

## PROCESSES INVOLVED IN GREEN-HOUSE GAS EMISSIONS AND MITIGATION POTENTIAL OF FOREST SOIL

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Forests act as a huge sink for C accumulation, containing 80 % of above-ground and 40 % of below-ground C, and are responsible for 60-70 % of net primary production of terrestrial ecosystems. Moreover, their importance rely to the important contribution, around 70 %, on gas exchanges between biosphere and atmosphere.

The three main green-house gases (GHG) emitted from forest ecosystems are carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O), which contribute for around 60 %, 20 % e 6 %, respectively, to the global warming. Several processes are involved in GHG production and emission: autotrophic and heterotrophic respiration, methanogenesis, nitrification and denitrification. These processes depend on a variety of biotic and abiotic factors, which influence either the dimension or the direction of gas exchanges between forests and atmosphere, determining the GHG accumulation and release capacity of forest ecosystems, acting as sink or source. Therefore, the type of soil and its physical, chemical and biological characteristics, influencing both the substrates availability and their accessibility to microbial communities involved in the GHGs production, are important drivers of emissions and should be considered in further studies. The understanding of such processes is fundamental to adopt appropriate management options to reduce GHG emissions from forests. In particular, forest management strategies related to afforestation and reforestation intervention, to the recovery of degraded forests and to forest plantations should aim at the reduction of GHG emissions, contributing to improve the climate change mitigation potential of such ecosystems.

*Keywords:* forest ecosystem, CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, mitigation.

*Parole chiave:* ecosistemi forestali, CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, mitigazione.

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### 1. Greenhouse gas emissions from forest soils

Carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O) are the most important greenhouse gas (GHG) emitted from agricultural and forest soils, contributing 60, 15 and 5 %, respectively, towards enhanced global warming. The radiative forcing of GHGs has led to an increase in the average global surface temperature of 0.6°C since the late 19th century (Folland and Karl, 2001). Consequently, changes in the amount, distribution and intensity of rainfall/precipitation are also expected to occur. CH<sub>4</sub> and N<sub>2</sub>O have a large global warming potential (GWP) that is respectively 25 and 298 times greater than CO<sub>2</sub> over a 100 yr period (Houghton *et al.*, 2001).

Since pre-industrial times, increasing emissions of GHGs due to human activities have led to a marked increase in atmospheric GHG concentrations (IPCC, 2013). Between 1970 and 2010, total GHG emissions increased by 8 GtCO<sub>2</sub>eq over the 1970s, 6 GtCO<sub>2</sub>eq over the 1980s, and by 2 GtCO<sub>2</sub> over the 1990s, with an annual growth rate over these decadal periods of 2.0%, 1.4%, 0.6%, and 2.2%, respectively (IPCC, 2013). GWP weighted territorial GHG emissions

increased from 27 to 49 GtCO<sub>2</sub>eq, an 80% increase in forty years.

The emissions of these gases have increased at different rates. Between 1970-2010, global anthropogenic fossil CO<sub>2</sub> emissions more than doubled, and represented 75% of total anthropogenic GHG emissions in 2010, while CH<sub>4</sub> and N<sub>2</sub>O each increased by about 45%. Currently, Agriculture, Forestry, and Other Land Use (AFOLU) accounts for approximately a quarter of anthropogenic GHG emissions, largely deriving from deforestation and livestock, soil and nutrient management (IPCC, 2014). CO<sub>2</sub> emissions from deforestation and forest degradation have been estimated to account for about 12-20% of global anthropogenic CO<sub>2</sub> emissions (IPCC, 2007). These estimates can be improved as the magnitude of gas flux from the agricultural and forest sectors still has large knowledge gaps (Franzluibbers and Follett, 2005). In particular, estimates of N<sub>2</sub>O and CH<sub>4</sub> emissions from forest ecosystems are far from to be exhaustive. The decision no 529/2013/eu of the European Parliament and of the council of 21 may 2013 stated that "Member States shall prepare and maintain accounts that accurately reflect all emissions and removals resulting from the activities on their

territory falling within the following categories: a) afforestation, b) reforestation, c) deforestation, d) forest management”, “... covering emissions and removals of the following greenhouse gases: a) CO<sub>2</sub>, b) CH<sub>4</sub>, c) N<sub>2</sub>O”. Thus, accounting of emissions and removals of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O is fundamental in order to meet EU targets.

Although deforestation is the main source, forest degradation contribute to atmospheric GHG emissions through decomposition of remaining plant material and soil carbon (C). These larger emission are no more balanced by the C storage capacity in woody biomass and soil, due to unstable structural conditions of the degraded stands. Deforestation and forest degradation are important contributors to global GHG emissions, but if these processes are controlled, forests can significantly contribute to climate change mitigation. Forest degradation, implying a decrease in canopy cover and regeneration, as well as forest fragmentation, will affect the annual increment of C sequestration, reducing the potential of these forests to act as a sink or transforming them into a source of GHGs. CO<sub>2</sub> emissions from deforestation and forest degradation have been estimated to account for about 12-20% of global anthropogenic CO<sub>2</sub> emissions (IPCC, 2007). Nabuurs *et al.* (2000) estimate the potential of a broad range of forest-related activities (including protection from natural disturbance, improved silviculture, savannah thickening, restoration of degraded lands, and management of forest products) at 0.6 GtC/yr over six regions in the temperate and boreal zone (Canada, USA, Australia, Iceland, Japan, and EU).

## 2. Processes involved and main drivers

Processes involved in GHG production and emission are complex and different, depending on the gas considered. Main processes include autotrophic and heterotrophic respiration, methanogenesis, CH<sub>4</sub> oxidation, nitrification and denitrification. Main drivers of GHG production and emission are reported in Figure 1.

### 2.1 CO<sub>2</sub>

CO<sub>2</sub> emissions from soils are greater than all other terrestrial-atmospheric C exchanges, with the exception of gross photosynthesis (Raich and Schlesinger, 1992). An equivalent of almost 10% of CO<sub>2</sub> contained in the atmosphere passes through soils each year, which is more than 10 times the amount of CO<sub>2</sub> released by fossil fuel combustion (Raich and Potter, 1995). In European forests, about 55% of photosynthetically fixed C finds its way back into the atmosphere via belowground respiration (Janssens *et al.*, 2001). Due to the magnitude of this flux and the large stock of C present in soils, any change in soil C emissions in response to environmental changes could constitute a significant feedback on CO<sub>2</sub> concentration in the atmosphere. Mechanisms responsible for CO<sub>2</sub> production are the result of two distinct processes: i) breakdown of root-derived C (root and rhizosphere respiration) and ii) decomposition of soil-derived C

(heterotrophic respiration of SOM) (Ryan and Law, 2005).

The rhizosphere respiration includes belowground autotrophic respiration and heterotrophic respiration of C substrates originating from newly assimilated C, e.g. root exudates and recent dead root biomass (van Hees *et al.*, 2005).

In terrestrial ecosystems, about 35-80% of C fixed through photosynthesis is transferred belowground to fuel root activity, mycorrhizal networks and root exudates (Raich and Nadelhoffer, 1989; Davidson *et al.*, 2002; Giardina *et al.*, 2003; Ryan *et al.*, 2004). Root productivity and photosynthetic activity are thus the main factors controlling below-ground C allocation, and therefore the CO<sub>2</sub> efflux from soils (Högberg *et al.*, 2001; Kuzyakov and Cheng, 2001). Thus, soil respiration (SR) results from activity of a multi-organism network of oxidation pathways, where individual root/rhizosphere and heterotrophic components may respond to environmental constraints in contrasting ways (Trueman and Gonzalez-Meler, 2005). Indeed, one of the main problems with predicting soil respiration is that it is influenced by a multitude of interacting factors including soil temperature, moisture, soil C or litter quality, root density, microbial community structure and size, physical and chemical soil properties and vegetation type, nutrient status and growth rate (Raich and Tufekcioglu, 2000). Consequently, in most ecosystems the rate of soil respiration is highly temporally and spatially variable.

### 2.2 N<sub>2</sub>O

Reduction of N<sub>2</sub>O emissions from terrestrial ecosystems is particularly challenging due to the number and complexity of N<sub>2</sub>O production processes occurring in soil (Venterea *et al.*, 2012). Main processes include:

- i) chemodenitrification;
- ii) nitrification;
- iii) denitrification;
- iv) nitrifier denitrification,
- v) nitrate ammonification.

All these mechanisms are responsible for N<sub>2</sub>O emissions and can occur simultaneously in soil in different micro-niches. Nitrification is a microbial oxidative process that lead to the release of nitrate, via nitrite, starting from reduced forms of N, typically ammonia with a two steps reaction:

- 1)  $\text{NH}_4^+ + 3/2\text{O}_2 \rightarrow \text{NO}_2^- + 2\text{H}^+ + \text{H}_2\text{O} + \text{E}$
- 2)  $\text{NO}_2^- + 1/2\text{O}_2 \rightarrow \text{NO}_3^- + \text{E}$

The first, limiting step of nitrification is the ammonia oxidation carried out by a relatively restricted number of autotrophic chemolithotrophic bacteria. In aerobic systems, nitrification is one of the main mechanism responsible for N<sub>2</sub>O production, which is favored by high soil NH<sub>4</sub><sup>+</sup> concentrations, high soil temperature and water filled pore space lower than 60% (Norton e Stark, 2011).

Several microbial processes compete for  $\text{NO}_3^-$  released in soil: denitrification, dissimilatory  $\text{NO}_3^-$  reduction to  $\text{NH}_4^+$ , and anaerobic  $\text{NH}_4^+$  oxidation. Denitrification is a respiratory process in which  $\text{NO}_3^-$  is reduced stepwise to dinitrogen ( $\text{N}_2$ ) via nitrite, nitric oxide and nitrous oxide intermediates. In bacteria, this process typically occurs under low  $\text{O}_2$  or under anoxic conditions, with water filled pore space higher than 60%. In forest ecosystems the loss of  $\text{NO}_3^-$  from root zone represents the loss of an important plant nutrient while the incomplete soil denitrification can lead to release of  $\text{N}_2\text{O}$  to the environment (Tiedje, 1988).  $\text{NO}_3^-$  reductions are catalysed stepwise by four different reductases encoded by several genes: nitrate reductase (*narG*, *napA*), nitrite reductase (*nirS*, *nirK*), nitric oxide reductase (*cnorB*, *qnorB*) and nitrous oxide reductase (*nosZ*).

The composition of the nitrifying and denitrifying communities in soil and their functional diversity may be crucial in regulating  $\text{N}_2\text{O}$  emissions to the atmosphere (Cavigelli and Robertson, 2000; Holtan-Hartwig *et al.*, 2002; Enwall *et al.*, 2005).

### 2.3 $\text{CH}_4$

$\text{CH}_4$  production is the microbial end product of the anaerobic mineralization of soil organic matter (SOM) degradation performed by microorganisms of Archaea domain in anoxic environments, including submerged soils. The two main types of methanogenic pathways are acetate- and  $\text{H}_2/\text{CO}_2$ -dependent methanogenesis (Conrad, 1999):

- a)  $\text{CO}_2 + 4\text{H}_2 \rightarrow \text{CH}_4 + 2\text{H}_2\text{O}$
- b)  $4\text{HCOOH} \rightarrow \text{CH}_4 + 3\text{CO}_2 + 2\text{H}_2\text{O}$

$\text{CH}_4$  production is suppressed when other alternative electron acceptors ( $\text{O}_2$ ,  $\text{NO}_3^-$ ,  $\text{Fe(III)}$ , and  $\text{SO}_4^{2-}$ ) are present and typically occur at redox potential lower than 200 mV.

$\text{CH}_4$  is emitted in atmosphere through three main mechanisms: transport through plants aerenchyma, diffusion and ebullition. Aerenchyma transport is responsible for most of  $\text{CH}_4$  emitted from terrestrial ecosystems and act as a pipe for the  $\text{CH}_4$  present in groundwater in the presence of deep roots (Schenk and Jackson, 2005). Thus, wetland soils (swamps, bogs, etc.) and rainforests are the main natural source of  $\text{CH}_4$  with an estimated emission of 100-200 Tg year<sup>-1</sup> (Le Mer and Roger, 2001). Inverse process is  $\text{CH}_4$  oxidation, which is performed by aerobic methanotrophic microorganisms. Forest in oxic and upland soils are efficient  $\text{CH}_4$  sinks and are estimated to consume about 10% of atmospheric  $\text{CH}_4$  (IPCC, 2007).

Soil water content is therefore the main driver of  $\text{CH}_4$  production/consumption, influencing the presence of alternative electron acceptors and redox potential. Soil physical properties (such as texture, aggregation status, diffusivity...) and soil organic matter strongly affect  $\text{CH}_4$  production and emissions, by altering  $\text{O}_2$  and substrate availability.

## 3. Mitigation potential

Forest-based strategies offer a cost-effective means to mitigate climate change, so appropriate forest management can help both to reduce emissions from deforestation and forest degradation and to increase C removals (Balderas Torres *et al.*, 2013). With the 20-20-20 targets, the EU has set itself the objective of reducing emissions by 20% until 2020 (European Commission, 2012). The main mitigation options within AFOLU (Agriculture, Forest and Other Land Use) involve one or more of these three strategies: i) reduction/prevention of emissions to the atmosphere by conserving existing C pools in soils or vegetation that would otherwise be lost or by reducing emissions of  $\text{CH}_4$  and  $\text{N}_2\text{O}$ ; ii) sequestration – enhancing the uptake of C in terrestrial reservoirs, and thereby removing  $\text{CO}_2$  from the atmosphere; and iii) reducing  $\text{CO}_2$  emissions by substitution of biological products for fossil fuels or energy-intensive products. This work will focus on the three strategies, giving an overview of management options able to mitigate GHG emissions from soil. Some forest management practices which have demonstrated to affect  $\text{CO}_2$ ,  $\text{CH}_4$  or  $\text{N}_2\text{O}$  emissions, and the direction of changes, are reported in table 1. The capacity of ecosystems to store C depends on the balance between net primary productivity (NPP) and heterotrophic respiration. Whether a particular ecosystem is functioning as sink or source of GHG emission may change over time, depending on its vulnerability to climate change and other stressors and disturbances. Forest ecosystems generally represent a net sink for  $\text{CO}_2$  and have the potential to offset from 2% to 30% of expected emissions during this century, as confirmed by inventory measurements in both managed and unmanaged forests in temperate and tropical regions (Luyssaert *et al.*, 2008; Pan *et al.*, 2011). It has been argued that conservation of forests by using good silvicultural practice and through tree planting can enhance strongly the C sink provided by terrestrial ecosystems (Baral and Gupta, 2004). Although data on C sequestration potential are widely accessible in most part of the world, less is known about the potential for GHG emission reduction with proper management strategies. Moreover, even if the importance of  $\text{CH}_4$  and  $\text{N}_2\text{O}$  emissions is recognized, scientific research has largely focused on  $\text{CO}_2$ . Reducing GHG emissions and GWP is a fundamental aspect of climate change mitigation strategies and strongly depends on the adopted management options.  $\text{N}_2\text{O}$  emissions reduction is particularly challenging due to the complexity of processes involved and their interactions, thus the result may be achieved only if the different aspects of processes involved are considered.

### 3.1 Afforestation/reforestation intervention

Conversion of degraded soil from agricultural to forest use can accrue the pool of C stored into soil (Guo and Gifford, 2002), with a positive balance between GHG emissions and C accumulation. A decrease of  $\text{CO}_2$  emissions is the result of lower C mineralization rates

due to minor or absent soil disturbance, which increase physical protection of C. This reduction is maximum in case of conversion from agricultural to natural forests, while can be partial in case of plantations. Contrarily, conversions from pasture to forests can bring to net losses of C, mainly because of lower turnover rates of soil organic matter, in particular in case of pine afforestation (Groenendijk *et al.*, 2002).

Less studies focused on changes of CH<sub>4</sub> and N<sub>2</sub>O emissions after afforestation/reforestation intervention. Available results seems to indicate a tendency towards lower N<sub>2</sub>O emissions because of lower N input from fertilization or animal dejections (Merino *et al.*, 2004; Allen *et al.*, 2009).

Potential reduction of CH<sub>4</sub> emissions mainly depends on water conditions of soil before intervention. Main benefits have been found in peats ecosystems following drainage and water uptake by plants (Makiranta *et al.*, 2007). Impact of stand ages on GHG emissions have been less studied but first results seems indicate a trend toward lower CH<sub>4</sub> and higher N<sub>2</sub>O emissions with the forest age (Christiansen and Gundersen, 2011).

### 3.2 Forest degradation

The United Nations Framework on Climate Change (UNFCCC), at its thirteenth meeting in 2005 (COP-11), agreed to start a work program to explore a range of policy approaches and positive incentives for Reducing Emissions from Deforestation and Degradation (REDD). This process was further encouraged in the 2007 COP-13 with the explicit consideration of REDD activities as a means to enhance mitigation action by developing countries in the future (Corbera *et al.*, 2010).

As widely used by forest scientists, forest degradation implies a long-term loss of productivity, which thereby lower the capacity to supply products and/or services, including C storage capacity in vegetation and soil, changes in tree vigor and quality, species composition, soils, water, nutrients and the landscape. Forest-based strategies offer a cost-effective means to mitigate climate change, so appropriate forest management can help both to reduce emissions from deforestation and forest degradation and to increase C removals (Balderas Torres *et al.*, 2013). Increasing the C pool in vegetation and soil can be accomplished by protecting secondary forests and other degraded forests whose biomass and soil C densities are less than their maximum value and allowing them to sequester C by natural or artificial regeneration and soil enrichment. In this context, the conversion of degraded forest pine plantations to facilitate the introduction of late-successional native broadleaves species means to help restoring natural functioning processes (e.g. natural regeneration, or more generally, self-organization), increasing their stability, resilience and self-perpetuating capacity, besides their capacity to mitigate GHG emissions and increase C storage.

### 3.3 Silvicultural practices

Management of forest ecosystems for climate change mitigation may include several strategies: i.e. fire

protection, pest control, less intensive harvest, increasing the length of time to rotation (harvest), limitation of soil compaction, regulation of tree densities, selection of species, biodiversity conservation, residues management following felling. However, these strategies have the strongest and clear effect on C accumulation in forest biomass, while less is known on the impact on GHG emissions.

Forest management, such as felling and thinning could potentially change N<sub>2</sub>O emission rates by altering the soil water content owing to the absence of trees (felling) or reduction of shading (thinning). The few studies that investigated effects of clear-felling on GHG fluxes revealed that clear-felling resulted in a pulse of N<sub>2</sub>O, NO and CO<sub>2</sub> emissions (Zerva and Mencuccini, 2005). Clear-felling has been found to profoundly alter several pedo-climatic properties, which in turn may affect GHG emissions: soil temperature, soil water content, groundwater depth, soil bulk density and compaction (Frazer *et al.*, 1990; Schilling *et al.*, 1999). Soil compaction can bring a considerable increase of N<sub>2</sub>O e CH<sub>4</sub> emissions because of macropores volume reduction and water saturation, with a tendency towards anaerobic conditions (Zerva e Mencuccini, 2005).

An alteration of substrate availability is expected after clear-felling, either in terms of decomposable C or N. Above and belowground litter and forest residues are made available for microbial decomposition, thus increasing CO<sub>2</sub> emissions (Buchmann, 2000). Moreover, N<sub>2</sub>O emissions can be affected by clear-felling through modification in N availability: in fact, in the absence of plant uptake, the excess of N can trigger nitrification and thus N<sub>2</sub>O emissions, favored also by the higher temperatures (Frazer *et al.*, 1990). An increase of denitrification and methanogenesis has been found after clear-felling in high moisture environments (Dutch and Ineson, 1990). Thinning operation may affect GHG emission indirectly by altering soil temperature and moisture conditions. However, residues management can be extremely important in order to provide or remove organic matter available for decomposition, thus a proper strategy should be adopted depending on pedo-climatic condition of the site (Johnson and Curtis, 2001).

### 3.4 Fast growing plantations

Fast growing plantations or short rotation forests respond to the objective of substituting biological products for fossil fuels or energy-intensive products, thereby reducing CO<sub>2</sub> emissions (Zsuffa *et al.*, 1996). Their role is becoming more and more important in climate change mitigation strategies, but still their management should be accurately planned to reduce GHG emissions from soil. In particular, irrigation, fertilization and tillage are common practices in plantations, which may strongly affect GHG emissions. The influence of excess N or water has been already discussed: inappropriate or excessive fertilization can provoke peaks of N<sub>2</sub>O, while an excess of water can induce methanogenesis. Tillage operations before the implant or during tree growth significantly affect GHG emissions, directly by favoring diffusion rates into soil

and providing substrates for decomposition through aggregates breaking (Six and Jastrow, 2002) and indirectly altering temperature and moisture conditions for microbial processes.

#### 4. Conclusion

The quantification of GHG emissions from forest ecosystems and the impact of different management strategies for their reduction has still large knowledge

gaps and remain a challenge. The inclusion of the three gases CO<sub>2</sub>, N<sub>2</sub>O and CH<sub>4</sub> in estimates is important in view of the multiple factors influencing the emission rates, often in contrasting directions. Further research is therefore needed considering the whole soil-plant system and the impact of management options on soil physical, chemical and biological properties, which in turn influence biogeochemical processes responsible of GHG emissions.

Table 1. Schematic list of management strategies affecting GHG emissions from forest ecosystems.

<b>afforestation/reforestation</b>	
from pasture to forest	↓N <sub>2</sub> O, ↑CO <sub>2</sub>
From crop to forest	↓N <sub>2</sub> O, ↓CO <sub>2</sub>
From wetland to plantation	↓CH <sub>4</sub> , ↑CO <sub>2</sub>
<b>Silvicultural practices</b>	
Conversion of degraded coniferous plantations	↓↑N <sub>2</sub> O, ↓CO <sub>2</sub>
Thinning intervention	↓CO <sub>2</sub> , ↓↑ N <sub>2</sub> O
Reduced soil compaction	↓N <sub>2</sub> O, ↓CO <sub>2</sub>
Permanent soil cover	↓N <sub>2</sub> O, ↓↑ CO <sub>2</sub>
Prevention of acidification	↓CH <sub>4</sub> , ↓N <sub>2</sub> O
Hydrological regime	↓CH <sub>4</sub> , ↓N <sub>2</sub> O
<b>Management of plantations</b>	
Appropriate fertilization	↓N <sub>2</sub> O, ↓CO <sub>2</sub>
Appropriate irrigation	↓CH <sub>4</sub>
Minimum ploughing	↓CO <sub>2</sub>

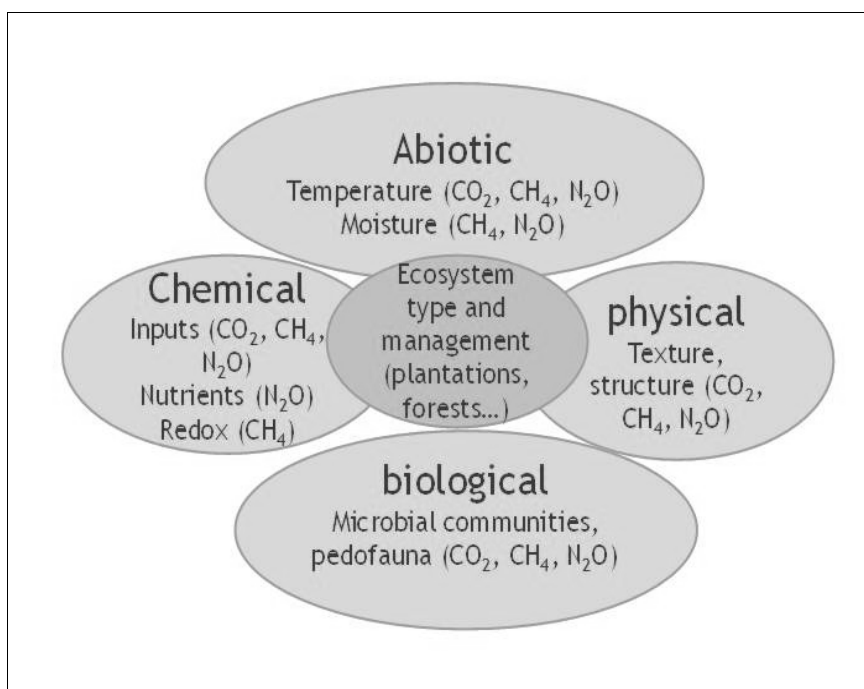


Figure 1. Synthesis of the main drivers of GHG emissions.

## RIASSUNTO

### Emissioni di gas ad effetto serra da suoli forestali: processi e potenzialità di mitigazione

Le foreste rappresentano un enorme *sink* di assorbimento del C, contenendo l'80% del carbonio epigeo totale ed il 40% di quello ipogeo, e sono responsabili del 60-70% della produttività primaria di tutti gli ecosistemi terrestri. Tuttavia, la loro importanza si riconduce anche al notevole contributo, pari a circa il 70%, che le foreste hanno sugli scambi gassosi tra biosfera e atmosfera.

I principali gas ad effetto serra (GHG) emessi dagli ecosistemi forestali sono l'anidride carbonica (CO<sub>2</sub>), il metano (CH<sub>4</sub>) e il protossido di azoto (N<sub>2</sub>O), che contribuiscono rispettivamente per circa il 60%, 20% e 6% al riscaldamento globale. I processi di produzione ed emissione di tali gas coinvolgono principalmente la respirazione (autotrofa ed eterotrofa), la metanogenesi, la nitrificazione e la denitrificazione. Tali processi dipendono da una varietà di fattori biotici ed abiotici che influenzano sia la dimensione che la direzione degli scambi gassosi tra foreste ed atmosfera, determinando così la capacità di accumulo e rilascio di GHG degli ecosistemi forestali, che possono agire come *sink* o *source*. In tal senso, il tipo di suolo e le sue caratteristiche fisiche, chimiche e biologiche influiscono sia sulla disponibilità di substrati che sulla loro accessibilità alle comunità microbiche coinvolte nella produzione di GHG e vanno considerati come fattori determinanti.

La conoscenza di tali processi è di fondamentale importanza per l'applicazione di tecniche di gestione idonee a ridurre le emissioni di GHG, contribuendo ad incrementare significativamente le potenzialità di mitigazione dei cambiamenti clima.

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