EIP-AGRI Focus Group Agroforestry

MINIPAPER: Agroforestry as a mitigation and adaptation tool
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Mitigation and Adaptation

1 Introduction

Expected increasing temperatures, variations in rainfall distribution, extreme events, intense droughts are usually known as Climate change. These unexpected events and variations on climatic factors affect agricultural systems through the temperature variations, water availability and quality, pest and disease, fire risk, storm damage, while agriculture impacts climate through the emissions of GHGs. Moreover, climate change will negatively impact all four food security dimensions such as to food availability (i.e. expected production drops), food access (i.e. expected infrastructure damages), food supply stability (i.e. expected price fluctuations) and food utilization (i.e. reduced by pest and animal diseases) increasing agricultural systems vulnerability (FAO 2008). Climate change is linked to previous and current greenhouse gases (GHG) emissions with different global warming potential namely, carbon dioxide, methane and nitrous oxide. Agriculture represents the 11,3% of the global emissions. Nitrous oxide and methane has 265-298 and 28-36 times more global warming potential than carbon dioxide over a period of 100 years, respectively. Agriculture strategy to overcome climate change is currently and mainly related to mitigation and adaptation options. Mitigation is defined as a human intervention to reduce the sources or enhance the sinks of GHG, while adaptation is understood as the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC 2001). Agroforestry -understood as the integration of woody vegetation and lower story agricultural production- and their different practices (silvopasture, silvoarable, riparian buffer strips, homegardens and forest farming) are currently recognized as sustainable land use measures to overcome climate change (Buttould 2013 Mosquera-Losada et al. 2016)..

Figure 1. Agroforestry in forestland with high value timber production (selected cherry trees with sheep production) and in agricultural land with walnut and maize.

Mitigation and adaptation options of agroforestry can be implemented at agricultural (silvopasture, silvoarable, hedgerows and riparian buffer strips) forestry (forest farming, silvopasture and forest farming) and periurban and urban (homegardens) land cover, but also at farm level affecting landscape (through the adequate distribution of forest and agricultural lands within (Figure 1) and between farms or the hedgerows and riparian buffer strips) mitigation and adaptation potential (Figure 2). The main aim of this paper is to understand how agroforestry practices can contribute to mitigate and adapt agricultural and forest systems to climate change

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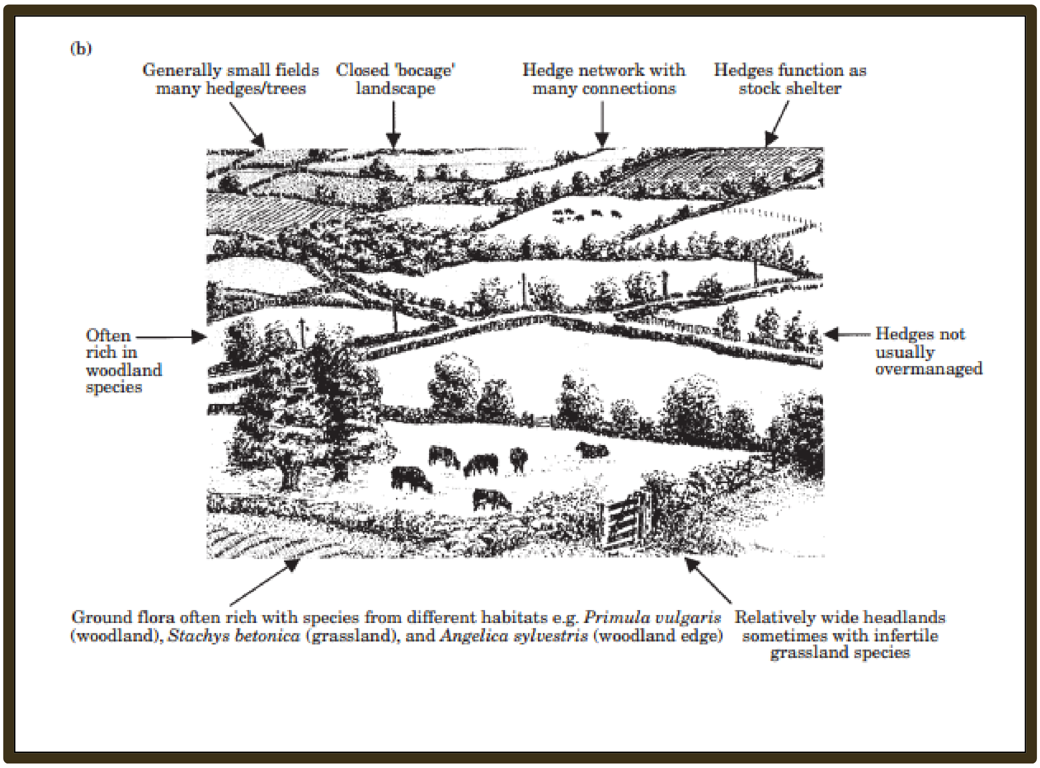

Figure 2. Examples of model hedgerow landscapes in Britain (a) An open landscape in East Anglia, England(b) a bocage landscape in the West Country (Source J. Baudry, R.G.H, Bunce and F. Burel)

2 Agroforestry as a mitigation tool

Agroforestry can act as a tool to reduce GHG sources thanks to the optimization of the use of the resources it causes, **avoiding or reducing GHG losses** and **promoting soil carbon sink** in agricultural lands. Nitrous oxide comes from two main sources, livestock manure and chemical fertilizers that are linked to agricultural production enhancement. Besides better management options when fertilizers are applied or animals are managed, woody perennials can act both limiting GHG sources and promoting carbon sink. Roots of woody perennials placed in deeper soil layers than herbaceous vegetation are able to act as a natural filter preventing from nitrogen compounds losses (i.e. nitrous oxide to the atmosphere and nitrate to the water bodies). Improving nitrogen and nutrient use by agricultural systems will increase biomass production per unit of land and therefore aerial and soil carbon stocks or provides potential for using this biomass as renewable energy resource therefore avoiding GHG emissions by the system itself or by avoiding use of non-renewable energy resources, respectively. For example, the combination of chesnut trees for fruit production with sheep grazing, avoids the use of fertilizers in the north of Portugal (Figure 3) in a farm of 400 hectares and 150 livestock units and at the same time improves animal welfare and reduce fodder needs as no profitable chestnut fruit is used as a feed. The pruned branches are also used as renewable energy for the farm heating and as part of compost, therefore producing materials that increases soil carbon and reduces fertilizer needs. Adequate selection of shrubs, such as legumes, when establishing an agroforestry practice in a livestock system can also help to mitigate climate change as less feed should be bought and therefore avoiding greenhouse gases emissions linked to external feed transport.

Figure 3. Overview of the most ancient European chestnut system producing chestnuts and livestock products in a continuous way (Braganza, North Portugal).

The presence of woody vegetation in agricultural lands facilitate temperature stability, reducing impact of extreme heat and the potential of ammonia and nitrous oxide volatilization and therefore GHG emissions. Moreover, the adequate distribution of trees or shrubs may reduce wind speed and therefore GHG emissions rates as well as nutrient recycling (Figure 4) from agricultural lands and even improve productivity as water retention and quality is ameliorated. The use of woody vegetation (tree lines or hedgerows) is key to perform better from a productive point of view in European countries such as Bulgaria or Check Republic (Takás and Frank, 2009; Kachova et al. 2016) with increases in wheat production that can be over 20% compared with tree-less systems

Agroforestry improves nutrient use and water quality. Hedgerows as well as Riparian buffer strips, shelterbelts, hedges tree in lines, etc.. were and are usually employed in Eastern European countries (Bulgaria, Czech Republic (Takás and Frank, 2009; Kachova et al. 2016)) to reduce the negative impact of winds on biomass production of arable lands, which are also useful to reduce GHG emissions (trees reduces temperature) and mitigate climate change from both the crop and the trees placed in strategic parts of the plot. These linear features are also used in western European countries to improve water quality (by up taking roots by woody vegetation) improve nutrient recycling and retain soils, delivering better and more ecosystem services (Mosquera-Losada et al. 2016).

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Figure 4. Nutrient uptake by trees in arable lands (left) allows better growth and extend the tree growing season (trees with leaves) compared with trees in forestlands (right).

The tremendous potential of agroforestry practices as a mitigation tool is based on the capacity of these systems to storage carbon in deeper soil layers than tree-less areas. Soils represent over the 80% of the carbon stored in terrestrial ecosystems, but in agricultural soils, only 25 (up to 50) cm is explored by roots preventing C store in deeper soil layers. Carbon soil sources are based on organic matter decomposition coming from animal and mainly from vegetation residues (roots, branches, dead material). Therefore, as biomass production per unit of land is increased, the amount of residues is raised and the amount of organic matter inputs in soil and therefore carbon in soil improved. Biomass per unit of land is increased when woody vegetation is mixed with herbaceous vegetation, as the amount of leaves (photosinthetically active infrastructures) is higher per unit of land due to the vertical exploration of the system (high volume of land) by leaves, which are the main organ able to fix atmospheric carbon dioxide. The presence of a tree or woody perennials with deeper roots than herbaceous increases the volume of soil explored by roots, so the potential belowground volume to storage carbon. Research carried out in the dehesa (Spain) have shown that the amount of carbon stored below the tree (50 tons per hectare) is double than 15 meters away fom the tree (25 tons per hectare) as shown Figure 5. Residues composition of trees are different than from herbaceous vegetation, being more difficult to decompose, meaning that C will be stored for a longer period of time above the soil. In a experiment comparing the capacity of broadleaves (birch) and conifers (pinus) to improve soil C storage it was found that the former is able to store C in finest soil particles, which in turn storage carbon for hundreds of years (Howlett et al. 2011b), therefore broadleaves seem to be a better option when establishing the woody component of an agroforestry practice or system than conifers from a mitigation point of view.

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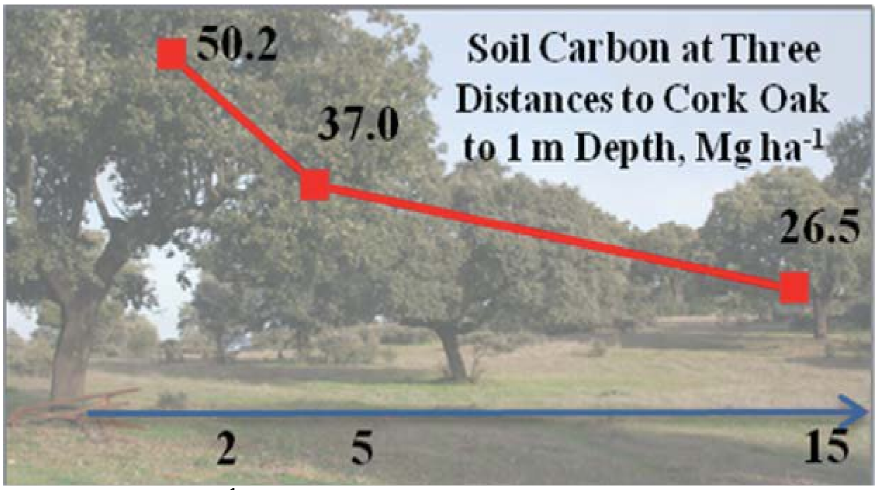

Figure 5. Soil carbon storage (Mg ha^{-1}) at three different distances (2, 5 and 15 m) from the tree (Howlett et al. 2011) to 1 m depth.

Forest lands are usually associated with high carbon storage in both aerial and soil layers compared with tree-less or arable systems. Main reasons already provided for agricultural lands can be also used for explaining how forest lands store higher amount of carbon than tree less systems, besides the scarce use of fertilizers in forestry. However, preventing forest GHG emissions is essential to mitigate climate change in some regions, where due to weather and climatic conditions exists important risk of fires. In forest lands, silvopasture practices (including woodland and forest grazing) reduces aerial biomass loads placed in the understory, main fuel to be fired in areas where fire risk is high. If adequately managed grazing increases biodiversity and therefore optimize the use of the resources allowing trees growing up better as urine from animals add nitrogen to the soil and competition with weeds is reduced (Figure 6).

Figure 6. Exclusion cage showing the situation of no grazing compared with the area where animals (goats and ships) were grazing. Fire risk is notably reduced if silvopasture is implemented in forest lands.

Other types of agroforestry practices (i.e. forest farming) aiming at promoting understory production (i.e. medicinal plants, mushrooms) helps to reduce this forest fuel loads, while increasing multiple production for forestlands and jobs in rural areas. Moreover, silvoarable practices were used in some areas of Europe in young tree plantations to reduce the tree-understory competition, forcing deeper root penetration which on turns ensures tree presence and the associated carbon linked to the presence of the woody vegetation (above and below the soil). The initial combination of crops and young trees in afforestation and reforestation increases plantation resilience to floodings and strong winds as the trees are better anchored. Moreover, when a legume is sown as part of the understory, the tree development is increased and the initial mortality rate of the plantations is reduced.

Preventing fires in forestlands contributes to mitigate climate change as GHG emissions are avoided, which is especially important for the commitments of the Kyoto protocol, Paris agreement and successive commitments(fired areas are always linked to the deforested section of the Kyoto protocol gases accounting). Agroforestry practices (silvopasture) have demonstrated to be cheaper than mechanical clearance to prevent forest fires, while improving biodiversity (RAPCA 2017, Etienne 1996). Moreover, the effect on reducing understory fuel loads is larger in time than mechanical clearance.

3 Agroforestry as an adaptation tool

Adaptation can be classified as **spontaneous** (the system is adapted without conscious intervention), **proactive** and **planned adaptation** (FAO 2008). Adaptation aims at increasing adaptive capacity understood as the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.
Agroforestry practices can be related with all adaptation types. Better **Spontaneous adaptation** is usually associated to higher biodiversity, which increases resilience. Moreover, having woody vegetation ecological trait is essential to have more resilient systems that also benefits from having legumes, shrubs and trees in strips, as it is highlighted in France. Already known traditional agroforestry systems, like montado or dehesas are more resilient to climate change than intensive monocrop arable systems. Trees are able to increase the grazing period as herbaceous vegetation is able to grow up below the tree but not far away from the tree (Figure 7). But the use of leaves and small branches in those especially dry years act as a fodder bank to feed animals preventing from using external resources usually associated to high energy costs and GHG emissions, therefore adapting the systems to climate variability.

Figure 7. High quality herbaceous vegetation can be associated to those areas below the trees as water balance is better than in tree-less areas.

Based on the learnt lessons from traditional systems **proactive adaptation** should be used in current open areas to prevent the impact of extreme heat or flooding events on arable systems. As mentioned tree reduces wind speed but also acts as a buffer for extreme heats or frosts allowing crop vegetation to survive to these undesirable events, which are unfortunately increasing frequently in the last years. Forest lands are usually highly dense, to obtain a higher volume per hectare, and therefore reducing the profitability per cubic meter

of the timber. Thinning as well as pruning are needed to improve timber quality, that at the same time improves the conditions to better understory production. High dense stands are usually with high height/diameter rate, which makes them more prone to be fall down when strong winds appear. The combination of trees with crops, makes the trees more healthy as fertilization is applied to the crop, therefore making trees more resilient against pests and diseases caused by high temperatures. Moreover, the continuous ploughing of soils to develop annual crops makes tree roots to be deeper, and therefore trees better anchored and resistant to strong winds (Figure 7).
Agroforestry can also explore the use of land during shortage periods such as winter and summer Cropping can be carried out during the autumn/winter time if temperature are high enough to avoid frosts and Morus alba (reaching a protein content on its leaves of around 24%) allows grassland to be developed in t he winter and high quality fodder in the summer (Figure 8)

Figure 8 Cropping vegetables during the winter time (left) and growing Morus alba in winter and summer time (right)

Wheat cultivation under 50 to 100 walnut trees has been found important in France to avoid periods with temperatures above 25ºC that reduces wheat productivity in France. Variety selection could also be an option to have high wheat production developed under shade (Dupraz 2016). Agroforestry improves soil macro and micropores, enhancing water infiltration and avoiding runoff and erosion.

Planned adaptation understood as the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to , maintain, or achieve a desired state (IPCC 2007) can be seen nowadays in the CAP and in different European Countries (Mosquera-Losada et al. 2016). The most important examples where agroforestry are involved are those related with the conditionality (maintenance of landscape features), greening (allowing agroforestry as part o Ecological focus areas), change of permanent grassland definition (including woody vegetation) and different Rural development programmes, like those linked to agri-environment schemes and those associated with the establishment of agroforestry practices and those linked to grazing in forest areas. However, a specific measure recognizing all types of agroforestry practices should be included in future CAP.

4 Conclusions

Agroforestry is an excellent tool to mitigate climate change in both reducing sources and increasing sinks but also to adapt to climate change as increases plot and farm resilience while reduce vulnerability to climate change in both agricultural and forestry lands.

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