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Potential CO_2 emissions mitigation through forest prescribed burning: A case study in Patagonia, Argentina

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ABSTRACT

Wildland fire is a natural force that has shaped most vegetation types of the world. However, its inappropriate management during the last century has led to more frequent and catastrophic fires. Wildland fires are also recognized as one of the sources of CO_2 and other greenhouse gases (GHG) that influence global climate change. As one of the techniques used to reduce the risk of destructive wildfires, prescribed burning has the potential of mitigating carbon emissions, and effectively contributes to the efforts proposed as part of the Clean Development Mechanism within the Kyoto protocol. In order to apply this concept to a real case, a simulation study was conducted in pine afforestation in the Andean region of Patagonia, Argentina, with the objective of evaluating the potential of prescribed burning for reducing GHG emissions. The scenario was established for a ten year period, in which simulated prescribed burning was compared to the traditional management scheme, which included the probability of annual average of wildfire occurrence based on available wildfire statistics. The two contrasting scenarios were: (1) managed afforestation, affected by the annual average rate of wildfires occurred in the same type of afforestation in the region, without prescribed burning, and (2) same as (1) but with the application of simulated prescribed burning. In order to estimate carbon stocks, and CO_2 removals and emissions, we followed the guidelines given for GHG inventories on the Agriculture, Forestry and Other Land Uses (AFOLU) sector of the International Panel on Climate Change (IPCC), while the terminology used was the established by IPCC (2003). Data of afforested area, thinnings, and biomass growth were taken from previous surveys in the study area. Downed dead wood and litter (forest fuel load, FFL) was estimated adjusting equations fitted to those fuels, based on field data. Results show that comparing the two scenarios, prescribed burning reduced CO_2 emissions by 44% compared to the situation without prescribed burning. The prescribed burning scenario represented about 12% of the total emissions (prescribed burning plus wildfires). Furthermore, avoided wildfires by simulated prescribed burning allowed an additional 78% GHG emissions mitigation due to extra biomass growth. Simulated prescribed burning in commercial afforestation of Patagonia appears to be an effective management practice not only to prevent wildfires, but also an efficient tool to mitigate GHG emissions. However, more studies in different scenarios would be needed to generalize these benefits to other ecosystems.

1. Introduction

1.1. Wildfire and climate change

Fire is a natural force that has shaped most vegetation types of the world, helping to maintain the function of ecological processes in many ecosystems (Komarek, 1965; FAO, 2006a). Historically, humans have learned to use fire, and its management as an agricultural tool is deeply rooted in culture, society and traditions of many countries (FAO, 2001). In agriculture, fire has been used to prepare lands for crops or grazing, and to open impenetrable lands for new agricultural uses (FAO, 2001). More recently, fire has also been recognized as an important tool, not only for achieving land management goals (such as prescribed fire), but also for fire-fighting activities (suppression fire, Narayan et al., 2007). This evidence, however, does not obscure the fact that unwanted or unmanaged wildfires annually consume millions of hectares of forests throughout the world, affecting biodiversity, and threatening property as

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well as human lives and wildlife. Besides the economic impact caused by the destruction of forest resources and other environmental, recreational and amenity values, wildfires contribute to global emissions, and are increasingly costly in terms of firefighting and suppression activities (FAO, 2005; Bowman et al., 2009).

The fire exclusion and suppression policy implemented in several countries about a century ago has failed in achieving the overall goal of reducing wildfire risks and impacts (Wuerthner, 2006). In fact, changes in land use and the effectiveness achieved in suppressing wildfires immediately after ignition has produced a general increase in biomass buildup in many ecosystems (Kitzberger and Veblen, 1999; Morgan et al., 2003). This unprecedented fuel accumulation has led to catastrophic events if a fire (either started by humans or by lightning) occurred under a set of extreme environmental conditions such as very high winds, hot and dry air masses, presence of a cold front, etc. (Brown et al., 1994; Dentoni et al., 2001; Defossé and Urretavizcaya, 2003; Fernandes and Botelho, 2003; Graham, 2003; Graham et al., 2004, 2009; Omi and Martinson, 2004; Vaillant et al., 2009).

One of the most important consequences of forest wildfires is their contribution to CO_2 concentration in the atmosphere through the alteration of the spatial and temporal dynamics of carbon storage between the atmosphere and the biosphere (Narayan et al., 2007; Balshi et al., 2009). The amount of biomass burning has significantly increased during the last decades, and is recognized as a significant source of atmospheric emissions at a global scale (UNEP, 1999). The global value of emissions for Agriculture, Forestry and Other Land Uses (AFOLU) reported for year 2000 was 7.6 Gt CO_2 e, 10% higher than the estimates for 1990 (WRI, 2005). Biomass burning increases greenhouse gas emissions (GHG's), such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). In the global context, these emissions should be added to those already produced by fossil fuels and their derivates (UNEP, 1999).

Forest biomass burning has been pointed out as the main source of atmosphere contamination in South America (Mielnicki et al., 2005). About 27% of CO_2 emissions are due to land use changes (basically by deforestation activities) which have occurred in this subcontinent (WRI, 2005). In Argentina, the National Inventory of GHG's (INVGEI), published in 2000, showed a level of emissions of 238,700 Gg of carbon dioxide equivalent (CO_2 e), of which 12,480 Gg of CO_2 e corresponded to biomass burning from forests, grasslands and shrublands (Fundación Bariloche, 2007). The AFOLU sector showed net removals of 43,280 Gg of CO_2 e. Wildland fire emissions accounted for about 30% of the gross removals of that sector (Fundación Bariloche, 2007). In correspondence with these numbers, from 2003 to 2007 an annual average of 1.5 million ha was affected by wildfires in Argentina, including 23 thousand ha in the Patagonian Andean region. About 2–3% of the vegetation affected by wildfires in Patagonia corresponded to conifer plantations (SAyDS, 2009). As is occurring in many countries around the world, in Argentina, and especially in the Andean Patagonian region, more people are moving to establish their dwells in forest wildland urban interfaces (WUI). This fact also increases the risk of fire occurrence in those areas (FAO, 2006b).

1.2. Afforestation projects in Patagonia and the CDM of Kyoto protocol

The Argentinean Patagonian region has approximately 2 million ha of potential land for afforestation (Ferrer et al., 1990; Irisarri and Mendía, 1991; Irisarri et al., 1995; Loguercio et al., 2004). Environmental and economic constraints, however, may reduce this figure to about 800,000 ha (Loguercio and Dececchis, 2006a,b). In spite of these constraints, and if compared to other areas of the world, Andean Patagonia presents good competitive and comparative advantages to develop afforestation within the Clean Development Mechanism (CDM) of the Kyoto protocol (Loguercio et al., 2004). These advantages can be summarized by mentioning that this region comprises vast overgrazed rangelands with low above ground biomass vegetation, and rich subsoil of volcanic ashes to which roots of native vegetation generally do not reach (Colmet Daage et al., 1995). Pine afforestation in these zones of Patagonia have shown good growth rates, and the low amount of carbon found in native vegetation (the base line) enhances their potential for carbon sequestration within CDM (Loguercio et al., 2004).

By 2005, conifer afforestation in the Patagonian provinces Neuquén, Rio Negro and Chubut, covered 76,000 ha. These afforestation were planted with the objective of diversifying production, and, at the same time, satisfying the demands of an incipient forest industry (Loguercio et al., 2004, 2005; Gonda, 2005). The main species used is ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.), which comprises about 75% of all plantations (Gonda, 2005; Loguercio et al., 2005). The afforestation productivity and growth rates are greater than the sites of origin in northwestern United States (Urzúa, 1991; Gonda and Lomagno, 1995; Gonda, 1998).

In the development of any economic activity, it is necessary to minimize risks in order to preserve the productive assets from unwanted events. Related to conifer afforestation in Patagonia, wildfires constitute a high risk. In this region, human set fires are recognized as the primary source of ignition, accounting for about 80% of all wildfires affecting afforestation. About 9% are produced by lightning while the rest are due to unknown causes (Servicio Provincial de Lucha contra Incendios Forestales, Río Negro Province; Servicio Provincial de Manejo del Fuego, Chubut Province, and General Direction Forests of Neuquen province, unpublished data). Fire suppression capacity is constituted by a national firefighters brigade based in Río Negro Province, and several brigades belonging to provincial services. Afforestation owners are starting to create first attack private consortiums with the economic support of the national government. As a result of these facts, however, fire protection of these plantations at present only imply firefighting activities, and fuel management (i.e. prescribed burning) is rare or uncommon (Kunst et al., 2002). It is probable that the fire exclusion policy, strongly advocated and supported for many years by National Parks Administration, and later adopted by the Provincial forest resources management agencies, has influenced afforestation management practices carried out by many producers. Another detail that may explain this factor is the lack of interest, or reluctance, of some forest producers to use prescribed fires as a management tool, because the afforestation stands are still young (about 20–25 years) and the need for fuel management is not yet appreciated. It should be remembered, though, that ponderosa pine is a fire prone species (Wright and Bailey, 1982), and sooner or later it would need prescribed burnings to develop viable plantations and reduce the risk of unwanted wildfires (Weaver, 1957).

1.3. Prescribed fire to reduce wildfire emissions

The effectiveness of prescribed burning to reduce wildfire intensity and severity has been well established in international literature (Weaver, 1957; Fernandes and Botelho, 2003, 2004; Finney, 2001, 2003, 2007; Ager et al., 2006; Finney et al., 2005, 2007; Vaillant et al., 2009). There is also much information on the usefulness of this practice, either alone or combined with other silvicultural treatments, to reduce fuel buildup and continuity (Graham, 2003; Graham et al., 2004, 2009; Hurteau and North, 2009; Omi and Martinson, 2004; Pollet and Omi, 2002). However, literature as well as data and information about the effectiveness of prescribed burning in reducing GHG's emissions as compared to the emissions produced by wildfires, is rather scarce (Fernandes, 2005; Narayan et al., 2007; Wiedinmyer and Hurteau, 2010).