, and some have no opinion about this topic. Here an identification made that farmers from different countries have different opinions in relation to CAP. A common need can be identified as well that CAP is not perfect, and some people are not facilitated from this policy. CY and Greece largest percentage from farmer communities suggest that it requires revision as they feel that is not fair for some while for NMK highest percentage support that is necessary for farmers the way it is. The highest percentage showed that are somewhat interested in carbon farming with a medium percentage to be interested in carbon farming. The rest of the responses are either not interested at all or interested a little in this topic. Additionally, interest in using satellite and ground base measurements showed that 46% are somewhat interested while the 41% is very interested in these technologies. More than half of the participants showed their interest in participating in the activities conducted in the Carbonica project while the rest are not very interested. Both countries showed their willingness to participate in Carbonica project activities showing a mutual understanding that things must evolve in order to achieve CO_2 reduction through carbon farming.

Policy Makers:
Policy makers' main motivation to participate in this questionnaire was the development of innovative agricultural solutions while for the minority is the searching of business opportunities. All the participant opinions about cooperation with other stakeholders from the MAP of the Carbonica projects are that is important or necessary to achieve goals and to exchange ideas and experiences. Most of the participants from the policy makers category believe that CAP is necessary to support farmers and ensure sustainable development while the minority suggests that it needs revision. Their interest in carbon farming was showed with the most to be somewhat interested and the rest to be very interested. Nevertheless, on the question about their interest in using satellite and ground-based measurements, most of the participants are extremely interested while the rest are somewhat interested. Regarding participation in the activities of Carbonica all the participants from the policy makers category supported their involvement in these activities.

<u>Public</u>:

Most of the public motivation to be involved in this survey was the exploitation of business opportunities. The second in a row motivation was the promotion of sustainability in the agricultural sector while the rest was the exchange of knowledge and experiences with other stakeholders. Out of 12 responses about participants' thoughts on collaboration with other stakeholders from MAP of the Carbonica project, 10 are either believe that is important or necessary to achieve goals and exchange knowledge and ideas. One participant from the public domain suggests that is not mandatory but is desirable while the rest showed that do not have an opinion on this subject. The highest percentage of people answered from public about CAP believes that it is necessary for farmers support as well as to ensure sustainable development. The rest of the participants are either not familiar with CAP or do not have an opinion about this topic. Most of the people showed that are somewhat interested or very interested in carbon farming while the minority showed that are not interested at all or have little interest in carbon farming. However, interest expressed about using satellite and ground-based measurements by the highest percentage of the responses. Interest also appeared from public to participate in the activities of Carbonica project by the largest amount of people.

<u>Non-governmental organization</u>:

Non-governmental bodies' main motivation for participating in this questionnaire varies between participants. The highest percentage of participants' main motivation was the promotion of sustainability in the agricultural sector. The other main motivation was the development of innovative agricultural solutions while the minority was to exchange knowledge and experiences with other stakeholders. The thoughts on cooperation with other interested parties participating in MAP within the framework of the Carbonica project all the participants believe that is important or necessary to achieve goals and exchange knowledge and ideas. Moreover, a mutual opinion observed for CAP since all the participants supports that is necessary the way it is to support farmers and ensure sustainable development. Out of six participants from non-governmental organizations, five are very interested in carbon farming as well as using satellite and ground-based measurements in agriculture while one participant is somewhat interested in both subjects. Only one of the participants is not interested in participating in the activities of the Carbonica project while the rest are very interested in participation in this project.

12 Face-to-face interviews

One of the objectives of this survey was the implementation of face-to-face interviews with interested bodies for needs identifications. Firstly, an introduction about Carbonica's project aims took place. Then, a few questions were prepared and asked during the interviews. The questions are listed below as follow:

1. List by each country's goal achievement in numerical order of importance? An overall list from each country presented during the interviews for discussion.
2. Are you willing to adopt carbon farming practices for CO_2 and carbon footprint reduction?
3. Do you know what is Monitoring, Reporting and Verification (MRV)? Are you willing to apply carbon farming and keep daily data from your activities?
4. What are the benefits you are expecting by applying carbon farming techniques?
5. In what ways will it make it easier for you to adopt carbon farming?
6. Would you be more interested in implementing practices if there were measures to support their implementation?
7. Do you need training, if yes what kind of training?
8. Do you think you're ready to implement carbon farming? Do you need some training? If so, what kind of training?
9. Which training model would help? (consultant / training / toolbox / calendar)
10. Are farmers willing to pay for a support service?

In the subchapters below discussion will be held about the main outcomes obtained from the face-to-face interviews held with the categories from the quadruple helix.

12.1 Cyprus face-to-face interviews

Farmers:

Introduction to the Carbonica project and the creation of the MAPs took place during our interviews with farmers. Some of the participants showed an interest in the MAPs supporting that can contribute to the CF knowledge transfer and bring farmers closer to these activities. When farmers asked if they believe that farmers are ready for CF adoption responded that it is a difficult pathway due to farmers fear of changing their practices.

''Also, they stated that if the CY ecosystem knew about CF, they would know that some practices are not a financial burden and are helpful and they will adopt some of them. They also suggested that policies should be created about this topic. However, the steps toward CF should be slow because they are not ready to fully adopt these methodologies. ''

From the conversation during the interviews the participants supported that the financial income is the most key factor for them to be successful as a business. However, they stated that this does not mean that they do not want to contribute to climate mitigation. They supported the idea that if there is financial stability all the other goals can be achieved either. All the options mentioned are interconnected so for them to be achieved, financial capacity should be in a good place for implementation. Moreover, some do not fully agree with the priorities selected and they mentioned that they would change some of them, especially the increase in yield production and irrigation. Finally, they mentioned that an increase of interest related to soil health and improvement should be of high priority since is the beginning of all.

They mentioned that climate change is noticeable on their farms so on their own they are trying to find solutions and some of them are already using some methodologies that are considered carbon farming methods. They are positive in the perspective of applying carbon farming application, but they support that the consumers are the ones that need training and awareness on this matter. If consumers do not understand what carbon farming is and what are the benefits the product can provide to them, then there is no market for these products. In addition, they mentioned that supermarkets can have a major role in affection by the way they promote this kind of product. Farmers also mentioned that the bureaucratic procedures are very hard for them and require time and this is an important drawback in acceptance of new methodologies.

Participants do not know what MRV is except for one so an explanation on this matter took place. Most of them believe that they already do this and are willing to continue doing it. Participants stated that they already have some data (e.g., Diesel consumption since they pay monthly on a specific gas station, they receive a statement). Farmers mentioned that there are a lot of people that need to change towards better practicing and some of them are already experimenting on their lands. They showed an interest in having a toolbox for doing these activities, but some obstacles appeared with the time management. Nevertheless, they are ready to overcome obstacles so they can benefit financially.

‘’One of the participants supported that MRV will not interest the farmers. This is because in the past reporting books existed where 99% did not follow the reporting or reported false data. The attendee stated that people fear making mistakes since this kind of situation causes trouble with policy makers and are missing fundings or experiences fees.’’

They are expecting that they will have economic benefits by applying carbon farming techniques. Some mentioned that can have the knowledge multiplier role on the MRV by showing to others the CF practices they are using on their lands and what are the benefits from it. Farmers appeared to be negative related to smart application development since they support most are old and are not familiar with technology only a few could use this kind of applications. They said that only if they had help from others and that is not the best option. They prefer to have a hard copy and filling showing us the technological limitation of farmers and their difficulty adapting to advances. In addition, they showed us that young people are needed in the agricultural field. Nevertheless, some support that if an easy and use friendly application is created it will be good for the advancement of agricultural sector. A comment derived from a farmer related to environmental perspective was that farmers are improved to this matter sharing an experience with us related to trash collection that nowadays is reduced by farmers. Some supported that farmers might be scared to use CF methodologies with the thought of losing their production. However, if funding is available, they will make them take risks and increase their interest to try something new.

Farmer associations support that we will face negativity especially to the matter of using fertilizers. Thus, ways to promote CF should be created. They said that we should promote in a correct way the effects of CF and state from the beginning that this approach is for their interest related to yield increase and the economic perspectives. They also mentioned that simple language should be used, and the message must be clear (e.g., interest, what are the benefits and rewards). Participants also shared that if they have more support, they will implement more activities based on carbon farming that would help the environment. An additional opinion was to prepare them that at some point these practices will be mandatory and if not implemented there will be possible fines, thus it would be wise from their part to start processing these CF practices and start to implement them from their own interest.

Participants prefer support from external parties for services implementation since they believe the less expenses the best for them financially as well as motivation to participate. They also mentioned CAP or the creation of independent funding for these purposes. They also mentioned that CAP have a lot of issues now that should be fixed. Participants stated that agronomists will have the greater impact on knowledge transfer to farmers. The reason is that farmers have their own agronomists, and they created a trust bonding with them speaking their own language of understanding. Thus, this will make it easier for them to adopt new practices and understand the impact of CF. Onsite visits could be a motivational activity for farmers in order to be interested in CF and see in real time its benefits. Moreover, some farmers mentioned that maturity on this matter should occur and informative activities with simple language should be used.

Finally, participants mentioned that farmers will not easily accept paying for this kind of training since they pay for other things too and that support should be given to them. During the conversation they asked what a way can be to trigger farmers to support the environment, farmers mentioned that it is impossible to not care about the environment because is their land and this is important for them. Farmers when the asked if they want to be part of the Cyprus MAP they showed an interest and wanted to participate.

Academia:
Six individuals attended the face-to-face interviews from the academic community where Carbonica project and the MAP creation was explained followed by the interviews. The attendees from academia support that the highest percentage of farmers do not have knowledge about CF only a small percentage might have a basic knowledge on CF field. They believe that farmers practicing organic farming will have knowledge of this sector.

In addition, conversation leaded to a conclusion that if there are no financial benefits from CF, farmers will not intend to start using these methodologies. This is because crop types differ in relation to carbon sequestration thus if there is no financial benefit of changing the way of practicing on a specific crop, they would not be willing to change it. Academia stated that there are crops that cause the release of CO_2 and some that reserve it and thus it is of importance of what we are cropping and if it has value to change practicing for carbon sequestration purposes. In addition, the academic community stated that from their nature some crops must be treated in a specific manner and cannot allow changes. One of them mentioned an example related to crop saying that:

‘’If farmers crop barley they will not change their practices because they would not have a financial gain from it.’’

According to scholarly opinions, it makes sense that farmers prioritize market expansion and financial gain when it comes to the hierarchy of needs for the agricultural industry. They stated that they do not agree with this decision since it is illogical to rank the rise in production as the fourth factor and the economic gain as the first. They pose the question of how farmers will benefit monetarily if raising in production is not their primary objective.

Regarding the familiarity question on MRV, every participant is knowledgeable about this subject. A related question during the interview is if they believe farmers could use this method where they stated that age is an important implication to this topic since it is difficult for an older farmer to keep data and information despite the technological advances. They also believe that farmers would show an interest in doing this process but if there is not a financial gain coming from it, they would stop it. In addition, they mentioned that some farmers already do this kind of data collection but is problematic and new advances should come to this domain. The main motivation to start MRV is the financial perspective however if this becomes mandatory from policy makers and government, they would do it. Participants from academia also mentioned that if this kind of technology comes out should be user friendly so that everyone can use it despite their age. They mentioned that new applications should be developed so that farmers can use them all day long and record their activities on databases. An additional motivation for using the MRV is to support farmers through fundings. The academic community also stated that farmers would be very interested in carbon credit collection since they will be an extra income.

Academic community asked what they believe should be their role on the MRV certification. They believe that can be the certifiers on these procedures so that they can monitor what farmers activities are. An opinion difference derived from some individuals in relation to certifications since some believe that this is not academia’s role but government’.

In relation to what data farmers should keep, academia believes that should have GPS records of how many meters a tractor crosses so that we can monitor fuel consumption and estimate the carbon footprint.

Additional data can be tilling practices either no tillage, conservation tillage or tillage on each pilot site. Smart tractors can be a good alternative in relation to CO_2 emissions, however academia support that comes with a high cost and farmers will never be able to afford it since they do not all have huge plots and incomes. Nevertheless, academia supports that policies should be created about tractor kind and use and maybe should create subsidies for support or to create a sharing system for all.

In relation to willingness to adopt CF practices and the factors that might contribute to this, the academic community believe that branding might be a good idea by somehow raising the product cost. This will have as an outcome to receive attention from farmers and see the opportunities for CF labeling on their products. In addition to this, academia supports that government has a key role in promoting CF to farmer communities and provides them with support and training. They support that training should be organized and held so that farmers can see in practice the opportunity and the meaning of carbon farming both from economic perspective and environmental preservation. Also, they support, like farmers did, that consumers should be informed too since consumers have the primary and last word on the food market.

About their opinion in relation to if farmers require training in CF, academia believes that they need it since they do not know certain things about these methodologies. They support that the main activities that should be held firsthand are seminars for knowledge transfer and state the benefits of this technology. At these seminars a special session should be held related to financial gains so that we can get their attention. One attendee mentioned a previous example about fertilizers:

''For purchasing fertilizers, a member card is required. Farmers to get this member card are required to attend seminars so this might be a good example for CF. The member also stated that EU should also keep the promises and policies created on this matter.''

Most of the participants support that policy should be created related to CF, if not farmers are not forced to do anything.

The academic community supports that farmers might not be able to collect data so industry should be an alternative to this. In addition, agronomist consultants can be part of this so that can do the measurements and data collection for them. They stated that different offer packets can be created so that all can afford it. They also stated that it is difficult for everyone to have a toolbox, thus one can have it to support multiple farms. They also mentioned that despite the farmers, consumers and young children should be trained about CF. Conclusion to this question with all the participants agreement they stated that:

''The main stakeholder that has the primary role in this is the Agricultural ministry.''

Academic community showed a great interest in registering in the Cyprus MAP and wants to be part of it.

<u>NGOs</u>:

The hostage of people from non-governmental organizations (NGOs) was performed in the frame of Carbonica's face-to-face interviews. An introductory speech made for MAP explanation in addition to question of their opinion related to the creating of MAP. A positive and mutual perspective shared among the participants supporting that collaboration with other stakeholders is a key to success. They also stated that fruitful sharing of experience in addition to knowledge transfer is a step forward to goal achievement. Thus, collaboration coming from the MAP is an important asset to face challenges in the agricultural sector. Comparison between the agricultural sectors of the three countries is an important asset towards changes as well as the expertise sharing from the three countries.

- ***Level of knowledge derives from other countries. So, exchange of experiences is beneficiary.***

In addition, participants asked about their familiarity with CF, answering that they are well familiar with this topic, but they state that is an infant field for the rest of the world in addition to farmers. An additional comment derived from this conversation is that the agricultural sector is not ready yet for adopting these methodologies.

Participants from NGOs asked if they agree about the order preference chosen during the survey about the goals that are the most important to achieve. Participants responded that they somehow expected these preferences since the most important parameter from the affected stakeholders is the economic benefits. However, participants stated that they cannot step on their feet because farming is their main source of income. Like farmers, NGOs they found these answers somehow paradox since in order to achieve financial gains and market expansion promotion of sustainability and increase in production yield should be first achieved. They stated that farmers might not know that CF can increase productivity. This shows the urgent need for knowledge transfer on this topic. However, NGOs find a positivity to the matter that participants place the development of innovative solutions and technologies in the agricultural sector as a second preferred goal. However, they stated that the answers on their own are all important.

Participants, when they asked about their knowledge on MRV, tell us that they are not familiar with this terminology. An explanation to the guests was made observing a great interest in this matter asking for their opinion. Participants believe that if it is financially beneficiary for the farmers, they will for sure adopt these procedures of keeping data of their daily activities. They also stated that farmers should have the expertise to keep up with this procedure, coming to the outcome that training should be held for farmers about this topic. In addition, participants added that recruitment should be done in order to not burden more with extra activities, and this might be a financial problem for the farmers. They stated that a good idea is to hire external services that can do this for them. Participants from NGOs can see themselves on this matter as a promotion body of CF and networking from their current contacts. Also, they believe that can contribute to knowledge transfer and to monitoring of farmers' activities. Promotion can be done through social media so that interested stakeholders can register to the MAP and bring together all the interested parties. They stated that:

''An important factor that will determine the farmers willingness on CF adoption is the financial benefit and nothing more. ''

NGOs support that support measures should be created in order to motivate farmers to use CF. This can somehow be done by monitoring their practices after all the training that will be held for the farmers and if they meet the conditions can obtain money. Regarding the training model they believe should be followed, participants support that farmers who know about carbon farming can contribute to training activities in addition to expert bodies. Moreover, advisors can contribute to the training and then on a farm level. In addition, they stated that an effective motivational system could be a face-to-face contact with them where explanation on CF and the environment impact from it will be a motivation to them especially if we make them feel that this process will be their own achievements. We should listen to them and their concerns so that we can build training courses based on them. Finally, they showed an interest in registering in MAP.

<u>Policy makers</u>:

Policy makers regarding the collaboration derive from MAPs support that this kins of collaboration is always a knowledge source and experience transfer from different people so as to improve current issues. Policy makers supports that farmers do not have the knowledge related to CF practices. In addition, policy makers mentioned that on a country level the situation of CF is still a conservative matter. They suggest that farmers need training on this topic to open their horizons to new approaches that will benefit their products as well as their financial status. Participants mentioned that there are some portions that have basic knowledge about these new farming methods but are not fully qualified. In addition, participants mentioned that there are current policies related to increasing the above ground material and farmers implement those kinds of practices, but they do not know that they are related to CF. Thus, training activities on a farm level and informative activities are required. They mentioned that there is an ignorance from farmers in addition to their organization about CF and this has as an outcome the delay of CF deployment. Financial benefit is the only way for them to employ those practices by providing them with all the relevant information and training so them to see how this approach can benefit them. Consumers are another part that must be considered and hold informative activities since they are the last acceptance of a product.

One person from a policy maker position said that is not surprised about the scale of importance of the goals that need to be achieved. However, the largest portion was curious about the 3rd and 4th preference they expected them to be lower in the ranking. A common opinion from all is that they were expecting the first choice placed by the highest percentage on economic values and market expansion. They also stated that:

''Farmers from European countries recently strike around Europe about financial matters, so these answers were more than expected.''

Attendees from policy makers positions mentioned that other matters concerning farmers rely on electricity from an economic perspective and most of them seeking to install photovoltaics. Funding opportunities are available in Cyprus for the installation of photovoltaic systems. However, it has been observed that farmers are not embracing this initiative due to environmental considerations but due to financial benefits. Participants stated their opinion related to ranking, saying that the second choice should have been the increase in productivity and third choice the improvement of productivity that comes to food security.

Policy makers like other parts from the quadruple helix participating in these interviews do not have the knowledge on the existence of MRV protocols. An explanation on this subject took place. Attendees responded that a small group of farmers will be interested in this topic, especially with the financial gain from it. However, they stated that the farmers as a whole if this strategy won't become mandatory will not show an interest in this. This is due to the reason that will burden them with their daily activities, and it will be hard for them to record everything they do on their lands. They noted that the existing bureaucratic burdens already consume a significant amount of their time, and any additional required activities would likely provoke a reaction from them. Policy makers are considering a potential solution to this issue through the creation of policies that would mandate compliance, both at the national level within the Cyprus government and through EU directives. Policy maker bodies stated that from this to be successful a good reason for them to keep information and data should be explained in order to provide an impact. During the conversation some mentioned that big farming business will be interested in MRV since they would provide them with certifications and thus their product could be labeled and have higher cost. Nevertheless, small farming businesses will struggle with this since it would not be financially viable for them. Regarding their thoughts on the possible struggle of keeping and collecting data they mentioned that there are already templates for data collection of farmers' daily activities and for farmers to collect subsidies. However, it is difficult to pursue all these activities because some might not be interested or do not have the capacity. If programs that will provide financial support develop there is a chance for them to be interested in CF. In addition, user-friendly platforms could be created so that all of them can be use it.

Policy makers perspective on who will be the ideal sector to perform educational trainings support that is difficult for consultant subsidies due to farms load on consultants for other things. However, if a consultant has all the skills including CF to keep one person to do everything on a farm level (e.g., keep daily activities record, collect data etc.) might work. They state:

''It is difficult to have several people working as consultants on one farm. This comes with high money demand and farmers will not accept the force of having different people for different things.''
''The motivation of farmers on CF will only lie on the financial perspective, only a small group of people will see the environmental impact. ''

Policy makers' participants about their opinion on the presence of support measures would increase the interest of farmers to implement carbon practices believes that will come a step forward on convince farmers to adopt CF practice. Ideas about what support measures will be ideal mentioned purchases of new innovative technologies and training activities for farmers. On their own farmers stated that will not do the effort to buy new technologies it is financially difficult for them. In contrast with academic community mentioning the purchase of technologies for sharing, policy makers that this is impossible to happen due to policies on that matter and that is not how it works. In terms of sharing, it advocates that approval can only be obtained if there are changes in governmental policies alongside those of the EU.

Industry:
Attendees were asked if they believe that the ecosystem of Cyprus are familiar with CF responding that most of the people are not familiar with this methodology. However, even though most of them are not familiar with CF they believe that most of the farmers are ready for a change, especially if that comes with financial support. People from industry believe that financial income is the most important parameter in the agricultural sector in order to achieve business sustainability. They support that if the economic situation is good then all the goals regarding employing new methodologies are easily applicable. This is because farmers will not be afraid to adopt new methods since they have the economic strength. They stated that businesses, in order to be vital, it has to be an earning business and technological advances should be increased in order to provide more profit. They support the priority on the goals set from the overall survey attendance with a few disagreements related to yield production since they believe is somehow invalid to expect financial gains if yield increase is not on the top three priorities. However, they mentioned that all the answers given for them to choose are interconnected and all of them are equally important in the agricultural sector.

Regarding the MRV, people from industry are not very familiar and explanation of this term took place. Participants showed an interest in this field since it is an opportunity for extra financial gains. They mentioned that are already report their activities on their daily practices. However, they stated that it might be a time-consuming procedure for small farms since they do not have either the financial strength or support. Nevertheless, if provision of financial support will give to them will show high interest of start doing these procedures. People from industry when they asked about what will increase the willingness of start using CF, they supported that the only way to increase willingness is the financial perspectives and through subsidies. The environmental aspect mentioned will always be a secondary thought for them since they want financial stability.

Strong support appears to raise awareness among consumers since they have the prior and final role for them to survive financially. If awareness speeches take place and make people, seeking for these products will be easier for farmers and businesses to implement carbon farming practice. On the training aspect, participants support that they would be interested in providing their teams with all the expertise gained from training on their own. They would like to train their existing work forces and to avoid external consultants due to cost. However, if there is a limitation regarding help and time are willing to hire an external consultant to do this for them.

Another factor that will matter for them to start adopting carbon farming practices is support measures from interested parties and governments. One of the participants practices organic farming and has financial support from an external organization supporting that this is much easier for the business to survive. The participant also support that Cyprus community is not ready yet due to knowledge gaps. Thus, further activities should take place for raising knowledge on this topic to people. People from industry showed a great interest in the CY MAP creation and they intend to register.

Figure 31. Face-to face interview in CY

12.2 North Macedonia face-to-face interviews

All the experts in the field are informed and familiar with the objectives of the project and spoke positively about the benefits of the implementation and realization of the project Carbonica. However, this group of respondents are not familiar with the idea of the MAP creation. Moreover, each of them has clarified the positive opinion within the idea of creating a MAP and their involvement within. All respondents unanimously and positively support the idea of creating MAP establishing common goals and cooperation. Most of the discussion (9) emphasized the collaboration challenges and need of this kind of support in the agricultural sector. Furthermore, some of them (5) specifically emphasized the need for the platform in the direction of immediate and intensive cooperation with the agri-food sector, including a large number of stakeholder profiles. One expert remarked on the mandatory need of this agri-tool as a potential mechanism for sustainable development of national and regional agriculture production.

More than 50% of those interviewed (11) indicated the impact of the climate crisis in reducing production yield and soil health and impact on the financial profits and market expansion. They believe that this situation can be improved through primary with 1) Development and application of innovative technologies in agriculture, through 2) Promotion of sustainability and environmental protection. Enhancing soil health and carbon sequestration was also proposed as an effective tool in improvement of production and efficiency in the agricultural sector (4).

The entire group of interviewees declared that they were not familiar with the term MRV (Monitoring Reporting Verification). Some of them (12) emphasized the need for an available information system for these new terminologies that are part of modern and sustainable agriculture.

All interviewed experts believe that the University is the optimal environment for advancing knowledge. But initially these modern practices and technologies need to be introduced as mandatory components in the curricula for future agronomists. In addition, it emphasized the need for training that needs to be conducted in academic environments, as experts from the areas will improve their knowledge.

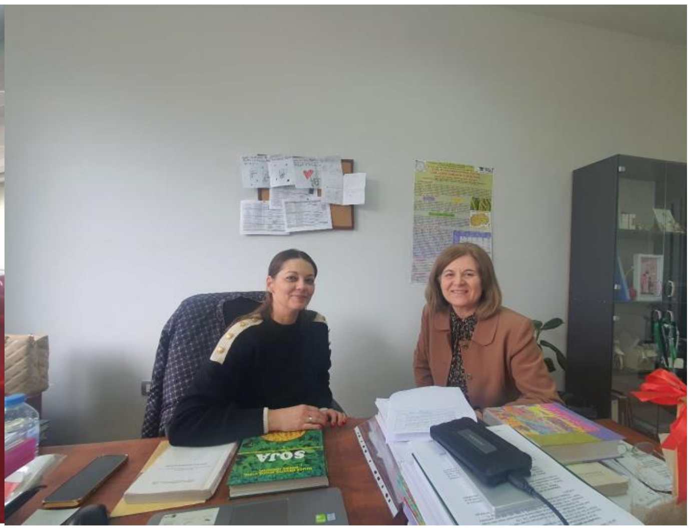

Figure 32. Face-to-face interviews NMK

12.3 Greece face-to-face interviews

In Greece, the adopted strategy involved organizing networking events to facilitate discussions and interviews on the above specific questions relevant to CF. These events brought together diverse groups representing the quadruple helix model: Farmers, Academia, Land management professionals/agriculture consultants/agri-businesses, and policy-makers. Although not everyone was familiar with the concept of Carbonica, they were well-versed in CF and regenerative agriculture. The presentation of the Carbonica Excellence Hub was met with enthusiastic approval, sparking engaging and insightful conversations. Farmers and landowners tended to concentrate on the challenges hindering carbon farming, whereas agribusinesses and consultants showed a stronger interest in devising strategies to overcome difficulties. They were particularly focused on exploring economic motivations and the potential for new investment opportunities. A significant outcome from these discussions was the agreement among stakeholders that the primary motivations for landholders to engage in carbon farming were financially driven, highlighting the chance of increasing income. The ability to enhance business resilience, diversify enterprises, and mitigate risks also received high priority.

However, the interviews revealed several barriers to adopting soil carbon sequestration practices. Top of these as identified in farmers, land owners, consultants and agri-businesses were a lack of knowledge about carbon farming the practices, insufficient information, and concerns over the costs associated with implementing new activities, despite the presence of financial incentives. At the heart of these barriers lies the uncertainty of return on investment, critical for farmers considering the transition to carbon farming practices. Challenges include the need for farmers to effectively market their sustainable products to processors and retailers, the long-term nature of carbon sequestration benefits that may not be immediately realized, especially for those leasing land, and the administrative burden of establishing a carbon farming business model. Additional barriers identified include the absence of a market for carbon-sequestrating crops and reluctance from farmers to adopt carbon farming techniques due to fears of their extra efforts becoming misunderstood.

A substantial gap in awareness and trust was identified as a major barrier from farmers and land owners to directing private sector finance towards farmers aiming for agricultural transitions. Concerns about data sharing potentially leading to penalization by agrifood and financial sectors, and the misappropriation of proprietary data, were prevalent. Uncertainties surrounding carbon pricing, environmental market regulations, and the credibility of standards further discouraged farmer participation. The uncertainty of financial entities and companies to commit support in the absence of clear governmental guidance exacerbates these challenges.

An added layer of complexity in addressing agricultural emissions lies in the challenges of accurately measuring, reporting, and verifying (MRV) these emissions at the farm level—a barrier frequently highlighted by scientists and policy-makers. The data needed for MRV, coupled with the sheer volume of farmers, present a significant barrier for the adoption of market-based instruments, largely due to elevated transaction costs. Academia specifically points out the substantial uncertainties in assessing agricultural emissions, especially concerning livestock emissions and soil carbon dynamics. They note that agricultural emissions are inherently variable, influenced by local soil compositions, management practices, and climatic conditions. Furthermore, the dispersed nature of these emissions complicates efforts to mitigate them, making agricultural sectors more challenging to regulate compared to industries with point-source emissions.

Farmers and landowners expressed their disappointment with existing carbon markets searching, citing issues such as low compensation, cumbersome paperwork, unpredictable credit calculations, and a bias towards larger-scale agriculture. Concerns over greenwashing and the lack of additionality in carbon credit systems were also mentioned. The data needed for land management and support services is often scattered, inconsistent, and costly to access, creating additional barriers to effective carbon farming practices. The protection of sensitive data and the equitable sharing of information emerge as critical needs in fostering a transparent and beneficial relationship between farmers, land managers, and support entities.

Interviewers from academia, agronomists, and policymakers have expressed concerns regarding the concept of additionality in agricultural projects, highlighting the absence of a comprehensive dataset that includes a comprehensive mix of climate-smart agriculture. This dataset would ideally include a variety of soil types, climates, geographic locations, farming practices, and crop types. A major challenge complicating this issue is the lack of a consistent trend in the adoption of soil enrichment practices, which varies significantly by region and cropping system. This variability makes it challenging to compile a definitive list of additional practices and to offer evidence-based agronomic advice tailored to individual producers. Moreover, the decision-making process of farmers often deviates from the traditional model of rational economic actors as defined in academia. Influences on their decisions can include personal and cultural factors, such as the opinions of family members, which might sway a farmer's willingness to adopt new and potentially transformative agricultural practices. Although adopting practices like no-till farming may seem financially beneficial in the long run, the immediate perspective of a farmer facing the necessity of a significant initial investment and a departure from familiar methods is vastly different. An observer from outside the farming community might not appreciate the need to balance potential financial benefits against the increased risks and uncertainties these changes introduce to the farming operation.

The collective barriers outlined make difficult the ability of farmers to ulock financial opportunities within the carbon farming sector. The challenges of aligning small-scale farming operations with environmental market demands necessitate collaborative models, yet there is a lack of formal support and guidance for these initiatives. Misconceptions about tax regulations, soil carbon markets, and the principles of additionality further obstruct the path to effective carbon farming practices. Lastly, concerns over the double-use of carbon credits in voluntary markets, particularly in relation to greenwashing and the question of additionality, highlight the need for careful examination and support for succeed environmental sustainability efforts within agriculture.

What farmers, land owners and agronomists explained was that in order to understand the economic implications and risks associated with carbon farming requires an appreciation for the diverse agricultural landscape, which spans from small-scale family operations, to large-scale, possibly state co-owned farms exceeding. This diversity encompasses everything from vegetable cultivation to cereal production, livestock raising, and grassland management. Land acquisition by major agribusinesses and imports from outside the EU further threaten the viability of small and medium-sized farms. Additionally, concerns about market competition loom large for farmers, many of whom view EU support, especially in the form of subsidies, as vital for sustaining their operations amidst these challenges.

The outcomes form the interviews can be summarized on the following categories:

- **Financial Incentives and Economic Viability**

The primary motivation for adopting CF practices is linked to financial incentives. However, the uncertainty of return on investment, especially for those leasing land or with limited market access, poses a significant barrier. This uncertainty is strengthened by upfront costs and the long-term nature of benefits, which may not be immediate or guaranteed.

Response: To mitigate financial barriers, there needs to be a shift towards providing upfront subsidies and public funding to reduce the initial economic burden. Implementing guaranteed minimum carbon prices or premiums for carbon-sequestered products could offer more predictable income streams, encouraging adoption. Furthermore, developing insurance products to hedge against the risk of investment in CF practices could alleviate concerns over uncertainty.

→ **Knowledge and Information Gap**

A lack of knowledge on carbon farming practices and their benefits is a significant barrier. This gap is not merely about the availability of information but also about its accessibility and relevance to farmers' specific contexts.

Response: Tailored extension services that provide context-specific information and hands-on support can bridge this gap. Utilizing local networks and farmer-to-farmer learning can also enhance knowledge dissemination. Furthermore, integrating carbon farming practices into agricultural education and training programs can prepare future generations of farmers.

→ **Market and Administrative Challenges**

The absence of a robust market for carbon-sequestering crops and the administrative burden of setting up a carbon farming business model discourage farmers. These challenges are compounded by concerns that sustainable practices will become expected norms without additional compensation.

Response: Developing certification schemes for carbon-sequestered products can create market differentiation. Simplifying the administrative process and providing technical support for business model development can lower entry barriers. Policy interventions to recognize and reward early adopters and innovators in carbon farming are also crucial.

→ **Data and Privacy Concerns**

Concerns about data privacy and the high costs of data collection deter participation in carbon farming. The dispersed and inconsistent nature of environmental data complicates risk evaluation and environmental strategy development.

Response: Establishing standardized, transparent data-sharing platforms can alleviate concerns. These platforms should ensure data privacy and facilitate access to high-quality, relevant data. Incentives for sharing data, coupled with strict privacy protections, can encourage participation.

→ **MRV and Policy Barriers**

The complexity of MRV at the farm level and inadequate policy support further complicate the transition to carbon farming. National GHG inventories may not accurately reflect emissions reductions from carbon farming practices, reducing the encouragement for their adoption.

Response: Investment in technology and methodologies to streamline MRV processes is critical. Policy reforms that recognize and incorporate carbon farming practices into national and international emissions accounting frameworks can enhance their attractiveness. Cross-sectoral policy coordination can also ensure that carbon farming practices are integrated into broader agricultural and environmental strategies.

→ **Carbon Market Concerns**

Concern about the functionality and fairness of existing carbon markets, including concerns over greenwashing and additionality, undermines confidence in carbon farming as a feasible strategy.

Response: Strengthening standards and verification processes for carbon credits can address concerns over integrity. Transparent pricing mechanisms and fair-trade practices can ensure that small-scale farmers are not disadvantaged. Additionally, public awareness campaigns highlighting the benefits of carbon farming can counteract greenwashing.

Figure 33. Face-to-face interviews GR

13 Discussion

Common goals identified between the three countries of the IES along with some differences in relations to opinions about agricultural sector. An important need and goal to be achieved identified on this questionnaire derived from both countries is related to financial profit and market expansion. Increasing total sales is the goal of market expansion to provide producers and marketers of agricultural products with better returns. Market development is a multifaceted problem. It reaches back to the farmer and penetrates every aspect of the marketing system. Farmers must first provide the best possible products to build markets. It is anticipated that the marketing system will help farmers achieve this by running a productive pricing system and applying market research to direct production in the necessary directions. Additionally, it is anticipated that the system will transfer farm products in an orderly fashion at fair pricing without sacrificing quality from producer to consumer. This entails a wide range of marketing tasks, including processing, shipping, sanitation, standardization and grading, and marketing research. One of the most crucial aspects of the market growth process is the synchronization of all these activities. Improvement of production and efficiency in the agricultural sector for all countries was selected by the majority to be the least important goal to achieve. Thus, effort should be made through information activities to promote and pass knowledge in relation to long lasting benefits by improving production and efficiency along with eco-friendly practices for environmental and soil health and the financial benefits from it.

It is important that a high portion of participants showed a prominent level of interest in carbon farming in addition to the usage of satellite and ground-based measurements. This encourages the Carbonica project to collaborate with many people from the agricultural sector towards CO_2 emissions reduction and be part of the climate change mitigation policies. It is of importance to state that some people showed no interest on carbon farming thus awareness campaigns can be critical to address the benefits can gain from it and an extra motivation can be given with the provision of evidence derived from research done.

An encouraging result also derived from the willingness of participants to take part in the activities of Carbonica's project. An understanding of this gives us an insight that people want to be part of the project goal and need a change so they can benefit from it.

Thoughts on collaboration with other stakeholders from the MAPs of the Carbonica project showed a positive outcome since most of the participants believe that is important for exchange of experiences and knowledge. Collaboration with other stakeholders is important for the implementation of several goals including the adoption of carbon farming practices and ensure that policies will be created for them to get the support needed to encourage them adopt those techniques.

Face-to-face interviews revealed common opinions between the three ecosystems in relation to economic perspective derived from farmers. Farmers need new business opportunities that will give them more financial gains and cover their needs. In addition, barriers appeared in relation to CF knowledge where all the three ecosystems have low knowledge about CF and the opportunities that it can provide. Mutual fear observed from farmers due to the economic instability they are facing creating an extra barrier to change the methodologies they are currently using. All the three ecosystems require training in the CF domain as well as informative events in order to provide them with all the relevant knowledge and opportunities that they will have from this field. Concerns are also observed in relation to the current system where they are facing a lot of paperwork procedures, creating a barrier in relation to MRV. A commonly held perspective within academic circles, particularly in relation to soil variations and the suitability of different crop types for implementing CF practices.

14 Conclusion

Sustainable agricultural production methods are urged due to the rising human needs and their effects on the environment. Using less intensive and wisely planned farming techniques can stabilize the dependence of agricultural output on climatic change. In order to find farming systems that can manage the delicate balance between climatic change and agricultural production, the agro-environmental parameters must be carefully taken into account. In this context, carbon farming offers a comprehensive and sustainable land-use management strategy that is good for the environment and society. As was previously mentioned, there are a number of carbon farming techniques that have been shown through research to improve carbon sequestration and raise the SOC.

The European Commission acknowledges that the Carbon farming initiative can significantly contribute to climate change mitigation. The importance of robust carbon monitoring is likely to increase in the coming years, thus setting this as a priority is essential for the wide European Farming sector to participate in the carbon farming goals. As relevant literature demonstrated, the agronomic practices that may be adopted are diverse, and their success varies according to many factors including climate, soil type, landscape, and local economic and cultural conditions. Based on several recent studies, it is worth reporting that many farmers, even nowadays, don't understand the exact meaning of carbon farming, and they lack detailed information about the pros and cons of carbon farming. Despite that, studies and academic literature demonstrate that amongst others the most effective means for increasing soil carbon sequestration is through changing land cover, such as converting annual cropland to forest or perennial crops.

As mentioned above, the support of the European Union contributes to research but also involves stakeholders that can support the creation and ascension of projects, showing the importance of involving carbon farming in the agricultural sector. The research and agricultural community have greatly enriched the existing knowledge on carbon farming and elucidated the beneficial practices to maximize carbon sequestration in soils. The findings of this literature review showed that it is important to develop protocols suitable for the correct and accurate measurement and adapt carbon sequestration practices of soil in the Mediterranean region. Therefore, it is necessary not only to upgrade the agriculture sector but also to convert it towards climate change mitigation.

Apart from the methods that assess and monitor soil carbon stocks using only satellite data, the relevant literature has shown plenty of approaches that leverage a combination of available satellite data, field soil spectroscopy measurements, soil models, and machine learning techniques. The SALUS model is one of those process-based models developed to simulate the interactions between soil, climate, crop genotypes, and management strategies on crop growth, water, and nutrient cycles during growing seasons. Additionally, Artificial Intelligence for Ecosystem Services, InVEST - Integrated Valuation of Ecosystem Services and Tradeoffs, or LUCI - Land Utilization and Capability Indicator, are widely used in studies to model the consequences of different management practices on land use and land cover changes and carbon emissions, such as agriculture, forestry, livestock, and the conservation of natural areas.

The survey created in the framework of the Carbonica project showed that the agricultural sector requires training and informative events where CF opportunities will be provided. In addition, farmers' needs were identified through this survey as well as from the face-to-face interviews. Participants demonstrated significant enthusiasm for integrating CF methodologies into their practices and expressed keen interest in actively participating in the MAPs.

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