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Food production and climate protection—What abandoned lands can do to preserve natural forests

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ABSTRACT

Approaches to reconciling food production with climatic and environmental protection often require agricultural intensification. The production of more food per unit of agricultural land through “sustainable intensification” is intended to enable the protection of natural ecosystems elsewhere (land sparing). However, there are problems associated with agricultural intensification; such as soil erosion, eutrophication or pollution of water bodies with chemicals, landscape homogenization and loss of biodiversity; for which solutions have not yet been found. Reuse of abandoned agricultural lands – which are abundant throughout the world – to address the rising demand for food is a potentially important alternative, which up to now has been widely ignored. To test the power of this alternative, equilibrium economic land allocation to various land-use practices by risk-avoiding tropical farmers in Ecuador was simulated. The reestablishment of pastures on abandoned cattle lands lowered prices for pasture products, and also triggered conversion of existing pasture into cropland. The resulting land-use change increased total annual food production in a moderate scenario from the current level of 17.8–23.1 petacalories (10^{15} calories), which amounted to a production increase of 30%. At the same time, there was a 19% reduction in the amount of payments to farmers required to preserve tropical forests – one of the world’s greatest terrestrial carbon stores.

1. Introduction

Food security has long been a part of the international political agenda (Harrar, 1955; Pawley, 1974; Walters, 1975; Brown, 1981; Parry et al., 1999). More recent discussions (e.g. Foley et al., 2011), however, demonstrate a new trend. As pointed out by Daily et al. (1998), the negative impacts of food production systems on the world’s environmental systems must be reduced. However, food production systems require high productivity to satisfy the demand for food, which is predicted to rise by 50–70% by the year 2050 (Tilman et al., 2011). In addition, food production must now compete for scarce land resources with first generation fuel production systems (Searchinger et al., 2008; Wise et al., 2009).

An extrapolation of past land-use patterns by Tilman et al. (2011) predicted that richer countries will continue to intensify agricultural production on a decreasing land area, while poorer countries will continue to clear new land for agricultural use, resulting in CO_{2eq} emissions on the order of 3 petagrams (Pg) per annum. However, because of the adverse consequences of agricultural land expansion on the environment, clearing additional land is no longer an acceptable practice (Godfray et al., 2011). Consequently, Godfray et al. (2010) concluded that in future, more food must be produced on the same, or even less land, which appears feasible only through agricultural intensification.

In agreement with Godfray et al’s conclusion, many researchers favour the agricultural intensification option (for example, Wise et al., 2009; Koh et al., 2009; Burney et al., 2010; Godfray et al., 2011; Tilman et al., 2011; Foley et al., 2011; Phalan et al., 2011a,b; Knoke et al., 2012) over agricultural extensification (i.e. expanding the agricultural area). However, some doubts about the effectiveness of agricultural intensification have been raised (e.g., McIntyre et al., 2009, p. 21). For example, Phelps et al. (2013) concluded that increasing productivity and profitability through intensification might even promote further agricultural land expansion – including that accomplished through deforestation – and finally, escalate the costs for conservation. Thus, it is widely understood

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that the negative environmental impacts of agricultural intensification must be kept to a minimum through additional regulations designed to prevent further land clearing in response to increased economic incentives. "Sustainable intensification" (Godfray et al., 2010) now appears to be the preferred formula to reconcile the world's future food production needs with environmental protection. Interestingly, Matson et al. (1997) pointed out that intensification has long been a major subject of agricultural research and development, in an effort to reconcile increased food production with protection of the environment. In general, these strategies have been referred to as "sustainable development".

In fact, past experience shows that conventional agricultural intensification may have severe negative impacts on the environment (e.g. Fischer et al., 2011). Conventional agricultural intensification is characterized by increased use of chemicals and pesticides, enlargement and alteration of agricultural parcels through the removal of important landscape elements such as hedgerows or small forest patches, severe soil disturbance (compaction), and the loss of crop diversity (Harms et al., 1987); in addition to having possible disadvantages for plant health (Matson et al., 1997). The European example of conventional agricultural intensification has been associated with a collapse of entire bird populations (Donald et al., 2001). Increased soil erosion and lower soil fertility have been mentioned as negative local consequences of agricultural intensification, pollution of ground water and eutrophication of rivers and lakes as negative regional consequences, and the pollution of the atmosphere as a negative global consequence (Matson et al., 1997). To save "sustainable intensification" from the fate of previous efforts which have been found to be largely ineffective, such as biodiversity conservation (CBD, 2010); more detailed concepts as well as some alternatives are essential.

Based on the assumption that big environmental problems may actually be solved by adequate land-use techniques, many recent studies on new land-use approaches limit their perspectives largely to agricultural intensification, although its effectiveness is critically discussed (Phelps et al., 2013). These approaches still disregard the option of expanding agriculture (extensification) by re-using previously abandoned – often as a consequence of degradation – and unused lands, which are abundant throughout the world (Field et al., 2007). The recultivation of these previously cleared, but presently unused lands provides an important alternative to clearing forest for agriculture (DeFries and Rosenzweig, 2010), thus relieving some of the obvious problems which result from the growing scarcity of land. Although some authors mention concerns about bringing degraded lands back into production, because of the potential loss of biodiversity inherent in degraded lands (Phalan et al., 2011b), exploring the food and economic potential of recultivation alternatives for abandoned lands still seems justified.

Given this background, our aim was to test the option of recultivation of previously abandoned grazing lands by means of a model driven by economic considerations. We are convinced that obtaining an economic perspective is important, because people's response to economic opportunities is often a central driver for land-use change (Lambin et al., 2001). Using modelled land-use scenarios, we thus investigated the following hypothesis:

"Simulating an increase in the production of food by the recultivation of previously abandoned lands leads to more efficient land allocation and to decreasing food prices, thus reducing the costs of preventing conversion of natural forests to agricultural lands."

2. Material and methods

2.1. Study area

We selected the country of Ecuador as our study area. Though rather small (~25 million hectares), Ecuador has a land-use/land-cover distribution typical for tropical countries. Its area comprises approximately 19% protected and 21% unprotected tropical forests, 1% forest plantations, 10% croplands, 13% pasture, 13% rarely used or abandoned pastures – often covered by bracken fern and/or shrubs (Roos et al., 2011) – and 23% "other areas" (Table 1).

Table 1
Considered land-use options/land covers.

Land-use type/land cover	Actual area (%)	Comment	Source[a]
Tropical forest			
Protected	19		Herrera et al. (2007)
Managed		Low impact management introduced as a future option, hardly applied in the current situation	Knoke et al. (2009a,b)
Unmanaged	21		
Forest plantation	1	Assumed as fast-growing native *Alnus acuminata*. Calculations on economic performance based on long-term experiments carried out in the frame of a multi-partner project in Andean ecosystems in the South of Ecuador.	Weber et al. (2008), Knoke et al. (2009a,b)
Cropland	10	Represented by corn fields – note that actually ~50% are perennial crops. The crop weight was converted into dietary energy by 2.89 kcal g^{-1}. Cropland area expansion was limited to 142% of its actual area.	Erb et al. (2009)
Pasture	13	Products were converted into dietary energy by 0.95 kcal g^{-1} considering 50% dairy and 50% meat production.	
Abandoned cattle lands	13	37% of total pasture area recorded by FAO (2012) plus shrublands.	Southgate et al. (1993)
Recultivation to pasture		Backed by special experiments carried out in the frame of a multi-partner project in Ecuador. 32,400 grass plantlets of common pasture grass *Setaria sphacelata* used per hectare.	Beck et al. (2008), Roos et al. (2011)
Reforestation		With *Alnus acuminata*. Calculations on economic performance based on long-term experiments carried out in the frame of a multi-partner project in Ecuador in Andean ecosystems in the South of Ecuador. 1111 trees used per hectare.	Weber et al. (2008), Knoke et al. (2009a,b)
Other area	23	Páramo (tropical montane vegetation above the timberline), wetlands, shrimp production, eroded areas, mangroves, water, urban areas, snow/rock areas and banks, as well as barren land not suitable for either reforestation or recultivation.	

[a] If not stated otherwise, source is FAO (2012); for economic coefficients see Knoke et al. (2011) and/or main text.