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Air quality loss in urban centers of the Argentinean Dry Chaco: Wind and dust control as two scientifically neglected ecosystem services

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ABSTRACT

The Dry Chaco is one of the most active agriculture frontiers, which imposes trade-offs and synergies among ecosystem services (ES). Most studies analyze real or potential supply of ES associated to land use change; but they usually neglect ES social demands. Interviews to inhabitants of small urban centers in the Argentinean Dry Chaco revealed that wind speed control and dust control are high valued ES in towns within agricultural contexts. The absence of such perception in forest context towns, and the presence of vegetation covering soil during the windy and dry season support such demand. Loss of air quality –as an agricultural disservice- is a socially perceived ES so far ignored in the environmental research agenda, which should be reversed.

1. Introduction

Changing human activities drive changes in ecosystems. In turn, human well-being can be altered. According to the Millenium Ecosystem Assessment (MEA, 2005), 15 of 24 ecosystem services (ES) are being degraded or used in unsustainable ways, and only four are increasing their provision, including livestock and crop production. Increasing agriculture production reflects the global effort to maximize food production for growing global food demands (Hancock, 2010). As a result, approximately 40% of the terrestrial area is currently converted into croplands and pasturelands (FAO, 2009).

Forests can improve air quality by extracting chemicals and particles from the atmosphere and by reducing their emissions (MEA, 2005; Terzaghi et al., 2013). Agriculture expansion-driven deforestation increases soil exposure, which may enhance particle emissions to the atmosphere, especially in arid and semiarid climates (Buschiazzo and Aimar, 2003). Extreme examples of wind erosion are the "the Dust Bowl", one of the most severe environmental catastrophes, which occurred in the 1930s in the American Great Plains of US (e.g. McLeman et al., 2014) or the more recent dust storms in China since 1970 (e.g. Zhuang et al., 2001; Wang et al., 2010).

Air quality strongly affects human health, particularly in developing countries. Typical health problems related to air quality include asthma, allergies and a variety of respiratory problems (MEA, 2005; WHO, 2013). Researchers have documented the effect of particulate matter (PM) on human health. WHO (2006) suggests for PM, annual threshold values have to be lower than 10 $\mu g/m^3$ for $PM_{2.5}$ (2.5 μm size) and 20 $\mu g/m^3$ for PM_{10} (10 μm size), for be considered air as healthy. Additionally, these particles are composed by a variety of chemical components from different sources, and with different behaviors and impacts (Pio et al., 2007).

To understand changes in air quality due to agricultural practices, it is important to study both dust sources (i.e. soil erosion) and the "receiving conditions" of the human environment. However, studies tend to focus separately on wind erosion in agricultural fields (e.g. Graves et al., 2011; Kagabo et al., 2013; Kurothe et al., 2014); and on air quality in urban ecosystems (Gomez-Baggethun et al., 2013; Haase et al., 2014), and typically center on urban-originated pollutants from industries and transportation (Maas et al., 2006; Smith et al., 2013). Dust exposure and its effects on health has been studied in rural settings (Schenker, 2000; Norton and Gunter, 1999) but received comparatively less attention in relation to urban settings. In small towns surrounded by agriculture expansion, however, this process is unlikely to be negligible.

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Linkages between land-use changes and ES are a typical target of socioecological studies. To understand these links, in addition to studying ES provision and disservices[1], information concerning perceptions and demand of ES is needed (Mastrangelo et al., 2015). Here, we focused on these perceptions in the Argentinean Dry Chaco, one of the most active agriculture frontiers in semiarid ecosystems (Hansen et al., 2013). In the Chaco, ES studies have been limited to quantifications of carbon emissions assessments (Gasparri et al., 2008), biodiversity conservation (Torres et al., 2014), and soil conservation (Busnelli et al., 2006), without taking into account social perception and demand. In a systematic search of peer-reviewed publications related with human health and agriculture using Scopus database (June 2016), we only found 356 studies when we searched for *agriculture* + *human health* + *dust*. When limiting the same search to the Chaco region only, we did not find studies. In this work, we report the first results about social perceptions of ES provision in urban centers of the Argentinean Dry Chaco.

2. Methods

2.1. Study area

The Great Chaco extends over Bolivia, Paraguay, and Argentina, with 6.5 million km^2 in Argentina. Currently, the Dry Chaco is one of the most dynamic deforestation frontiers in South America (Hansen et al., 2013; Graesser et al., 2015). Between 1972 and 2011, the deforested area in the northern Argentinean Dry Chaco increased from 3000 km^2 to 30,000 km^2 (Gasparri et al., 2013) mainly for soybean crops and cattle ranching. Our study area (Fig. 1) spans over eastern Salta province (including Orán, Anta and Rivadavia departments), the main core of agricultural expansion in Argentina in the last two decades (Aide et al., 2013; Grau et al., 2005). National and provincial laws ("Forest Law" 26 331, and Provincial Law 7543) specify the obligatory establishment of windbreaks in agriculture fields to avoid hydrologic and wind erosion. However, the regulation of forest windbreaks exhibits low levels of compliance by producers (Guinzburg et al., 2012) and it is not enough to prevent wind action over soils (Leon, pers. comm.).

2.2. Data

2.2.1. Urban surroundings

We classified towns into "forest" or "agricultural" contexts, based on the proportion of cultivated land area (CLA) in 2000, within a 50 km radius buffer. We used deforestation maps previously developed by visual interpretation of Landsat images, and with an overall precision above 90% (Grau et al., 2005). Deforestation maps were performed according to the national forest monitoring system (e.g., Gasparri and Grau, 2009; Gasparri et al., 2013). With cluster and decision tree analyses, we explored the towns relationships based on cultivated land area, and we operationally defined the urban surroundings.

2.3. Social perception

In order to explore social perceptions about current deforestation and its impact on air quality, we conducted 160 face-to-face semi-structured interviews with open-ended questions to local people in seven towns (>2000 inhabitants, INDEC, 2001) (Fig. 1). Each town (mean size: 6500 inhabitants) was visited during 3–5 days between March and July 2014. Sampled population was older than 20 years old and randomly selected to cover a wide range of backgrounds and socio-economic conditions. The interviews (which are part of a wider project) included: (a) land-use change perceptions; (b) associations between land-use change and socio-economic conditions; (c) perceptions about ES and its links with well-being; and (d) impacts of land-use change on ES. We used non-technical language, for an easy interpretation by the respondents. We did not force respondents to give answers about ES nor about relations between ES and human health if they did not identify any (Sherren and Verstraten, 2013; Quintas-Soriano et al., 2016).

For this particular study, we analyzed questions of (c) and (d) related to regulatory ES (MEA, 2005) and their link with air quality and human health. We excluded provisioning, cultural and supporting ES from the analyses. We analyzed the frequency of mention as an important variable (which considers only one mention in each interview) for each regulatory ES. We then used Kruskall-Wallis tests to analyze differences between forest and agricultural contexts. With a qualitative analysis of the narratives of the respondents (through codification and code occurrence), we identified ES and human health linkages.

[1] Disservices are defined as those negative consequences on human well-being derived from ecosystems (Agbenyega et al., 2008; Lyytimäki and Sipilä, 2009).

2.4. Biophysical data

Social perception about air quality was contrasted with proxies of potential exposure (or protection) to windblown dust. The combination of dry periods throughout the year, high wind speed and bare soil promotes erosion, and hence dust presence in the air. For an idea of monthly patterns, we used weather data and NDVI values to infer land cover during the year. Weather data was obtained from two meteorological stations: Piquete Cavado and Laguna Yema, with data available from 2009 to 2015 and 2006 to 2014 respectively. Piquete Cavado weather station belongs to the National Institute of Agricultural Technology (INTA) and is located in the main area of soybean crops (agricultural context). Laguna Yema station belongs to the Center of Validation of Agricultural Technology (CEDEVA) and it is located in a forest context, in Formosa province, 100 km from Salta province. These two climatic stations present wind data, which is not very common in the region. Weather data was used to infer the period when both dryness and high wind speed match in the study area along the seasons. We used mean monthly maximum wind speed (averaged maximum monthly wind speed between 2009 and 2015); and mean monthly accumulated rainfall. We used the NDVI index, a remotely sensed variable highly correlated with aboveground net primary productivity and with absorbed photosynthetically active radiation, providing an index of ecosystem functioning (Pettorelli et al., 2005). NDVI values below 0.3 indicate bare soil (Montandon and Small, 2008). Monthly averaged NDVI values were obtained from MODIS Collection 5 Global Subsetting and Visualization Tool (ORNL DAAC 2008), for two sites representing forest and agriculture contexts, along 5 years (from January, 2009 to December, 2015). We represented obtained values in boxplot graphs to detect periods of bare soil.

3. Results

3.1. Urban surroundings

The cluster analysis allowed us to identify two main groups of towns with a cophenetic index of 0.88. We used CLA (%) in the decision tree analysis to identify threshold values that define two classes: (a) forest context (<20% cultivated land area) and (b) agricultural context (>20% cultivated land area) (Fig. 2).