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Chapter 5

The role of agriculture in mitigating greenhouse gas emissions

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Introduction

Agriculture will not only be affected by climate change, but it will also play a central role in reducing greenhouse gas (GHG) emissions and, consequently, mitigating climate change impacts. Mitigating actions relevant for agriculture are also important actions to adapt to climate change, because increasing carbon sequestration fundamentally depends on reducing agroecosystem nutrient losses and increasing biomass and soil carbon stocks (Oliveira et al., 2014), which contribute to maintain high production standards and better use of natural resources, especially soil and water. Mitigating emissions lead to more favorable GHG balance in agroecosystems, which may occasionally turn into carbon neutral systems or even as GHG sinks. In any of these cases, reducing GHG emissions and increasing (mainly organic) carbon sequestration are one of the main objectives of transitioning to low carbon emission agriculture.

Agriculture and livestock

Embrapa has been carrying out several network projects in order to develop GHG emission mitigation practices and technologies for livestock, forestry and grain systems in varied Brazilian biomes, respectively Pecus, Saltus and Fluxus are the most outstanding. Embrapa has been identifying relevant strategies for GHG emission mitigation in agriculture. In crop systems, for example, biomass not harvested for food should be kept on the soil surface instead of being incorporated into the soil. This process was called No Tillage System (NTS), which should be combined with crop rotation (including leguminous species), cover plants, green manuring, and soil conservation and management practices. NTS increases productivity, soil organic carbon sequestration (Madari et al., 2005; Corbeels et al., 2016) and is beneficial to the health of cultivated soils (Salton et al., 1998). In addition to helping GHG emission mitigation, NTS improves soil biophysical conditions, prevents salinization processes, and reduces temperature and evaporation ranges, thus enhancing agroecosystems resilience (Giongo et al., 2014). Increasing nitrogen in the soil by Biological Nitrogen Fixation (BNF) is crucial because the carbon cycle is closely linked with that of nitrogen and other nutrients (Sisti et al., 2004).

In aerobic crop systems, the most important greenhouse gas is nitrous oxide (N_2O) mainly due to inorganic nitrogen fertilizers applied (Brasil, 2014). Technologies to promote the efficient use of these fertilizers, such as nanotechnology for slow release fertilizers (Kottegoda et al., 2017), or those to partially or totally avoid their use by stimulating BNF, can significantly reduce N_2O emissions. In anoxic agroecosystems of irrigated rice, methane (CH_4) emission can be reduced by intermittent management of flooding irrigation or by selecting rice cultivars for this purpose (Scivittaro et al., 2014, 2015). Using biochar can contribute both to carbon sequestration and to mitigating N_2O and CH_4 emissions in aerobic and anoxic agroecosystems (Karhu et al., 2011; Han et al., 2016; Sun et al., 2017).

One of the most suitable technologies for mitigating livestock emissions is pasture recovery and intensification (FAO, 2009; O´Mara, 2012; Oliveira, 2015), because of its great potential for soil carbon sequestration, given the vast areas used for this purpose in Brazil. Another important technology is reducing enteric CH_4 emission. The most indicated and impacting technologies to achieve this objective are improved zootechnical indexes and production efficiency (reduced age at slaughter, interval between calvings, animal performance). Related Embrapa projects are Novilho Precoce (Early Steers) and Inseminação Artificial em Tempo Fixo (Fixed Time Artificial Insemination – IATF) (Melo Filho; Queiroz, 2011). Additionally, balanced and better quality diets (well-managed pastures and forages, use of mineral, protein and energy supplementation) and ruminal fermentation modulating additives, may also contribute for mitigating enteric CH_4 emission (Oliveira et al., 2015; Moura et al., 2017). Biophysical modeling is a useful tool to help in agricultural GHG emission mitigation. Projects carried out by Embrapa have revealed that simulation models and GHG emission scenarios currently available fail to present satisfactory results due to lacking parameterization for Brazilian conditions. This is why new models are being constructed based on Embrapa’s Pecus Network database, which gathers data sets collected in Brazilian biomes.

Combining crops with livestock and the forestry sector has been encouraged to even more effectively mitigate GHG emissions by agriculture. Low-carbon emission agricultural production should be based on integrated livestock-forestry (ILF), crop-forestry (ICF) and crop-livestock-forestry (ICLF) systems and should combine recycling processes with minimal soil turnover and native vegetation conservation (Sacramento et al., 2013). Integrated production models allow higher tree carbon sequestration rates, which, in turn, provide greater thermal comfort to animals (Lemes et al., 2015; Botta et al., 2017), thus contributing to improved productive and reproductive zootechnical indexes. Studies on ICLF systems and sustainable management of swine (biodigesters, renewable energy generation and fertigation) in the state of Mato Grosso do Sul showed promising results, both in terms of socio-environmental aspects and GHG emissions mitigation (Buller et al., 2015). Adopting intensive ILF systems that combine forestry and no-tillage systems (Figueiredo et al., 2017; Oliveira et al., 2018) can potentially enhance organic carbon sequestration and GHG emission mitigation. Embrapa has encouraged important initiatives for livestock, such as carbon neutral meat and milk production, in which GHG emissions are neutralized by carbon sequestration during the production process. Mitigation is essentially due to the presence of trees in integrated systems and to certification.

Integrated management of agroecosystems, by incorporating and combining certified technologies from various areas of knowledge (integrated pest management, rational use of inputs and water, etc.), can further reduce water and carbon footprints of productive systems (Carmo et al., 2016). The main challenge has been the economic arrangement to provide bonuses for products with reduced or neutralized GHG emission, or by organic carbon sequestered in soil, for example in the form of carbon credit, an important mechanism for guaranteeing long-term sustainable agriculture.

Energy crops

Energy crops are economically and environmentally viable alternatives in addition to fossil sources. Biomass production potential depends on the crop, and the type of biofuel produced varies, from sugarcane or maize ethanol, soy biodiesel, to electrical energy from waste bio digestion (Bergier et al., 2012). Avoided burning of fossil fuels is already good reason to use these crops in the world energy mix. However, adopting production systems that are more efficient in terms of productivity and are more adjusted, such as no-tillage, inoculants to optimize BNF, waste management and effluent recycling, also helps mitigating GHG emissions. As between 60% and 85% of emissions related to biofuel production originates in or are related with the agricultural phase of its making, any changes in the practices involved in this phase are significant to improve the final carbon balance. Therefore, automation and process integration in agroecosystems will be crucial for effective refinements in correctives and fertilizers use, dosage and sources in order to significantly mitigate emissions and maximize productivity. In sugarcane fertilization, for example, substituting urea for ammonium nitrate reduces N_2O emissions, depending on soil characteristics, time of application and region. Using BNF with energy crops can further contribute to mitigating GHG emissions, because it can make N_2O emissions equivalent to those from soils with no fertilizer. For soybeans, the use of inoculant instead of mineral nitrogen fertilizer is already routine and contributes significantly to mitigating GHG emissions. In terms of soil management, the use of no-tillage during sugarcane fallow period can reduce CO_2 emissions between 11% to 20%, compared to conventional tillage.

Forestry sector

The forestry sector also has great potential to reduce GHG emissions. Planting trees, especially those for the furniture sector, and native vegetation areas in Legal Reserves, Permanent Protection Areas, and Private Reserves of Natural Heritage contribute to maintain carbon, water and biodiversity in agroecosystems. The United Nations launched, in 2008, a deforestation and forest degradation emissions mitigation program called REDD. Another important contribution of this sector is to use forest-based products to keep carbon stocked for a long period of time or to replace the use of fossil fuels. In addition, flood-free forest soils are CH_4 sinks. There are observations in Southern Brazil that the oxidation of CH_4 in soils under *Pinus taeda* plantations, even though it is of smaller size when compared to adjacent native forests (intermediate stage of succession), is significant (Higa et al., 2017).

Ecological systems

Encouraging the adoption of diversified and (certified) organic production systems meets a clear societal demand for healthy food that mitigates global warming impacts. Sustainable functional agroecosystem models will use increasingly complex relations between and within their multiple components. Using agroforestry systems as land use options relying on plant – soil interactions in different magnitudes presents great potential for mitigation and is also an important measure of adaptation to climatic risks, assigning greater resilience, food, energy and water security. Using native species is an important tool to recover degraded areas and conserve endangered species, thus adding even more value to local products. This may raise issues of public policies related to payment for environmental services and particularly climate regulation services (Anderson-Teixeira et al., 2012), that may be one among other measures for mitigating and adapting to climate changes.

Fish farming

Generally, water dams are sources of CH_4 (Deemer et al., 2016) and also store carbon in its sediments (Mendonça et al., 2017). Adding food in net pens directly impacts on the carbon balance of these confined aquatic environments, given that primary productivity, linked to use and occupancy, affects emissions (Bergier et al., 2014; Deemer et al., 2016). Further studies are needed to determine whether large-scale net-pen farming may result in anoxia and increased CH_4 emissions, aquatic cyanobacteria or macrophytes bloom and the consequent risks to aquatic life. Preliminary studies by Embrapa Environment provided first insights into the influence of aquaculture on GHG emissions. In the reservoir of Furnas in the state of Minas Gerais, three areas with production of Nile tilapia (*Oreochromis niloticus*) in net pens were monitored. Emissions of CH_4 were significantly higher when compared to an area without aquaculture production. Samplings were also carried out in net-pen fish farming areas Padre Cícero Reservoir, known as Castanhão, in the state of Ceará, and at the Chavantes reservoir, along the Paranapanema River in the states of São Paulo and Paraná. In both cases, significant CH_4 emission was observed in the area of net pens. On the other hand, no difference was noted in terms of CO_2 emission between farmed and non-farmed areas in the same reservoir. Preliminary results suggest that organic matter from fish farming promotes methanogenesis and consequent CH_4 emission to the atmosphere, while CO_2 emission/removal is more associated with the reservoir degree of eutrophication.

Therefore, it is fundamental to better describe aquaculture systems, to monitor water quality and better assess CH_4 emissions in net pens. Furthermore, and similarly to what has been done in more sustainable agroecosystems, it is necessary, depending on the scale, to integrate aquaculture with hydroponics (aquaponics) and/or with photovoltaic electric energy generation. In Asia, there are very interesting initiatives integrating photovoltaic and aquaculture industries, which can be repeated in Brazil as an adaptation to and mitigation of climate change strategy in both the energy and aquaculture sectors. Placing solar panels on the surface of reservoirs generates renewable energy, increases the albedo and reduces sensible and latent heat, thus minimizing water loss due to evaporation.

Final considerations

Embrapa, with its partners, has been working on the development of solutions to reduce greenhouse gas (GHG) emissions in agriculture and, consequently, to mitigate climate change impacts. Some technologies, such as recovery of degraded pasture, crop-livestock-forestry integration, no-tillage system, biological nitrogen fixation, planted forests and agroforestry systems, as well as animal waste management, are already part of national public policies, such as the ABC Plan, which are aligned with international policies and initiatives for mitigation and adaptation to climate change. However, studies to describe the impact of agricultural systems are still needed to identify problems and to fill gaps in our knowledge of this aspect of productive systems. There is also room for developing or improving technologies already recognized as mitigators. There are some areas, such as fish farming, in which technologies for GHG emissions reduction must be developed or adapted. Among the future challenges, we can still mention that incentives for the productive sector to adopt large-scale GHG emission mitigating technologies are still lacking. It is also a significant challenge to develop mechanisms to encourage long-term (for 20 years or more) adoption of such technologies; this is the time frame needed to achieve Brazil's reduced GHG emission targets as suggested in international agreements. In addition, monitoring the adoption of mitigating technologies is in itself a complex challenge. The long-term adoption of mitigating technologies would also be favorable in order to avoid a possible increase in GHG emissions, thus enhancing climate change. However, challenges of adopting and maintaining technologies in use require solutions that go beyond scientific research and technological development, because they involve especially political and economic issues that encourage varied processes of GHG emission mitigation and fight against climate change.

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