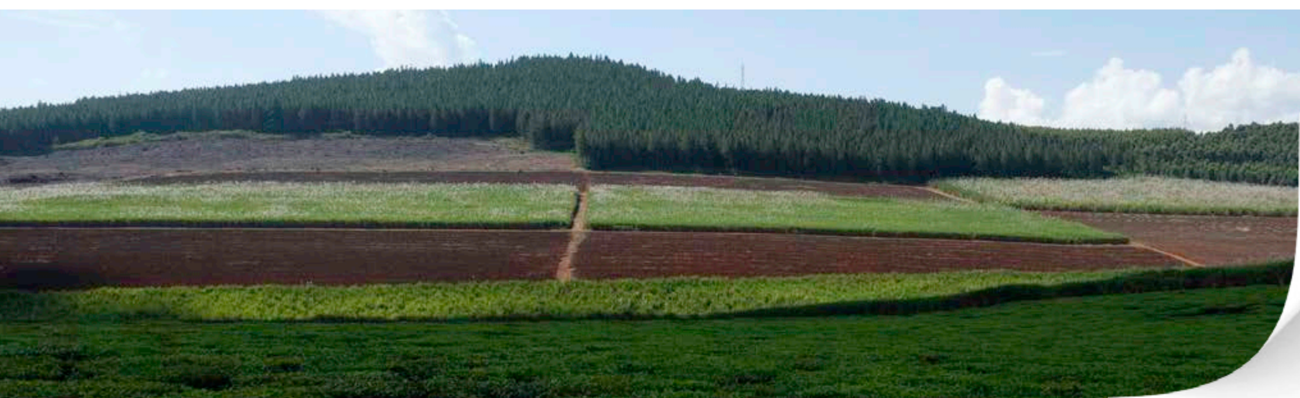
TRAINING NOTEBOOK

- ENVIRONMENTAL MANAGEMENT -

SUSTAINABLE AIR QUALITY MANAGEMENT



COLEACP

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This publication is an integral part of a COLEACP collection, which is made up of educational and technical tools and materials. All of them are suited to different types of learners and beneficiaries and levels of education found in agricultural supply chains, production and sales.

This collection is available online for COLEACP members and beneficiaries.

SUSTAINABLE AIR QUALITY MANAGEMENT

Dear trainers, some advice...

WHY A TRAINING NOTEBOOK?

The "Manuals" edited by COLEACP are valuable training materials. To write them, COLEACP approached the best experts in the field with the aim of producing a technical document for a large public on a given theme that brings together and structures most of the current knowledge. These manuals are intended to be as accurate and complete as possible, adapted to the ACP context and focused on cross-cutting issues in horticulture. But the objective was also to make them affordable, understandable and enjoyable to read by people who are not necessarily experts in the field. Nevertheless, it is a **considerable effort to** assimilate all the material collected in a short time.

The training manuals, which are aimed primarily at experts and the most qualified people, are **often voluminous and complex,** and **it was necessary to help the expert trainers to identify the most important elements to retain**, and to collect for them a list of 'key messages' to be disseminated to learners during COLEACP training. This Training Notebook is therefore **a valuable and practical tool** that is at your disposal to **help you prepare your training on the** topic covered in this Booklet.

WHAT DOES THE TRAINING NOTEBOOK CONTAIN?

Each Training Notebook contains:

1. The list of materials to be delivered to participants during the training

This is a summary table of contents of the Training Manual. This list allows you to have an **overview of** all the **main points that** will have to be covered during the training. The o**rder of the list does not necessarily have to be respected,** as the organisation of the sequences is left to your discretion and may depend on other factors (e.g. availability of an expert trainer; timing of the training sequences; space reserved for exercises...).

In some cases, **only certain aspects** (or chapters) of the **subject will be covered** (for example: if the participants have a perfect command of certain parts of the subject covered in the training, it is not necessary to present them in detail; a small reminder may be sufficient and effective to cover the rest).

However, when you cover part of the material (a chapter), the main 'points' listed for each chapter allow you to organise your presentations and animations in a logical and relevant way for the learner. **You are also advised to present all the points of a chapter.**

2. Training leaflets

A Training Notebook contains as many 'leaflets' as there are chapters in the training manual. Each sheet contains the **Training objectives of** this part of the subject to be delivered (what the learner must be able to deliver...), and on the other hand, according to the structure of the table, the '**key messages**' (what the learner must have assimilated by the end of the training). It is therefore very important to ensure that **all messages are well distributed during the training sequence.**

3. A summary of the content of the manual

A summary of the manual has been included in this Training Notebook. Structured in the same way as the manual, it contains most of the content in 15-20 pages but is much less complete (the summary does not include tables or figures).

This summary is **primarily intended for the trainer.**

- **At the beginning of the mission**, when preparing its intervention sequences and supports, it allows you to quickly become familiar with all the content you will need to address and to visualize the links between the different parts of the material to be delivered.
- **During the training,** you can use this summary **to prepare your daily summaries**, reminding participants of the essential elements seen during a day (15-20 minute summary at the end of the day with answers to questions).
- **At the beginning or end of the training,** if you wish, you can give participants a copy of this summary. If the summary is distributed at the beginning of the training, it is advisable to ask participants to highlight the passages mentioned in your end-of-day summary (benchmarks in the subject).

The summary is also useful for learners at the end of the course: it will allow them to **remember in a** few minutes the **main part of the topic covered** (for example, before an assessment of prior learning), whereas reading the entire manual could be tedious.

HOW CAN THIS TRAINING NOTEBOOK HELP YOU PREPARE YOUR TRAINING INTERVENTIONS?

The intention of making this Training Notebook available to you is to **help you prepare your training sequences and structure your program day by day.**

- **Consider that each leaflet represents a whole:** if there are for example 4 leaflets, it means that there must be 4 distinct parts in your training. Sufficient time must therefore be allowed in the programme for each of these 4 parts. Each part of the subject will also have to be subject to a competency assessment.
- **Then consider the training objectives:** this will help you to choose: (a) the most appropriate training method for achieving your objectives (e.g. should you plan exercises, simulations, group activities etc.); (b) the method for evaluating the learning acquired in this part.
- **Finally, prepare your materials** (e.g. PowerPoint, flipcharts or animation sheets, evaluation questions) by ensuring that all key messages are included ("Have I planned to discuss all these points? Have I planned an evaluation on each key point?").

DON'T FORGET TO COMPLETE THIS TRAINING NOTEBOOK!

This Training Notebook is made **for you...** It is **a tool that must live!**

At the end of each leaflet, a space was left free to add **your personal notes:** as a trainer you can note some thoughts on how to get messages across, note your questions, participants' reactions, points that raise difficulties... ***i.e.* capitalise on your experience as a trainer!**

You can also **note the types of media you have used.** This will be very useful when you have a new session to facilitate on the same theme. COLEACP provides you with many tools and materials, but do not hesitate to create others or use other existing materials that may be available... the **rule is to master each of the materials used in training** and to ensure that they help to convey key messages more effectively than in their absence.

Materials to be delivered

CHAPTER 1 – AIR QUALITY BASICS

- Introduction
- Composition and air quality
- Impacts of air pollution: main facts
- Nature and health effects of air pollutants
- Nature and environmental effects of air pollutants
- Provide a framework for air quality management

CHAPTER 2 – IMPACTS OF CULTURAL PRACTICES ON AIR QUALITY

- Influence of agricultural practices on air quality
- Atmospheric pollution by fertilising materials
- Air pollution by plant protection products

CHAPTER 3 – GREENHOUSE GASES AND THE CARBON FOOTPRINT

- Greenhouse gases (GHGs) and climate
- The main international agreements relating to GHGs
- Carbon and nitrogen cycles
- The main sources of GHGs in the agricultural sector
- The different methods of calculating GHGs in the agricultural sector

CHAPTER 4 – IMPACT OF AGRICULTURAL PRACTICES ON AIR QUALITY AND MITIGATION STRATEGIES

- Agricultural practices and GHG emissions
- Emission mitigation and offsets opportunities
- Need for holistic assessments and a systems approach

Training Leaflet

LEAFLET 1

Air quality foundations

TRAINING OBJECTIVES

At the end of this training sequence, the participant must be able to:

- know the definition of air pollution;
- identify the nature of the main air pollutants;
- understand the stakes of air pollution;
- know the composition of the atmosphere and its different layers;
- understand the impacts of air pollution on health, the environment and agriculture;
- know the role of major international agreements and the legal framework on air quality, emissions and limit values.

KEY MESSAGES

1) Introduction

- Aair pollution is "the contamination of the indoor or outdoor environment by a chemical, physical or biological agent that alters the natural characteristics of the atmosphere";
- The pollutants involved are gases or particles. They are of natural or anthropogenic origin;
- Agriculture has a responsibility for the presence of greenhouse gases and fine particles in the atmosphere;
- Air pollution has health, environmental and economic impacts;
- The most harmful pollutants are ozone, CO, nitrogen dioxide (NO_2) and SO_2, POPs and pesticides. CO_2 is not a pollutant!

2) Composition and air quality

- Agricultural inputs (fertilisers and plant protection products) can act as air pollutants.
- The atmosphere has 4 zones according to altitude (troposphere, stratosphere, mesosphere and thermosphere).
- The proportions of nitrogen, oxygen and argon are constant throughout the atmosphere, while the proportions of water, carbon dioxide, sulphur dioxide and ozone vary with altitude.

- Most climatic phenomena (clouds carrying storms, cumulonimbus clouds etc.) are confined to the troposphere. The troposphere is therefore the most troubled layer.
- Climatic phenomena explain how pesticides sprayed on a crop plot can disperse vertically in the 'atmospheric boundary layer' (ALC) and then travel long distances.
- Turbulence is thermal or mechanical and varies according to the air temperature which depends on the altitude.

3) Impacts of air pollution: main facts

- Air pollution is a major environmental health risk.
- The effects are: strokes, heart disease, lung cancer and respiratory diseases, including asthma.
- More than 90% of the world's population lives in places where air quality is not respected.
- The highest number of premature deaths occur in poor countries.
- Domestic smoke is also a serious health risk.

4) Nature and health effects of air pollutants

- Particulate matter is a mixture of solid and liquid particles.
- They are composed of elemental carbon (soot), minerals (soil erosion), salts (sulphates, nitrates, ammonia, sodium chloride) and organic matter (volatile organic compounds).
- For the coarser particles we speak of 'dust'.
- For particles whose size is less than 100 micrometers, we speak of aerosols.
- Particles with a diameter of less than 10 µm (PM10) can penetrate and lodge deep inside the lungs.
- Those with a diameter less than or equal to 2.5 µm (PM2.5) are even more harmful to health.
- Livestock and field crops generate dust and fine particles (PM10 and PM2.5).
- Ammonia, nitrogenous fertilisers, contribute significantly to the formation of these particles.
- Even at low concentrations, small particle pollution has a health impact; indeed, no threshold below which it does not affect health has been identified.
- At high concentrations, ozone has significant effects on human health (including asthma attacks).
- The respiratory system is affected by ozone, nitrogen dioxide or sulphur dioxide.

5) Nature and environmental effects of air pollutants

- Pollutants emitted by industry and agriculture contribute, after processing, to the acidification and eutrophication of natural environments (e. g. acid rain due to SO_2).
- Ammonia and particulate deposits from deposition change the quality of water and soil in natural environments.
- These deposits can promote the growth of some species of fauna and flora at the expense of others, and cause local biodiversity loss.
- There are close links between particulate pollution and ozone formation.
- The greenhouse effect is a natural phenomenon that maintains an average temperature of 15 °C at the Earth's surface.
- The contribution of each GHG to the greenhouse effect is expressed through an indicator called global warming potential (GWP).
- Agricultural areas are major sources of GHGs and fine particles.
- Agricultural and forestry areas are both sources and sinks of air pollutants.
- Air pollutants generated by agriculture are gases dispersed in the air – mainly nitrous oxide (N_2O), ammonia (NH_3) and methane (CH_4) – or particles, solid or liquid, suspended in the air.
- Agriculture releases methane (livestock and soil), nitrous oxide (nitrogen fertilisation and animal waste management) and carbon dioxide (energy consumption).
- Pollution causes a loss of sanitary quality of foodstuffs (heavy metals such as Pb and Cd, and POPs).

6) Provide a framework for air quality management

- There are many examples of policies to reduce air pollution.
- The 1997 Kyoto Protocol aimed to limit emissions of 6 GHGs, but the mobilisation of the international community was considered insufficient.
- The Paris Agreement (COP21 – Paris Climate Conference) defined a new protocol to keep global warming below 2 °C.
- At EU level, Directive 2008/50/EC sets air quality objectives to improve human health and environmental quality by 2020.
- Directive 2008/50/EC and Directive 1999/30/EC define alert thresholds and limit values, as well as action obligations in the event of an exceedance.
- Framework Directive 96/62/EC on air quality sets out the fundamental principles of a strategy for setting ambient air quality objectives.
- According to the Directive, ambient air quality must be monitored throughout the territory of the Member States.
- There is extensive legislation at European level setting emission ceilings for certain air pollutants (e.g. arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons).
- Directive 2010/75/EU (FDI Directive) defines an integrated approach to the prevention and reduction of pollution from industrial and agricultural installations. One of its guiding principles is the use of best available techniques (BAT).

- Indicative occupational exposure limit values (IOELVs) are set to protect workers from the risks associated with exposure to chemical agents.
- Indicative occupational exposure limit values (IOELVs) are the time-weighted average limits of the concentration of a chemical agent in the air in a worker's breathing zone over a specified reference period.
- Real-time and time-delayed measurement systems (analysis devices) have been developed.

PERSONAL NOTES AND REFERENCES OF THE MATERIALS USED

LEAFLET 2

Impacts of cultural practices on air quality

TRAINING OBJECTIVES

At the end of this training sequence, the participant must be able to:

- understand the effect of agricultural practices on air quality and the complex relationships between agriculture and air quality;
- distinguish the role of fertilisers and other inputs in air pollution;
- understand how fertiliser materials impact air quality;
- understand the mechanisms of pollutant dispersion in the air;
- understand how pesticides contaminate the atmosphere and disperse through the air.

KEY MESSAGES

1) Influence of agricultural practices on air quality

- Agriculture is a particular sector with regard to air pollution. Agricultural areas are, depending on the practices adopted, sometimes sources, sometimes sinks of carbon.
- Industrial agriculture is responsible for 35% of GHG emissions.
- The air is altered by biological pollutants (pollen, viruses, bacteria, spores...), physical pollutants (wind erosion, soot) or chemical pollutants.
- In some circumstances, suspended particles and gases are cocktails of pollutants that produce a toxic and/or ecotoxic effect.
- Agriculture and forestry emit 53% of total suspended particulate matter, 89% of N_2O, 76% of methane, 10% of nitrogen oxides, 50% of biogenic VOCs and 97% of ammonia.
- Soil preparation, fertilisation and cultivation operations will generate the emission of primary particles depending on the type of soil (the more degraded the soil, the faster it will emit dust) and the weather.
- Pollution is also indirect due to volatilisation and accumulation of soil pollutants (pesticides, fertilisers, livestock effluent, manure).
- Biomass combustion ('burning'), a common phenomenon in the tropics (87% of cases), is an important source of trace gases and suspended particles.
- In the fumes, there are many chemical substances (mainly CO_2, but also CO, VOC particles, NO_x).
- The quality of groundwater is also affected by fires.
- In southern Africa, the relatively stable atmosphere during the dry season allows the

development of strong thermal inversions, trapping particles in the lower layers of the atmosphere.

- Farmers use nitrogen fertilisers, pesticides and mechanize tillage on a large scale.
- Plants only absorb half of the fertiliser. The excess ends up in the atmosphere, soil and water, polluting rivers and impacting aquatic biodiversity.
- Plant protection products are a possible cause of the decline of bee colonies and other pollinators, and biodiversity in general.

2) Atmospheric pollution by fertilising materials

- Organic fertilisers (effluents, manure and slurry) are very interesting and popular sources of organic matter.
- It is nitrogenous fertilisers that pollute the atmosphere (mainly ammoniacal nitrogen and nitrous oxide).
- The volatilisation of nitrous oxide and ammonia is the main route of nitrogen loss when spreading livestock manure (effluents, manure...) or fertiliser.
- Three very slow basic processes are involved in nitrogen recycling: bacterial conversion of atmospheric nitrogen (N_2) to assimilable nitrogen (NH_4^+), nitrification and denitrif ication.
- The spreading of livestock manure generates more than a third of total ammonia emissions that will interact with acid compounds present in the atmosphere (e.g. H_2SO_4 or HNO_3) to form secondary aerosols of ammonium salts.
- In the vicinity of emission sources, aerosols or ammonia are deposited dry, which leads to an intensification of nitrification in the soil (soil acidification).
- All soils emit nitrous oxide, but emissions depend largely on soil characteristics.
- More than 80% of the EU's urban population is exposed to excessive concentrations of PM10.
- Ammonia is the most poorly known of the pollutants, while it causes a cascade of environmental effects. Ammonia concentrations show significant seasonal variations.

3) Air pollution by plant protection products

- The atmosphere plays a key role in the spread of pesticides, but due to a lack of measurements, diffuse contamination has gone unnoticed and underestimated.
- Legislation on ambient air quality does not set limit values for pesticides.
- Contamination can be direct: during application due to drift losses (loss by vertical and horizontal transfer of part of the spray mixture into the atmosphere).
- Contamination can be indirect: in post-application either by volatilisation from the treated soil or canopy, or by wind erosion.
- Atmospheric transfers can occur over long periods of time, which explains the persistence of some pesticides in the air.

- During spraying, the spray liquid is divided into different fractions. Spray drift is an atmospheric transport of very small droplets or pesticide vapours out of the treated area due to the wind that occurs at the time of application or shortly after.
- The drift varies according to: meteorological conditions (temperature, relative humidity, wind speed); the type of sprayer used (size of drops generated); spray parameters (pressure, boom height, type of nozzle used, working speed, type of product etc.).
- The size of the drops plays an important role in the distribution and coverage of the crop, and therefore in the effectiveness of the pesticide applied, but also in drift: it increases inversely with the size of the droplets.
- Droplets that are too fine (less than 100 µm) reach their target at random due to their long drop time and sensitivity to wind.
- Volatilisation describes the phenomenon of dispersion in the atmosphere that occurs following plant protection treatments. It varies according to vapour pressure, water solubility and Henry's constant (volatilisation from the aqueous phase), sorption coefficient Koc (volatilisation from the solid phase), half-life time in air.
- Movement in the air is achieved by a combination of two mechanisms: atmospheric movements that disperse by mixing with the surrounding air (diffusion); and turbulent movements (advection) that develop in unstable air or are generated by the wind.
- Wet or dry pesticide deposition occurs through atmospheric deposition processes (precipitation, gases and particles).
- Studies show that pesticides are present in outdoor air in both rural and urban areas.

PERSONAL NOTES AND REFERENCES OF THE MATERIALS USED

LEAFLET 3

Greenhouse gases and the carbon footprint

TRAINING OBJECTIVES

At the end of this training sequence, the participant must be able to:

- know the characteristics of the different greenhouse gases and their contribution to the problem of climate change;
- identify GHG sources within a company;
- carry out a summary analysis of the GHG-emitting items in a company;
- understanding the concept of 'carbon sinks';
- distinguish between the different methods of calculating or estimating GHG emissions.

KEY MESSAGES

1) The atmosphere, greenhouse gases (GHGs) and global warming

- There is a close link between humans and climate types. Man prefers to settle in places where living conditions are favourable.
- Climate change is an additional constraint to human existence and sustainable development. Agriculture contributes to this because of greenhouse gas (GHG) emissions.
- The atmosphere is the gaseous layer that envelops the planet Earth and is subdivided into sublayers of varying importance.
- The main components of the atmosphere are the three chemically unreactive gases: molecular nitrogen N_2 (78.08%), molecular oxygen O_2 (20.95%) and argon A_r (0.93%).
- Three main factors that naturally contribute to the heating of the atmosphere are:
    i. the absorption of a fraction of the incident solar flux and the thermal flux emitted by the earth;
    ii. the emission of the latent heat flux during the condensation of water vapour;
    iii. direct heating of air in contact with the Earth's surface.
- The atmosphere plays an important role in the energy balance at the Earth's surface through mechanisms that interact with solar and land-based fluxes.
- The greenhouse effect is a natural mechanism that traps heat from the absorption and re-emission of radiation into the atmosphere at the Earth's surface.
- The main greenhouse gases (GHGs) naturally present in the atmosphere are methane (CH_4), water vapour (H_2O), carbon dioxide (CO_2), ozone (O_3) and nitrous oxide (N_2O).

- Changes in GHG concentrations in the atmosphere seriously influence the average temperature values recorded at the Earth's surface.
- Not all GHGs have the same impact on climate change and the contribution to the greenhouse effect is expressed through the GWP indicator or global warming Potential, which is CO_2 (1 by convention), CH_4 (25) and N_2O (298).
- Gas exchanges between the atmosphere and the Earth's surface are influenced not only by natural factors, but also and above all by anthropogenic factors.
- Climate determines the weather at a given location on Earth and is characterised by the main meteorological variables (radiation, temperature, precipitation, humidity, atmospheric pressure).
- Global warming refers to: significant changes in climatic conditions, exceptional phenomena with their frequencies, temperatures outside their usual average value ranges, feedbacks and a continuous increase in GHG concentrations (CO_2 in particular) in the atmosphere.
- Human activities often act not only through increased GHG concentrations, but also through other effects related to albedo, aerosol emissions and the water cycle.

2) The main international agreements relating to GHGs

- The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 by the World Meteorological Organization (WMO) and the UN Environment to provide assessments of the state of scientific, technical and socio-economic knowledge on climate change, its causes, potential impacts and response strategies.
- The IPCC's fifth *Assessment Report* having confirmed the main role of human activities in climate change, the limitation or the reduction GHG budgets in the atmosphere is the key. This report highlights a number of consequences of climate change that could be avoided if global warming were limited to 1.5 °C, not 2 °C or more.
- The United Nations Framework Convention on Climate Change (UNFCCC) was established in 1992 to help reduce global warming and cope with any inevitable increase in temperatures. With 197 parties, the United Nations Framework Convention on Climate Change (UNFCCC) enjoys almost universal adherence.
- Several international meetings have resulted in important agreements on the measures and synergies needed to combat climate change: the Kyoto Protocol in 1992 and the Paris Agreement in 2015. The Kyoto Protocol has been ratified by 172 countries and has entered into force since 2005. It limits the total emission of greenhouse gas emissions to the world's major economies.
- Countries have collectively committed to reduce their emissions by 5% from 1990 levels over the period 2008-2012.
- The main measures suggested by the Kyoto Protocol concern energy CO_2 emissions (transport, industry, energy production, housing) and those related to deforestation.
- The Paris Agreement follows negotiations at the Paris Climate Conference (COP21) of the United Nations Framework Convention on Climate Change. Under this agreement, the parties committed themselves to take ambitious measures to keep the global temperature rise below 2 °C by the end of the century.

3) Carbon and nitrogen cycles

- Carbon dioxide CO_2 is one of the key elements of the Earth's life cycle. Together with water vapour and light, it constitutes the first links of living matter. Initiator of life, it is also the final product of its degradation.
- The global carbon cycle consists of carbon exchanges between the major reservoirs: the oceans, the atmosphere and terrestrial ecosystems (fossil resources, biomass and soil).
- The global carbon cycle, relatively in equilibrium in its natural state, has been unbalanced in recent decades, mainly due to anthropogenic emissions of GHGs (mainly CO_2) into the atmosphere.
- The ecosystem (plant and soil) will release CO_2 back into the atmosphere through the process of respiration.
- The agricultural sector can mitigate global warming through the adoption of agricultural practices that promote carbon storage in the soil.
- Fossil fuel production and use pathways contribute to the emission of gaseous compounds into the atmosphere, including CO_2, CH_4 and N_2O.
- The GHG emission factor (EF) is very essential in calculating the GHG balance.
- The IPCC guidelines have published default values for PAs, but they can also be determined for each crop according to the precision required and the specificities of the regions or even countries.
- The atmosphere is made up of about 78% nitrogen (N), one of the elements essential to the living because it is found in proteins. The nitrogen cycle consists of several processes combining the actions of a multitude of bacteria.
- Nitrogen cycle processes (fixation, nitrification and denitrification) are very slow and excessive nitrogen fertiliser and agricultural effluent could limit the assimilation processes of NH_4^+ ammonium, NH_3 ammonia and NO_3^- nitrates (the most common forms of ionisation of nitrogen fertilisers).

4) The main sources of GHGs in the agricultural sector

- GHG emissions, mainly CO_2, CH_4 and N_2O observed in agriculture, come from upstream, inside and downstream of farms.
- The main sources of agricultural emissions are enteric fermentation (CH_4), nitrogen inputs to agricultural soils (N_2O), livestock manure management and storage (CH_4, N_2O), burning of biomass or agricultural residues (CO_2, CH_4, N_2O), phytosanitary treatment (CO_2), conversion of grasslands to agricultural land (CO_2, CH_4, N_2O), rice cultivation (CH_4) and transport (CO_2).
- Carbon emissions in agriculture are mainly due to the use of machinery (fuel), agricultural practices and the conversion of natural ecosystems (forests, savannahs, grasslands etc.) into agricultural plots.
- The operation of machinery and the heating of greenhouses or livestock buildings on farms consumes fuel (fossil energy), a source of CO_2 emissions.
- The addition of organic or mineral fertilisers to the agricultural soil can promote CO_2 emissions.

- The mineralisation of soil organic matter and the respiration process of ecosystems are important contributors to CO_2 emissions.
- N_2O emissions come from the application of nitrogen to agricultural soils necessary for the growth and harmonious development of crops. N_2O emissions are also recorded at the livestock level. They are due to nitrification-denitrification processes during the stay of animals and the storage of excreta.
- CH_4 emissions are produced by enteric fermentation (especially in ruminants), animal waste management and rice cultivation.

5) The different methods of calculating GHGs in the agricultural sector

- In the agricultural sector, several methodologies are used to estimate GHG emissions, including those proposed by the IPCC.
- The methods are mainly based on emission factors (EF), research results (field or laboratory), statistics and models (biophysical modelling).
- In the assessment of CH_4 and N_2O emissions, direct and indirect emissions are taken into account.
- For CO_2, on the other hand, changes in use or not are included. Some countries have adopted other specific provisions depending on the specific commitments.
- GHG emissions in agriculture remain complex and difficult to understand.

PERSONAL NOTES AND REFERENCES OF THE MATERIALS USED

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LEAFLET 5

Impacts of agricultural practices on air quality and mitigation strategies

TRAINING OBJECTIVES

At the end of this training sequence, the participant must be able to:

- understand that horticulture contributes to GHG emissions at all stages of the supply chain;
- know the main sources of GHG emissions in agricultural production and horticultural supply chains;
- know the relative importance of the different sources of GHG emissions and the factors that influence emissions;
- understand that agriculture and horticulture can contribute to climate change mitigation efforts;
- identify opportunities on farms and in the wider food system to reduce emissions and increase the amount of carbon stored;
- understand that the most appropriate climate mitigation measures must be identified on a case-by-case basis and in a site-specific manner;
- assess the potential for improving individual farm management in a holistic way to increase system efficiency and reduce emissions;
- understand the need for holistic approaches.

KEY MESSAGES

1) Agricultural practices and GHG emissions

- Agriculture and horticulture are linked to climate change in three ways: greenhouse gas (GHG) emissions; contribution to the fight against climate change because they have the potential to retain carbon in soils and biomass; they are already and will be increasingly affected by climate change.
- Agricultural soils are a net global source of GHGs: carbon (decomposition of MO), N_2O and CO_2 emissions (application of mineral and organic nitrogen, urea-based fertilisers).
- Carbon loss from cultivated soils is affected by land use, land-use changes, vegetation cover and land management.
- One of the main factors leading to soil carbon depletion is the conversion of soils, forests and grasslands to cultivated agricultural land (or land-use change – LUC).

- Tillage (ploughing) and drainage of organic soils increase the mineralisation of soil organic matter and therefore CO_2 emissions.
- The application of nitrogenous materials to agricultural soils results in direct and indirect emissions of N_2O.
- Volatisation of ammonia from animal manure and nitrogenous fertilisers, especially urea-based fertilisers, also contributes to the formation of particles.
- The spreading of fertilisers containing lime and urea on the soil causes CO_2 emissions as a result of chemical processes.
- Agricultural work, irrigation, storage of fresh produce and processing use fossil fuels (diesel, gasoline or electricity) and emit GHGs that contribute to climate change.
- When crop residues are ploughed into the soil or left on the soil surface, they return the nitrogen that has already been applied in fertilisers to the soil.
- The conversion from one land use category to another is called TUEC. Emissions due to LUC are included in product-related carbon footprint calculations when LUC occurred up to 20 years before the calculation.
- The conversion of forests, grasslands, savannahs, wetlands or tropical shrublands also leads to significant carbon emissions.
- The drainage of tropical peatlands, mangroves and waterlogged organic soils increases the decomposition of organic carbon and releases CO_2 and N_2O.
- Emissions from the production and transport of inputs are an indirect, upstream source of emissions for farms that purchase these materials.
- The importance of transport for the carbon footprint of individual horticultural products depends to a large extent on their destination market, their degree of perishability and the possibility of transporting them by ship or air over long distances.
- Refrigeration generally involves the use of these substances that have a very high impact on climate change and can contribute significantly to the carbon footprint of products.
- Packaging of fresh produce, consumer car travel, food preparation and waste are all sources of emissions.
- One third of the food produced is lost or wasted and accounts for about 8% of all global GHG emissions. Fruits and vegetables account for the largest share of waste by weight.

2) Emission mitigation and offsets opportunities

- All industrial sectors can and should contribute to mitigation efforts.
- There are three main opportunities to mitigate climate change in agriculture and horticulture:
  i. reduce emissions (e.g. by using nitrogen fertilisers more effectively);
  ii. improve removals (e.g. by retaining carbon in soils or tree biomass); and
  iii. avoid or replace emissions (e.g. by using bioenergy).
- Companies can implement climate change mitigation measures that lead to emission reductions or removals.
- There are two types of carbon markets: the regulatory carbon market, (offsets are sold

to organisations and governments that must comply with GHG emission reduction targets set by the Kyoto Protocol or other regulatory initiatives); and the voluntary carbon credit and offset market.

- Carbon offsetting has been criticised because companies should reduce emissions from their own activities rather than pay for others to make reduction efforts elsewhere.
- The balanced and efficient use of mineral fertilisers, the reduction of energy consumption and the increase of energy efficiency reduces emissions on the farm.
- Among the GHG reduction measures, it is important to increase the efficiency of irrigation (methods adopted; efficient systems).
- Soils can contribute to climate change mitigation by absorbing atmospheric carbon, but they have a limited capacity to do so until they have reached a new equilibrium.
- Increasing the MO stock can be achieved by turning over residues, increasing biomass production, applying composts, cover crops, perennial crops and complex crop rotations.
- Minimum tillage, reduced tillage and no-till systems often increase soil carbon content because they reduce or avoid soil disturbance.
- The use of cover crops, green manures and mulches can increase soil organic carbon stocks, alone or in combination with reduced tillage.
- Carbon can also be sequestered in agroforestry systems, shade trees, hedges, grass strips or perennial horticultural crops (fruit trees or spice trees).

3) Need for holistic assessments and a systems approach

- All practices and net effects of mitigation measures on all GHGs must be considered to avoid unintentional transfer of the burden from one process or GHG to another. For example, without tillage, the level of soil organic carbon increases but N_2O emissions increase at the same time.
- At the farm level, the so-called "conservation agriculture" systems approach combines several practices that can improve soil fertility, reduce the risk of erosion, conserve soil moisture and contribute to climate change mitigation by increasing soil carbon levels.
- It is important to take a holistic approach to the interrelated challenges in the land use sectors, mitigation and adaptation to climate change must go hand in hand.

PERSONAL NOTES AND REFERENCES OF THE MATERIALS USED

Summary of the manual

Sutainable air quality management

1. AIR QUALITY FOUNDATIONS

1.1. Introduction

The pollution of the air we breathe is now a major societal concern. The pollutants involved are gases or particles whose sources are natural (e.g. forest fires) or anthropogenic. The main causes of air pollution are related to the ignition of fossil fuels (coal, oil and gas) used by humans. Road transport, industry, the residential sector, but also agriculture are among the main human activities contributing to air pollution. **Agriculture is not exempt from a share of responsibility for the presence of greenhouse gases and fine particles in the atmosphere.**

Air pollution has health and environmental impacts, and, consequently, significant economic impacts. Exposure to particulate matter (PM) and various gases affects human health. The **pollutants that are most harmful to** public health include carbon monoxide (CO), ozone (O_3), nitrogen dioxide (NO_2) and sulphur dioxide (SO_2), persistent organic pollutants (POPs) and 'pesticides' in the air.

1.2. Composition and air quality

The atmosphere has 4 zones depending on altitude (troposphere, stratosphere, mesosphere and thermosphere). The proportions of nitrogen, oxygen and argon are constant throughout the atmosphere, while the proportions of water, carbon dioxide, sulphur dioxide and ozone vary with altitude. Most climatic phenomena (clouds carrying storms, cumulonimbus clouds etc.) are confined to the troposphere. In general, the Earth's climate is closely dependent on the effects of the Sun's heat on the entire atmosphere. Meteorology and climatology are particularly interested in events that occur in the lowest layer, the troposphere.

The layer of the atmosphere that matters most to us **is the part of the troposphere that extends to an average altitude of 1 km, called the 'Atmospheric Boundary Layer'** (ALC). Vertical turbulence is due to phenomena that explain why pollutants (such as pesticides sprayed on a crop plot) can disperse vertically in the atmosphere and then travel long distances. Turbulence is related to the stability of the atmosphere. Indeed, air stability depends on the evolution of **air temperature with altitude, thermal turbulence and mechanical turbulence.**

1.3. Impacts of air pollution: main facts

According to the WHO, air pollution is a **major environmental health risk.** By reducing levels of air pollution, countries can reduce the burden of disease from stroke, heart disease, lung cancer and chronic or acute respiratory diseases, including asthma. In 2016, 91% of the world's population lived in places where WHO air quality guidelines were not respected. An estimated 4.2 million premature deaths worldwide were caused by ambient (outdoor air) pollution in urban, peri-urban and rural areas.

In addition to outdoor air pollution, domestic smoke poses a serious health risk to an estimated 3 billion people who cook their food, heat and light their homes using biomass, fuel oil and coal-based fuels.

1.4. Nature and health effects of air pollutants

Particulate matter is classified according to its diameter and emitting source. They are formed by a complex mixture of solid and liquid particles of organic and mineral substances suspended in the air. The largest particles are grouped under the term 'dust'. The coarser particles are rich in mineral fractions from mechanical processes (terrigenous particles generated by erosion, sea salts etc.).

Particles smaller **than 100 micrometers** (10-9 to 10-6 m) are called either '**aerosols**' (e.g. droplets < 100 µm emitted into the atmosphere when spraying pesticides) or, when the particles are even smaller, '**fine particles**' (or PM). Chronic exposure to fine particles contributes to the risk of developing cardiovascular, respiratory diseases and lung cancer.

Particles with a diameter of 2.5 or less µ (≤ PM2.5) are the most harmful to health. They can cross the pulmonary barrier and enter the bloodstream. **Livestock and field crops generate dust and fine particles** (PM10 and PM2.5). Agricultural emissions of these primary contaminants are distributed among crops during **tillage**, harvesting and **burning of crop residues** and, for livestock, mainly in livestock buildings. There is a strong and quantitative link between exposure to high concentrations of particulate matter (PM10 and PM2.5) and increased mortality and morbidity rates, both on a daily basis and over the longer term. WHO has established guideline values for PM10 and PM2.5.

Ammonia (nitrogenous fertilisers) **contributes significantly to the formation of these particles.** Even at low concentrations, small particle pollution has a health impact; indeed, no threshold below which it does not affect health has been identified. At high concentrations, ozone has significant effects on human health (including asthma attacks). The respiratory system is affected by ozone, nitrogen dioxide or sulphur dioxide.

1.5. Nature and environmental effects of air pollutants

Pollutants emitted by industry and agriculture contribute, after processing, to the acidification and eutrophication of natural environments (e. g. acid rain due to SO_2). **Ammonia** and particulate **deposits** from deposition change the quality of water and soil in natural environments. These deposits can promote the growth of some species of fauna and flora at the expense of others, and cause local **biodiversity loss.** There are close links between particulate pollution and ozone formation.

The greenhouse effect is a natural phenomenon that maintains an average temperature of 15 °C at the Earth's surface. The contribution of each GHG to the greenhouse effect is expressed through an indicator called **global warming potential (GWP),** a unit of measurement that corresponds to the effect of a gas on cumulative atmospheric warming over a 100-year period. This value is measured in relation to CO_2. For example, 1 kg of CH_4 emitted into the atmosphere will have the same effect over a century as the emission of 25 kg of CO_2.

Agricultural areas are major sources of GHGs and fine particles. Agricultural and forestry areas are both sources and sinks of air pollutants. Air pollutants generated by agriculture are gases dispersed in the air – mainly nitrous oxide (N_2O), ammonia (NH_3) and methane (CH_4) – or particles, solid or liquid, suspended in the air. Agriculture releases methane (livestock and soil), nitrous oxide (nitrogen fertilisation and animal waste management) and carbon dioxide (energy consumption). Pollution causes a loss of sanitary quality of foodstuffs (heavy metals such as Pb and Cd, and POPs).

High concentrations of atmospheric CO_2 have a positive influence on photosynthesis. This is called the **fertilising effect of** CO_2. CO_2 also has an **antiperspirant effect**: the increase in

CO_2 in the atmosphere reduces the number and openness of stomata, which reduces plant transpiration and leads to more efficient water consumption.

1.6. Provide a framework for air quality management

There are many examples of policies to reduce air pollution. The **1997 Kyoto Protocol** aimed to limit emissions of 6 GHGs: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (NO), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF6) by setting emission allowances for developed countries, which are considered the largest emitters of GHGs. By 2012, the GHG emissions of the countries committed to the Kyoto Protocol were expected to be lower than those of 2012. However, the mobilisation of the international community was considered insufficient.

The Paris Agreement (COP21 – Paris Climate Conference) defined a new protocol to keep global warming below 2 °C. To this end, the Paris Agreement requires all committed countries to review their GHG emission reduction commitments every five years.

At EU level, **Directive 2008/50/EC** sets air quality objectives to improve human health and environmental quality by 2020. Directive 2008/50/EC and Directive 1999/30/EC define alert thresholds and limit values, as well as action obligations in the event of an exceedance. **Framework Directive 96/62/EC** on air quality sets out the fundamental principles of a strategy for setting ambient air quality objectives. According to the Directive, ambient air quality must be monitored throughout the territory of the Member States. There is extensive legislation at European level setting emission ceilings for certain air pollutants (e.g. arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons).

Directive 2010/75/EU (FDI Directive) defines an integrated approach to the prevention and reduction of pollution from industrial and agricultural installations. One of its guiding principles is the use of best available techniques (BAT). Indicative occupational exposure limit values (IOELVs) are set to protect workers from the risks associated with exposure to chemical agents. Indicative occupational exposure limit values (IOELVs) are the time-weighted average limits of the concentration of a chemical agent in the air in a worker's breathing zone over a specified reference period. Real-time and time-delayed measurement systems (analysis devices) have been developed.

2. IMPACTS OF CULTURAL PRACTICES ON AIR QUALITY

2.1. Influence of agricultural practices on air quality

It is recognised that agriculture plays a major role in altering air quality, **especially since the practices adopted are aggressive to the environment and far from the principles of agro-ecology.** The paradox of agriculture is that agricultural areas have the particularity of being, depending on **the practices adopted** (conventional agriculture *vs*. agro-ecological or organic agriculture), **sometimes sources, sometimes sinks for** air pollutants.

Industrial agriculture is responsible for nearly 35% of greenhouse gas emissions (GHG: CO_2 and methane in particular), while on the other hand agricultural soils are very important carbon sinks. Agriculture also appears as a **particular sector: emitter** of GHGs and air pollutants (mainly ammonia, NH_3); but also **victim of** air pollution (decrease in yields, degradation of the quality of soil, water and plant products, degradation of biodiversity etc.).

The air is altered by **biological pollutants** (pollen, viruses, bacteria, spores...), **physical pollutants** (wind erosion, soot) or **chemical pollutants.** In some circumstances, suspended particles and gases are cocktails of pollutants that produce a toxic and/or ecotoxic effect. Agriculture contributes to emissions of nitrogen compounds, VOCs, methane and pesticides, as well as primary particulate matter.

In agriculture, **soil preparation, fertilisation, the supply of plant protection products, farming operations will generate the emission of primary particles depending on the type of soil** (the more degraded the soil, the faster it will emit dust) and the weather (the drier the soil, the more dust it will produce; the hotter it is, the more intense the volatilisation will be). Air pollution is also indirect: it is linked to the presence, volatilisation and accumulation (atmospheric fallout) of soil pollutants (pesticides, manure, livestock effluents, fertilisers).

According to FAO, biomass combustion ('burning') is a common and widespread phenomenon throughout the tropical world. Vegetation fires, whether started for various reasons by people or by lightning, are frequent and cover large areas. Fires fuelled by wood, charcoal or agricultural residues are the main source of domestic energy for cooking and heating. Fire is also used to remove biomass when clearing land for agriculture, or, after cultivation, to dispose of unwanted agricultural residues. **All these fires are a significant source of trace gases and suspended particles** released into the atmosphere. Forest fires have many impacts on the environment and in particular on air quality, and ultimately on health. According to the ANSES (France), two types of pollutants are to be considered for their health effects:

- suspended particles: they represent the highest air pollutant in relation to regulatory thresholds in the areas affected by smoke; about 80% of the mass of the fumes are fine particles (diameter < 2.5 μm);
- carbon monoxide (CO).

The pollutants that make up the fumes from wildfires can settle, distribute and undergo chemical changes in the ground and water bodies. The quality of groundwater is therefore at stake by these fires. These negative effects must be weighed against the apparent benefits of burning vegetation, as perceived by the population.

2.2. Atmospheric pollution by fertilising materials

Farmers use massive amounts of **nitrogenous fertilisers and other fertilising materials** to provide plants with the nutrients they need to grow and which may be lacking in soils that are too infertile or over-exploited. The problem is that plants only absorb half of these fertilisers, and a small fraction of pesticides actually reach the target. The **rest ends up in the atmosphere, soil and water,** polluting rivers and damaging aquatic biodiversity. Inputs that are widely distributed in the environment can enter the atmosphere: directly during application, or indirectly by spreading through wind erosion or vaporisation of their deposits on treated areas. Fertilising materials (organic or chemical fertilisers) can be a source of air pollution, through volatilisation, and especially water pollution, when they are applied in quantities greater than what crops and soil can absorb.

Nitrogen pollution in agriculture is mainly in the form of nitrous oxide (N_2O), ammonia (NH_3) and nitrates (NO_3). The excess nitrogen is redistributed in different forms, in water but also in the air. The **volatilisation of nitrous oxide** (or nitrous oxide) **and ammonia is the main route of nitrogen loss** when spreading livestock effluents (slurry, manure...) or ammonium-rich fertilisers such as urea – $CO(NH_2)_2$ – or amnonitrate (mineral nitrogen fertiliser based on ammonium nitrate, NH_4NO_3).

Three basic processes are involved in nitrogen recycling:

1. **the bacterial conversion of atmospheric nitrogen** (N_2) into assimilable nitrogen (NH_4^+) by plants and animals;
2. **nitrification** which transforms the products of fixation (NH_4^+, NH_3) into NOx (e.g. nitrates, NO_3^-) in soils low in oxygen (O_2);
3. **denitrification**, which returns nitrogen in its molecular form N_2 to the atmosphere, with CO_2 and nitrous oxide N_2O as secondary products.

These processes are **very slow,** and the excessive use of nitrogen fertilisers and agricultural effluents limits the assimilation processes of NH_4^+ ammonium, NH_3 ammonia and NO_3^- nitrates (the most common forms of ionisation of nitrogen fertilisers).

Ammonia, by its acido-basic nature, will interact with acid compounds present in the atmosphere (e.g. H_2SO_4 or HNO_3) to form **secondary aerosols of** ammonium salts – $(NH_4)_2SO_4$ or NH_4NO_3. The deposition of ammonia or ammonium also leads to an **intensification of nitrification in soils (soil acidification).** A number of natural or semi-natural terrestrial ecosystems are highly sensitive to nitrogen deposition. This eutrophication effect can lead to local biodiversity losses of flora and fauna.

One of the difficulties in predicting the evolution of pollution thresholds in the short term (a few days) is due to the lack of knowledge of ammonia sources related to agricultural and livestock activities. Ammonia is the most poorly known of the pollutants regulated by the European air quality directives: its emission registers are not very precise, and its global and systematic monitoring is difficult. Ammonia is now being monitored in the atmosphere. It can be seen that ammonia concentrations have **significant seasonal variations** that differ depending on the main emission source. In rural areas, far from sources, ammonia concentrations are higher in summer. Conversely, if these areas are breeding areas, the maximum ammonia concentrations coincide with the spreading periods.

2.3. Air pollution by plant protection products

Plant protection products are pointed out as a possible cause of the **decline of bee colonies** and other pollinators, and biodiversity in general. It is a known fact that certain plant protection products affect the health of applicators, workers who come into contact with residual deposits, and consumers exposed to **residues in their food.**

Pesticide pollution is mainly perceived through their presence in surface and groundwater (those used primarily for food), soil and food. **However, the atmosphere plays a key role in the spread of pesticides at local, regional and global levels**, but in the absence of measurements of the presence of pesticides in the air, and the potential consequences of this, this diffuse contamination has gone unnoticed and has long been underestimated.

Pesticides are most often applied **by spraying droplets** onto plants or the soil. Several ways of contaminating the atmosphere are possible:

- **direct contamination** during application due to **drift** losses (loss by vertical and horizontal transfer of part of the spray mixture into the atmosphere);
- **indirect contamination** in **post-application** either **by volatilisation** from the treated soil or canopy, or **by wind erosion.**

Atmospheric transfers **can occur over long periods of time,** which explains the persistence of some pesticides in the air outside of application periods.

Spray drift is an atmospheric transport of very small droplets or pesticide vapours **out of the treated** area due to the wind that occurs at the time of application or shortly after. It is expressed a**s a % of the amount applied per hectare** (the drift is usually a few %). Some of the drift usually settles near the point of application (sediment drift), but **another part remains in the atmosphere longer and can be transported over longer distances (wind drift).** Many factors influence the extent of drift. Some factors are mechanical (e.g. working pressure or nozzle type used), others depend on the farmer's practice (e.g. boom height, forward speed, spray volume per hectare), but the most important are certainly those related to drop size and atmospheric conditions, such as wind speed and direction during application or temperature and relative humidity of the air.

3. GREENHOUSE GASES AND THE CARBON FOOTPRINT

3.1. Greenhouse gases (GHGs) and climate

The atmospheric layer plays an important role in the energy balance at the Earth's surface through the various mechanisms that interact with solar and land-based fluxes. The atmosphere is the gaseous layer surrounding the Earth and subdivided into layers of varying importance (troposphere, stratosphere, mesosphere, thermosphere and exosphere). It is **mainly composed of three** chemically weakly reactive **gases**:

- molecular nitrogen $\mathbf{N_2}$ (78.08%) ;
- molecular oxygen $\mathbf{O_2}$ (20.95%) ;
- argon **Ar** (0.93%).

These gases do not undergo phase change and their relative concentration is evenly distributed over the first 80 km of the atmosphere. Next come water vapour $\mathbf{H_2O}$ (on average 0.4%) and carbon dioxide $\mathbf{CO_2}$ (0.039%). Other components are clouds, aerosols and other gases including methane **CH_4**, nitrous oxide **N_2O** and ozone **O_3** that contribute little to atmospheric mass. Although these gases undergo a seasonal cycle, the content of CO_2, N_2O and CH_4 also remains homogeneous on an annual average. However, ozone and water vapour do not behave in the same way. The distribution of water vapour is strongly linked to evaporation and condensation.

Overall, just over 50% of the sun's radiation is absorbed by the Earth's crust and oceans, 20% by the atmosphere and 30% directly returned by the atmosphere to space. **Visible** short-wave **radiation** passes through the atmosphere before being absorbed by the Earth's surface, which it heats. Some of the long wavelength thermal radiation emitted by the heated surface is partially absorbed by the atmosphere (especially by some gases present in low concentrations). The second part is transmitted directly to the space leaving the Earth's surface. The absorbed energy flows **heat the atmosphere and are then re-emitted in equal parts to space and the Earth's surface.**

Meanwhile, much of the **infrared radiation** emitted by the sun is captured by the atmosphere and **scattered back to the Earth's surface.**

In short, the Earth's surface receives (and absorbs) solar radiation that is completely transmitted through the atmosphere, but also a significant part of the infrared flux emitted by the Earth's surface. The result of all these mechanisms is the warming of the Earth's surface. It's the greenhouse effect. **The greenhouse effect** is therefore a natural mechanism that retains heat from the absorption and re-emission of radiation into the atmosphere at the Earth's surface. The main greenhouse gases (GHGs) naturally present in the atmosphere are water vapour (**H_2O**), carbon dioxide (**CO_2**), ozone (**O_3**), methane (**CH_4**) and nitrous oxide (**N_2O**).

In recent decades, a major upheaval has been observed (IPCC reports). It is due to the **continuous increase in concentrations of certain 'greenhouse gases' (CO_2, CH_4) in the atmosphere.** This has significantly altered the heating fluxes of the Earth's surface, causing radiative forcing that seriously disrupts the climate balance. **Climate change,** now a global scientific reality, is an **additional constraint** to human existence and sustainable development. **Global warming** refers to significant changes in climatic conditions, exceptional phenomena with their frequencies, temperatures outside their usual average value ranges, feedbacks and a continuous increase in GHG concentrations (CO_2 in particular) in the atmosphere.

Agriculture contributes to this because of **greenhouse gas (GHG) emissions,** but also suffers from its impacts given its complexity, the number of people to feed and, above all, the challenges to be met. The impacts of climate change are even greater in less developed and highly vulnerable countries such as ACP countries. The agriculture/food production sector could be responsible for 35% of total global GHG emissions.

However, the **agricultural sector can mitigate global warming** through the adoption of agricultural practices that promote **carbon storage in the soil.**

3.2. The main international agreements relating to GHGs

The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 by the World Meteorological Organization (WMO) and UN Environment. In 2013, the IPCC clarified the role of human activities in climate change by publishing its fifth assessment report. His conclusion is categorical: climate change is real and human activities are the main cause. The IPCC's fifth *Assessment Report* confirms that the warming of the climate system is unequivocal and that many of the changes observed are unprecedented in decades, if not millennia. **This report highlights a number of consequences of climate change that could be avoided if global warming were limited to 1.5 °C, not 2 °C or more.** Thus, by 2100, global sea level would be 10 cm lower than it would be if global warming were limited to 1.5 °C than if it were limited to 2 °C. The report states that limiting global warming to 1.5 °C would require **"rapid and far-reaching" transitions** in land use planning, energy, industry, construction, transport and urban development. Net global emissions of anthropogenic carbon dioxide (CO_2) are expected to be reduced by about 45% from 2010 levels by 2030, and a **'zero emissions balance' should be achieved** by around 2050, which means that the remaining emissions should be offset by removing CO_2 from the atmosphere.

In 1992, countries joined an international treaty – the United Nations Framework Convention on Climate Change (UNFCCC) – to consider what could be done to reduce global warming and cope with any inevitable increase in temperatures.

Several international meetings have resulted in important agreements on the measures and synergies needed to combat climate change: the **Kyoto Protocol in 1992** and **the Paris Agreement in 2015.** The Kyoto Protocol has been ratified by 172 countries and has entered into force since 2005. It limits the total emission of greenhouse gas emissions to the world's major economies. Countries have collectively committed to reduce their emissions by 5% from 1990 levels over the period 2008-2012. The main measures suggested by the Kyoto Protocol concern energy CO_2 emissions (transport, industry, energy production, housing) and those related to deforestation. The Paris Agreement follows negotiations at the Paris Climate Conference (COP21) of the United Nations Framework Convention on Climate Change. Under this agreement, the parties committed themselves to take ambitious measures to keep the global temperature rise below 2 °C by the end of the century.

3.3. Carbon and nitrogen cycles

Carbon dioxide CO_2 is one of the key elements of the Earth's life cycle. Together with water vapour and light, it constitutes the first links of living matter. Initiator of life, it is also the final product of its degradation. The global carbon cycle consists of carbon exchanges between the major reservoirs: the oceans, the atmosphere and terrestrial ecosystems (fossil resources, biomass and soil). The global carbon cycle, relatively in equilibrium in its natural state, has been unbalanced in recent decades, mainly due to anthropogenic emissions of GHGs (mainly CO_2) into the atmosphere. The ecosystem (plant and soil) will release CO_2 back into the atmosphere through the process of respiration.

The atmosphere is made up of about 78% nitrogen (N), one of the elements essential to the living because it is found in proteins. The nitrogen cycle consists of several processes combining the actions of a multitude of bacteria. **Nitrogen cycle processes (fixation, nitrification and denitrification) are very slow,** and excessive nitrogen fertiliser and agricultural effluent could limit the assimilation processes of NH_4^+ ammonium, NH_3 ammonia and NO_3^- nitrates (the most common forms of ionisation of nitrogen fertilisers).

The agricultural sector can mitigate global warming through the adoption of agricultural practices that promote carbon storage in the soil. Fossil fuel production and use pathways contribute to the emission of gaseous compounds into the atmosphere, including CO_2, CH_4 and N_2O.

The GHG emission factor (EF) is essential in calculating the GHG balance. The IPCC guidelines have published default values for PAs, but they can also be determined for each crop according to the precision required and the specificities of the regions or even countries.

3.4. The main sources of GHGs in the agricultural sector

GHG emissions, mainly CO_2, CH_4 and N_2O observed in agriculture, come from upstream, inside and downstream of farms. They mainly concern crop and animal production, the agri-food industries, the use of fertilisers, plant protection treatment and transport. In particular, the main areas of responsibility are **enteric fermentation** (CH_4), **nitrogen inputs to agricultural soils** (N_2O), **livestock effluents management and storage** (CH_4, N_2O), **biomass or agricultural waste burning** (CO_2, CH_4, N_2O), **phytosanitary treatment** (CO_2), **conversion of grasslands to agricultural land** (CO_2, CH_4, N_2O), **rice cultivation** (CH_4) **and transport** (CO_2).

Carbon emissions in agriculture are mainly due to the use of machinery (fuel), agricultural practices and the conversion of natural ecosystems (forests, savannahs, grasslands etc.) into agricultural plots. The operation of machinery and the heating of greenhouses or livestock buildings on farms consumes fuel (fossil energy), a source of CO_2 emissions.

The addition of organic or mineral fertilisers to the agricultural soil can promote CO_2 emissions. The mineralisation of soil organic matter and the respiration process of ecosystems are important contributors to CO_2 emissions. N_2O emissions come from the application of nitrogen to agricultural soils necessary for the growth and harmonious development of crops. N_2O emissions are also recorded at the livestock level. They are due to nitrification-denitrification processes during the stay of animals and the storage of excreta. CH_4 emissions are produced by enteric fermentation (especially in ruminants), animal waste management and rice cultivation.

3.5. The different methods of calculating GHGs in the agricultural sector

In the agricultural sector, **several methodologies are used** to estimate GHG emissions, including those proposed by the IPCC. The methods are mainly based on emission factors (EF), research results (field or laboratory), statistics and models (biophysical modelling). In the assessment of CH_4 and N_2O emissions, direct and indirect emissions are taken into account.

For CO_2, on the other hand, changes in use or not are included. Some countries have adopted other specific provisions depending on the specific commitments. GHG emissions in agriculture remain complex and difficult to understand.

4. IMPACTS OF AGRICULTURAL PRACTICES ON AIR QUALITY AND MITIGATION STRATEGIES

4.1. Agricultural practices and GHG emissions

Agriculture and horticulture differ from other industrial sectors in that they are linked to climate change in **three main ways:**

1. they emit greenhouse gases (GHGs) into the atmosphere;
2. they can contribute to the fight against climate change because they have the potential to retain carbon in soils and biomass;
3. they are already and will be increasingly affected by climate change.

The **activities of agricultural and food systems contribute to climate change** by releasing GHGs into the atmosphere at all stages of agricultural value chains.

The **three main GHGs** associated with agriculture are carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4). Methane is particularly important on livestock and rice farms, but generally does not represent a significant source of GHGs on horticultural farms where CO_2 and N_2O are more important.

Agricultural soils are a global net source of GHGs. They can emit carbon from the decomposition of soil organic matter and N_2O and CO_2 related to the application of mineral and organic nitrogen, urea-based fertilisers and lime.

Agricultural practices can have **negative effects on soils**, including **loss of organic matter and associated GHG emissions.**

One of the main factors leading to this soil carbon depletion is the conversion of land occupied by forests and undisturbed grasslands to cultivated agricultural land. Management practices that contribute to soil carbon loss include residue removal, mechanised and intensive tillage operations, short (or non-existent) fallow periods, reduction or absence of crop rotation systems, nutrient depletion or imbalance.

The **consumption of fossil fuels in agriculture is considerable and is responsible for significant GHG emissions.**

- **It is direct,** for agricultural work, irrigation, storage of fresh produce and processing using fossil fuels (diesel, gasoline or electricity) and emitting GHGs that contribute to climate change. The **importance of transport for the carbon footprint of** individual horticultural products depends to a large extent on their destination market, their degree of perishability and the possibility of transporting them by ship or air over long distances. The **transport of harvested products** contributes to GHG emissions from fossil fuel and energy use. Different modes of transport are linked to different amounts of emissions. **Air freight** is associated with a much higher carbon footprint than maritime transport, so products transported by air generally have a relatively high carbon footprint that is dominated by this stage of transport. **Refrigeration** generally involves the use of these substances that have a very high impact on climate change and can contribute significantly to the carbon footprint of products. Packaging of fresh produce, consumer car travel, food preparation and waste are all sources of emissions.

- **It is also indirect:** emissions from the production and transport of inputs represent an upstream source of emissions for farms that purchase these materials. Moreover, more than a third of the food produced is lost or wasted and accounts for about 8% of all global GHG emissions. Fruits and vegetables account for the largest share of waste by weight.

The conversion of a land use category can lead to the emission of large quantities of greenhouse gases due to the release of carbon that was previously stored in biomass and soils. For example, tropical forests contain a lot of carbon that is stored in their soil and trees. Agriculture is the main direct driver of global deforestation and accounts for about 70-80% of all deforestation. The conversion of forests, grasslands, savannahs, wetlands or tropical shrublands also leads to significant carbon emissions. The drainage of tropical peatlands, mangroves and waterlogged organic soils increases the decomposition of organic carbon and releases CO_2 and N_2O. **The conversion from one land use category** to another is called LUC. Emissions due to LUC are included in product-related carbon footprint calculations when LUC occurred up to 20 years before the calculation.

4.2. Emission mitigation and offsets opportunities

Climate change mitigation means **reducing or preventing GHG emissions** on the one hand, and improving the removal of carbon from the atmosphere on the other (e.g. by planting forests).

Climate change mitigation includes activities such as:

- increasing the use of renewable energies;
- increasing energy efficiency;
- changing our behaviour and demand for GHG-intensive products;
- the introduction of new technologies such as electric cars.

Overall, **there are three main opportunities to mitigate climate change in agriculture and horticulture:**

1. reduce emissions (e.g. by using nitrogen fertilisers more efficiently);
2. improved sampling (e.g. by retaining carbon in soils or tree biomass in agroforestry systems);
3. avoid or replace emissions (e.g. avoid fossil fuel emissions by using bioenergy).

Companies can implement climate change mitigation measures that lead to emission reductions or removals within their own operations or supply chains. The amount of GHG saved through these projects is **controlled by independent organisations** that sell **CO_2 reduction certificates.**

Carbon offsetting has been criticised for several reasons. One reason is that companies, organisations and individuals should reduce emissions from their own activities rather than pay for reductions elsewhere.

4.3. Need for holistic assessments and a systems approach

The **relative importance** of emission sources can vary between production systems, countries, supply chains and individual farms. For example, if irrigation requires large amounts of energy, this can represent a significant share of total GHG emissions; if no irrigation takes place, other agricultural processes can become more important, such as mineral fertiliser production or fertilised soil emissions. Therefore, the best opportunities to reduce emissions **must be assessed on a case-by-case basis.**

The ability of soils to store additional **carbon** depends on the balance between photosynthesis, which binds CO_2 from the air, the respiration of decomposing organisms that release CO_2 into the air, and the stabilisation of soil carbon. For climate change mitigation, increasing soil organic carbon content is considered a low-cost option with a low ecological and water footprint and low energy consumption, *i.e.* a no-regrets option with few negative externalities. **Maintaining current soil organic carbon stocks should be the minimum objective.** Although soils can contribute to climate change mitigation by absorbing atmospheric carbon, it is important to consider that they have a limited capacity in time to do so, until they have reached a new equilibrium and that potential gains are easily reversible if management practices that promote carbon sequestration are abandoned.

Measures that can maintain and increase soil carbon content include:

- reducting physical erosion by wind or water;
- reducting mechanical soil disturbance;
- maintaining the vegetation cover;
- increasing the water content of organic soils;
- increasing the distribution of carbon underground (*i.e.* higher root density).

All practices and net effects of mitigation measures on all GHGs must be considered to avoid unintentional transfer of the burden from one process or GHG to another. **For example, minimum tillage, reduced tillage and no-till systems** often increase soil carbon content because they reduce or avoid soil disturbance that leads to increased decomposition and erosion. However, **this increase in soil carbon is not always evident in reduced tillage systems.** In addition, there is a risk of increased N_2O emissions in systems with little or no tillage, particularly in soils with limited drainage and wet climates.

At the farm level, the so-called 'conservation agriculture' systems approach combines several practices that can improve soil fertility, reduce the risk of erosion, conserve soil moisture and contribute to climate change mitigation by increasing soil carbon levels. Plants absorb carbon as they grow, so atmospheric carbon can also be sequestered in new farm biomass, for example in agroforestry systems, shade trees, hedges, grass strips or perennial horticultural crops such as fruit trees or spice trees.

It is important to take a holistic approach to the interrelated challenges in the land use sectors. Mitigation and adaptation to climate change must go hand in hand.

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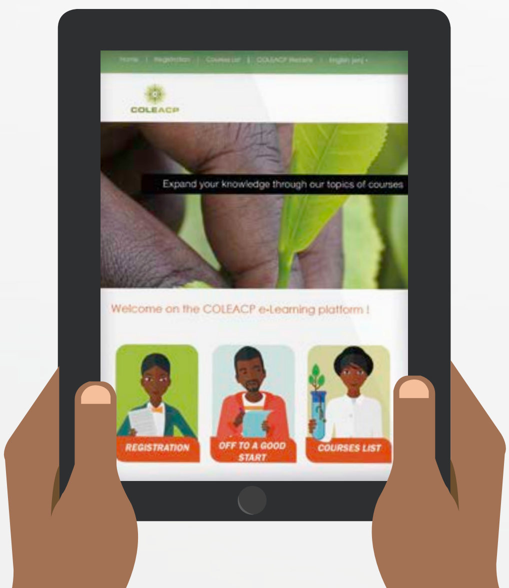

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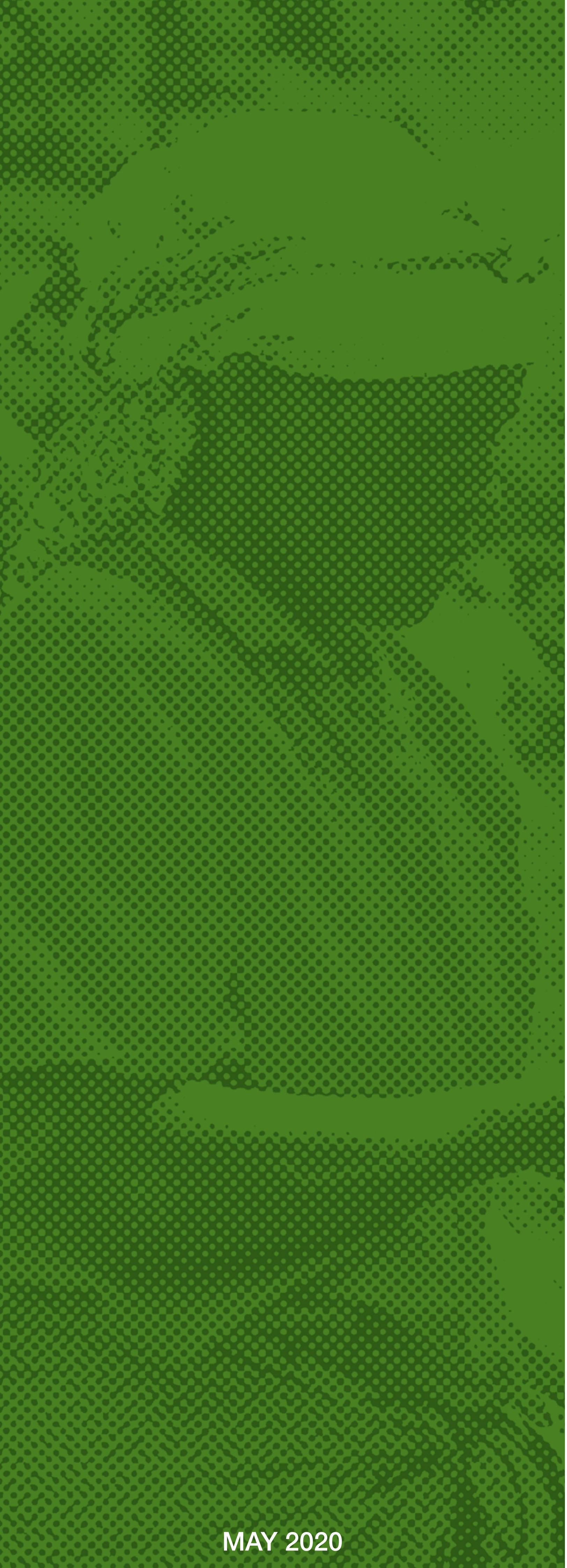

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