AGRICULTURE – CLIMATE CHANGE MITIGATION AGENT

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Abstract
The potential of agriculture for climate change mitigation derives from both increasing its capacity to sequestrate greenhouse gases and reducing the emissions by improving the technologies used for tillage and for livestock grazing. Transforming this potential in mitigation agent for climate change should take in account the fact that agricultural land provides food for the seven billion inhabitants of the Earth, raw materials for a variety of products used by humans, income source for billions of people and represents the foundation of sustainable development in many regions. Meanwhile, agriculture is the main economic activity for many communities, especially in developing countries.
Keywords
agriculture, climate change, greenhouse gases, production, consumption.

Introduction

Climate change is the most challenging environmental issues heading the global agenda. Recent reviews of the main drivers indicate that the goal of maintaining the average temperature change below 2 Celsius degree will not be met. Major increases in greenhouse gas emissions in China and mild interventions in US, along with the patterns of the energy consumption are serious concerns for climate policy. On global and European markets the price of carbon is very low and policy makers are concerned about the effectiveness of this tool. Despite major progress, renewable energy is still a very low contribution to worldwide consumption.

The modernization of the technologies used in agriculture significantly reduced the influence of meteorological conditions over agriculture, but it does not allowed to exclude climate factor from the group of key variables that have impact on the agricultural economy. On the one hand, there is a limit regarding the control of the influence. Thus, even the most advanced technologies succeed to avoid only certain effects of unfavourable climate conditions. On the other hand, the technical endowment of agricultural holdings is very different from one region to another, the most modern technologies being available for a relative small proportion of agricultural land.

Modern agriculture and the production and distribution of food have an important contribution to greenhouse gas emissions. In the last 150 years, carbon dioxide emissions of agricultural land is about 480 billion tonnes (Brown, 2001). Agriculture contributes to greenhouse gas emissions especially by favouring the decomposition of soil's organic matter, decay of nitrogen based chemical fertilizers, crops that necessitate water ponding (e.g. rise), ruminant livestock and others. Methane and nitrous oxide are the most important greenhouse gases from agriculture, while the distribution and processing of agro-food products contributes to the carbon dioxide and freon emissions.

1. Ecosystem services and agriculture

In agriculture there are used large areas of land that function based on the ecological principles, being agricultural ecosystems. Plants absorb carbon dioxide from the atmosphere and nitrogen from the soil for growth and provide the redistribution of these substances among different reservoirs, such as biomass from and on the soil, and also the death organic matter more or less decomposed. Carbon dioxide, methane and nitrous oxide are released in atmosphere by the breath of plants and decay of biomass and through burning. Human activities change both the path of emissions and the path of absorption. The potential for climate change mitigation could be inferred from the structure of ecosystem services.

The size and characteristics of agricultural sector allow foreseeing a slow, gradual transformation. In this process will be exceeded one by one mane difficulties determined by the availability of financial resources, poverty, institutional capacity, technological progress, social-economic development gaps etc. The possibilities to mitigate climate change could be analysed from two perspectives: the perspective of agricultural production and the perspective of the agro-food products' consumption.

2. Mitigation by changes in agricultural production

The opportunities for reducing greenhouse gases in agricultural production comprise options for avoiding emissions and for facilitating the sequestration of some greenhouse gases, especially carbon dioxide. The ecologic potential of the measures to be applied in the field of production is to be of 7.2-10.6 Gt carbon dioxide equivalent. These estimations comprise agriculture, as well as forestry and takes in account soils' capacity to absorb carbon dioxide. The contribution of agriculture is estimated to 0.3-4.6 Gt/year.

The economic potential of various possibilities to mitigate climate change in agriculture vary from one intervention to other. The greatest potential is for rebuilding soils' content in organic matter. By applying such measures a farmer could ain 100 USD for a tone of captured carbon (expressed in carbon equivalent). Interventions in livestock grazing could bring also important gains estimated to 20 USD per tonne. A synthesis of mitigation measures that could be employed in agriculture is presented in table 1.

Table 1 Possibilities to mitigate climate change within agricultural production

Crt. nr.	Categories	Interventions and impact
CROPPING		
1	Varieties	CO_2: technologies with great carbon sequestration potential – varieties, crop rotation, perennial crops, agricultural biotechnologies
		N_2O: improving the use of nitrogen
2	Fertilization	CO_2: using residual organic matter for the fertilization of crops
		N_2O: adjusting fertilization norms, periods of application, improving precision, using inhibitors
3	Soil tillage	CO_2: reducing intensity, retaining residual organic matter
4	Water resource management	CO_2: increasing water availability, including water retention
		CH_4: decomposing residual matter
		N_2O: drainage of excess water, reducing nitrogen leakage and runoff
5	Dropping crops for certain periods	CO_2: restoring of natural grassland or other vegetation
		N_2O: reducing nitrogen inputs
LIVESTOCK		

Crt. nr.	Categories	Interventions and impact
1	Varieties – pastures	CO_2: improving the composition of grassland using deeply rooted, high production, and resistant species
2	Varieties – livestock	CO_2: adjusting the density of animals, feeding pads, diversification of feeder production
		CH4: improved fodder and additives that reduce enteric fermentation, including optimization for age, nitrate and sulphur additives, antibiotics etc.
		N_2O: adjusting the density of animals according to the amount of manure
3	Fire	CO_2: prevention of wildfires, optimization of controlled fires for improving pastures' productivity
4	Manure	CH4: improved conditions for manipulation and storage, biotechnologies for decomposition, fodder additives
		N2O: fodder regimes that reduce nitrogen excretion, nitrification inhibitors, optimization of doses and periods
RESTORING VEGETATION		
1	Restoring vegetation	CO_2: restoring vegetation by other interventions than afforestation
		CH_4: cattle grazing could increase net emissions
		N2O: reducing nitrogen inputs
OTHERS		
1	Ecological restoration of organic soils	CO_2: restoring the carbon stocks of bogs, avoiding emissions by tillage
		CH_4: emissions could increase
2	Ecological restoration of degraded soils	Reintegration in the agricultural system: afforestation, fertilization, increasing water retention capacity

Source: IPCC. 2013. *Chapter 11: Agriculture, forestry and other land use (AFOLU)*, Contribution of WG III – Mitigation of Climate Change to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, pg.23-25, modified

According to Godfray et al. (2010), the analysis and evaluation of interventions that could be employed in agriculture should consider the following aspects:

- Non-permanence and reversibility;
- Saturation;
- Human and natural impact;
- Dislocation.

Non-permanence and reversibility. Mitigation activities such are the ones for reducing nitrogenous oxide emissions from fertilisation and emission reductions by fodder composition have permanent effects, since the avoided emissions cannot rebuild. The same is true for replacing fossil fuels with biomass or concrete with wood in construction.

The effects of these measures can be offset in certain cases due to natural phenomena that affect cropping and livestock. These could be early or late frost, insect attacks, wildfires etc. Although these phenomena could significantly reduce the annual carbon sequestration rate, the impact on permanent carbon stocks is reduced.

Saturation. The replacement of fossil fuels or construction materials with other that are less intensive in carbon could continue without restrains. Unlike this, increasing the carbon sequestration in soil or in plants cannot be done indefinitely. After a certain threshold, then the content approaches the natural level the path of sequestration is decreasing. Although the saturation is not fully reached, the sequestration rates are smaller and remain constant close to the saturation level.

Human and natural impact. Carbon sequestration capacity is directly and indirectly influenced by human activities and natural processes. The interventions mentioned in table 1 are human activities that directly contribute the increase this capacity. Both absorption capacity and storage capacity of carbon could be affected by natural processes such as soil type and hydrologic regime. Among the human activities with indirect influence there could be mentioned the ones that favour the formation of tropospheric ozone, which, on its turn, could offset the stimulating effect of higher carbon and nitrogen concentration.

Dislocation. This process takes place then an intervention reduces or increases the emissions in other areas than the one where they are applied. If the measures reduce emissions in an area, but increase them in other region, the net emission reduction is null. The emissions are transferred from one area to another.

Briefly, climate change mitigation in agriculture could be achieved by facilitating actions such as:

- Conversion of agricultural waste, especially manure in biogas – needs important investments for installations, but the potential for emission reduction, especially for methane is very high. It is recommended in regions with high density of animals and large quantities of manure is accumulated;
- Expanding organic cropping – respecting the requirements of organic cropping results, among others, in the reduction of greenhouse gases. This is determined by the restrains of using chemical fertilizers and favouring processes that allow the sequestration and storage of carbon in soil, diversification of species and varieties, using grass strips, organic fertilizers etc.;
- Facilitating biomass production for energy to support the replacement of fossil fuels – in this way there is supported the energy autonomy of rural areas. Extending the use of biomass and of biofuels depends on information, crop structure, investments in processing technologies and storage facilities. On the other hand, using bio-diesel does not imply major interventions in agricultural machinery (Bran et al., 2013).
- Equitable repartition of costs and benefits resulting from ecosystem services provided by agriculture – farmers contribution to the reduction of some ecological pressures and to the sustainable management of natural resources is of key importance for society and it should be mirrored in they incomes. Thus, farmers' interest in applying climate change mitigation measures could be significantly improved.

Taking in account the fact that agriculture is the second most important greenhouse gas emission source, the application of measures and interventions that reduce emissions will be critical for climate change mitigation. Identifying and assessing of main restrains in the adoption of these measures should be considered with priority in knowledge generation and in operational policy making.

3. Mitigation by intervention at the consumption level

As long as the demand and consumption of food and agricultural products is regarded, the interventions for emission reduction will envision waste generation, especially food waste, changes in food regimes and in wood consumption.

Changing the patterns of food consumption is a controversial topic since there are still major issues in delivering food security and food safety. The production in large enough quantities and the access to cheap food are critical factors for food security. Greenhouse gases could be reduced by changing the demand for agro-food products without affecting food security and wellbeing by:

- Reducing food loss and food waste on both food chain and final consumption;
- Changing food regime in such a way that greenhouse gas intensive foods are replaced by foods that are less intensive in emissions (for instance, replacing animal food with vegetal food while maintaining the proper content in protein);
- Reducing overconsumption in regions where this is the case.

Replacing animal food products with vegetal food products is a complex issue because in many situations the animals could be fed on plants that cannot be consumed by humans or grows on fields with high carbon stocks that cannot be cropped with comestible crops. In addition, animal food products have a key importance for food security in many regions.

In table 2 there are presented the main possibilities to reduce greenhouse gas emission at the demand level for agricultural products.

Table 2 Possibilities to mitigate climate change at the level of agricultural and food products' consumption

Crt.nr.	Intervention	Description
1	Reducing losses along the agro-food chain	Reducing the losses contributes to reduce the energy consumption and of greenhouse gas emissions for agricultural production, transportation, storage and distribution and area needed for cropping
2	Changes in food regime	Where there is possible it will be promoted low greenhouse gas intensive products. These changes in the demand's structure will reduce energy inputs and will reduce the area needed for cropping

Source: IPCC. 2013. *Chapter 11: Agriculture, forestry and other land use (AFOLU),* Contribution of WG III – Mitigation of Climate Change to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, pg.34.

At global level, it is estimated that 30-40% of the food that is produced is lost on the agro-food chain in between harvest and final consumer (Godfray et al., 2010). The energy embodied in food that is lost is of around 36 EJ/year (FAO, 2011). In developing countries, around 40% of the harvest is lost at farm level or during distribution due to inappropriate conditions for storage and transportation and obsolete conservation technologies. In developed countries, farm level losses and also distribution losses are smaller, but a similar proportion is lost or is thrown away in the food service sector or by the final consumer (Hodges et al., 2011).

Food loss cannot be entirely avoided because a part of this is given by removing inedible parts such as seeds, peels etc. For instance, in Great Britain it was estimated that 18% of food waste are unavoidable, 18% have the potential to be avoided and 64% could be avoided. Using data for Austria, Netherlands, Turkey and Great Britain it is appreciated that the food waste generated by one household during one year in developed countries is of 150-300 kg (Parfitt et al., 2010). For a household from developing countries the quantity is similar being of 280-300 kg (Gustavsson et al., 2011).

Among the possibilities to reduce food losses we could mention the followings:

- Investments in harvest, processing, and storage facilities in developing countries;
- Increasing awareness;
- Financial tools for reducing loss in retail and at the level of the final consumer in developed countries.

As long as the food regime is regarded, studies based on life cycle analysis (LCA) show that vegetal food products generate significantly less greenhouse gas emissions than the one of animal origin, although there are exceptions, such as vegetables grown in greenhouses or transported by plain. The same caloric and protein content could be provided by vegetal food products with 10 times less emissions than in case of animal food products (Carlsson-Kanyama and González, 2009).

Out of the animal food products, the largest emissions per unit of protein are recorded for cattle, followed at relatively great distance by pork, poultry, eggs, and dairy products. Beef production could use five times more fodder than a similar amount of dairy products.

Another issue that should be considered is that specific emissions vary greatly from one region to another due to different ecological conditions, technologies and production intensity. The smallest emissions per unit of protein produced are recorded in Europe and North America, while the largest in Africa, Asia and Latin America. Therefore, climate change mitigation strategies should focus on developing regions and pursue adapting intensive animal grazing systems with local ecological, economic, and social restrains.

In case that the food regime remains unchanged, the methane and nitrous oxide emissions from agriculture will be triple until 2055 (Stehfest et al., 2009). The contribution of food regime change to greenhouse gas emission reduction is estimated to be comprised between 34 and 64%. The change could be represented by a variety of options from the total elimination of beef consumption until a healthy and balanced food regime, as it is the recommended by the Harvard Medical School.

In the assessment of food regime change's potential for climate change mitigation should be considered several restrains that are related on the one hand with cultural barriers, and on the other hand to the precision of the estimations. Thus, the implementation of measures that favour food regime changes could face a strong resistance on the behalf of consumers who have diets framed by cultural and social models specific to each region (Smith, 2013). The estimates regarding emissions associated to different agro-food products are not very effective in capturing the effects determined by the changing carbon storage capacity of agricultural land. Thus, pastures that support livestock production have a larger capacity to sequestrate and to store carbon dioxide compared to numerous crops (Schmidinger and Stehfest, 2013).

Implementing climate change mitigation measures at the level of demand is facing many uncertainties and restrains. Nevertheless its potential for emission reduction is important and requests a careful exploration of possibilities and their applicability in different socio-economic and cultural contexts.

Conclusions

Climate changes result in the modification of climate parameters following patterns that are more or less predictable. The outstanding performances of modern agriculture are determined by technological progresses that allowed the intensification of control over a larger and larger number of interactions that are occurring in the agricultural ecosystem. A great part of these interactions are related with climate conditions and consisted either in cancelling the effects of climate factors or increasing the correlation between conditions and the cropped species ecological profile.

From the economic perspective, agriculture recorded less noticeable progresses. Thus maintaining a profit rate is possible only by intensification and continuous growth of productivity. Thus, although in the last decades the productions grew several times for many crops, including basic crops like cereals, the profitability of those crops remained constant or even fell. In addition, on the agro-food chain, the profit rate of the farmer is the smallest.

In such conditions, the impact of climate change in agriculture is considered important or even a challenge for that innovation should provide major technological improvement. Along with this improvement it should be also integrated the need to reduce emissions in various stages of production, storage, distribution, and consumption.

Since agriculture is the second largest source of greenhouse gases, accounting for around one third of the emissions, it is important to seriously consider the possibilities to intensify the mitigation measures. Meanwhile, cropping absorbs a lot of carbon dioxide and this role should be fostered by developing more effective crop varieties. Technical challenges are important, but creating an enabling economic framework is the key goal to improve mitigation efforts in all sectors, but especially in agriculture since it is the one that is struggling to maintain profitability within the sharp blades of global competition.

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