



Human appropriation of aboveground net primary production in Spain, 1955–2003: An empirical analysis of the industrialization of land use[☆]

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ABSTRACT

The human appropriation of net primary production (HANPP) is an indicator of the human domination of ecosystems that measures to which extent human activities alter the amount of biomass available each year in ecosystems. This paper analyses the development of aboveground HANPP (aHANPP) in Spain for the period from 1955 to 2003. During this period, Spain's agriculture underwent a transition from a largely pre-industrial to a highly intensified production system. Changes in land use patterns include a reduction of cropland area and an expansion of forest area. Results show that aHANPP declined from 67% of potential aNPP in 1955 to 61% in 2003. Biomass harvest strongly increased from 68 million tons dry matter biomass per year (Mt/yr) to 106 Mt/yr, with nearly all of this increase occurring on cropland. Productivity losses due to human-induced land conversions dropped significantly from 112 Mt/yr to 63 Mt/yr, mainly as a result of the surge in cropland productivity and the increase in forest area. Despite its decrease during the last decades, aHANPP in Spain is still at a remarkably high level in comparison with the global average or other industrialized countries.

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1. Introduction

The human appropriation of net primary production, commonly abbreviated as HANPP, has been developed as a measure of the human domination of terrestrial ecosystems (Vitousek et al., 1986; Haberl, 1997; Haberl et al., 2004a). Net Primary Production (NPP) is the net amount of biomass produced by autotrophic organisms (green plants) over a defined period of time (mostly a year), and forms the main nutritional basis for all food chains. HANPP measures the extent to which humans reduce the amount of NPP available for other species. It indicates the impact of socioeconomic activities on fundamental ecosystem functions (Wright, 1990; Daily et al., 1997; Haberl, 1997; Field, 2001; DeFries, 2002; Wackernagel et al., 2002; Haberl et al., 2004c; Gerten et al., 2005).

Conventional economic analyses, following a “chrematistic” approach and mainly based on monetary accounting, have failed in sufficiently integrating the environmental impacts of economic activities (Martinez-Alier, 1987). In the past decades, several methods have been developed to describe the economy using a biophysical approach, with the objective of improving the ability to adequately tackle sustainability problems. By analysing socioeconomic biomass flows, HANPP describes an important aspect of the physical economy

and of its impacts on ecosystem functions. It constitutes an extension of the methodological framework that has been developed to analyse physical dimensions of economic processes (Daniels, 2002; Daniels and Moore, 2001).

In recent years, a number of studies have been carried out to analyse Spain's physical economy, as well as its development over time (e.g. Simón Fernández, 1999; Arto Oleizola, 2003; Cañellas et al., 2004; Carpintero, 2005; Cussó et al., 2006). The detailed study by Carpintero (2005) showed the dramatic changes in Spain's social metabolism covering the period from 1955 to 2000, during which the total material requirement of the Spanish economy increased more than fivefold and the area of Spain's total ecological footprint more than threefold.

With this study, I would like to contribute to the achievements that have been made in quantifying the biophysical dimensions of society–nature–interactions in Spain by presenting the first detailed assessment of aboveground HANPP (aHANPP) in Spain on a national level. The aim of the study is not only to quantify the magnitude of aHANPP, but also to deepen the understanding of how patterns of aHANPP have evolved over time in the context of socioeconomic change. I aim to answer questions such as: What are the main pathways through which aHANPP occurs? To which extent do the different changes in land use patterns contribute to the development of aHANPP? What conclusions can be drawn for future developments?

This study covers the period from 1955 to 2003. During this time, the Spanish agricultural sector underwent significant changes towards a highly industrialized intensive agricultural production system (Naredo, 2004). Population has increased by more than 40%

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despite a rapid depopulation of rural areas. The political system changed from a dictatorship (until 1975) to a constitutional monarchy (since 1978). In 1986, Spain joined the European Community (now EU).

2. Materials and methods

2.1. Definition of HANPP

In this study, HANPP is defined as the difference between the NPP of potential vegetation (NPP_0) and the fraction of the NPP of the currently prevailing vegetation (NPP_{act}) that remains in ecosystems after harvest (NPP_t). NPP_t is calculated by subtracting harvested NPP (NPP_h) from NPP_{act} . That is, HANPP is defined as $NPP_0 - NPP_t$ which is equal to the sum of harvest (NPP_h) and land use induced changes in productivity (ΔNPP_{LC}). The biomass destroyed in human-induced fires is included in NPP_h and not treated as a separate flow as in Haberl et al. (2007). Due to limited availability and reliability of data on belowground NPP, all calculations are restricted to aboveground NPP flows which is indicated by the prefix “a” ($aNPP_0$, $aNPP_{act}$, etc.). The unit used in this study is metric tons dry matter per year (t DM/yr). $aHANPP$ is given in t DM/yr or as percent of $aNPP_0$. For details on general definitional issues see the introductory article (Erb et al., 2009–this issue).

2.2. Description of the study area

Mainland Spain is situated in South-western Europe where it covers more than 85% of the Iberian Peninsula. The country of Spain also includes the Canary Islands in the Atlantic Ocean, the Balearic Islands and some other small islands in the Mediterranean Sea, as well as two small enclaves in North Africa and one in France. Spain's total area is about 506,000 km². The average population density is 88 people per km², with strong regional differences (densely populated areas in the coastal regions and around Madrid). Spain is the second highest-lying country in Europe, with an average elevation of 660 m. Its topography is dominated by the large central plateau, which is surrounded by mountain ranges. There are a wide range of prevailing climatic conditions, with oceanic climate in the northern coastal regions, oceanic–continental and continental–mediterranean climate in the region of the central plateau, mediterranean climate in the eastern and southern coastal regions and on the Balearic Islands, subtropical climate on the Canary Islands, and mountain climates. Spatial differences in annual mean temperature surpass 18 °C, and average annual precipitation ranges from barely 150 mm/yr to over 2500 mm/yr (De Castro et al., 2005).

2.3. Land use data

To study HANPP in a historical context, it is crucial to be able to understand and quantify changes in land use that occurred throughout the time period observed. Unfortunately there are substantial discrepancies between the different data sources on land use in Spain. Apart from matters of data quality, this is mainly due to strongly differing classifications. For this reason, and because of rather imprecise definitions of categories in some cases, the different data sets are hardly comparable. For a better understanding of land use changes in the 20th century, a detailed revision of the different sources would be urgently needed.

Yearly data on the distribution of different land uses relating to the total country area are documented within the Spanish Agricultural and Food Statistics Year Book (MAPA, 1999–2006) and its predecessors (Ministerio de Agricultura, 1929–1972, 1974–1980; MAPA, 1981–1997) as from 1955. I denominate data from this source as “MAPA land use data”. Between 1955 and 1973, classifications of land use categories were changed repeatedly. Since 1973, consistent classifications have been used. The relation of many of the categories used nowadays to those used before 1973 is not clear. Other well-accepted

sources for land use changes in Spain are the land use maps of 1960 and 1985, compiled by the Ministry of Agriculture, as well as the National Forest Inventories (as a source for forest area) (ICONA, 1979, 1980; Ministerio de Medio Ambiente, 1998). Both sources have the disadvantage that they are only available for two, respectively three points in time within the studied time period, and that classification concepts have changed over time. For the purpose of this study, the data given in the MAPA land use data set have the advantage of temporal and spatial consistency, at least from 1973 onwards. They were therefore also taken as reference for the area of forest and shrubland, although the forest inventory data are a more widely accepted source for these areas. In the MAPA data set areas dominated by stunted trees with vegetative reproduction through sprouts from stumps or roots are not included in the forest area but in the area of shrublands. This at least partly explains why the forest area given in the MAPA data set is smaller than in the forest inventories. The high variation of the statistical data on forest area seem to be a general feature of forestry statistics in Mediterranean countries, as Grove and Rackham (2003) pointed out. This is partly linked to the specific diversity in forest and shrub land covers and the commonness of transitional land covers in Mediterranean regions.

The land use data set compiled for this study (Fig. 1) consists of 13 categories that have been aggregated to five main land use types. Sources and assumptions used for each land use category are summarized in Table 1.

2.4. Aboveground NPP of the potential vegetation ($aNPP_0$)

$aNPP_0$ data were taken from the work of Haberl et al. (2007), who used the Lund–Potsdam–Jena (LPJ) Dynamic Global Vegetation Model (Sitch et al., 2003) with an improved representation of hydrology (Gerten et al., 2004) for their calculations. Data on $aNPP_0$ were available as 10-year-averages (Erb pers. comm., 2007; see introductory article)

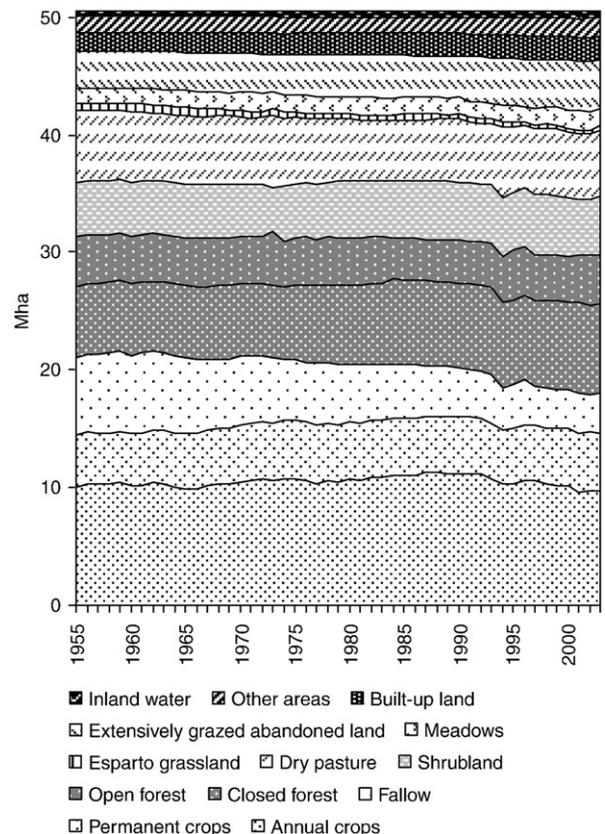


Fig. 1. Development of land use in Spain, 1955–2003 (stacked area chart). Sources: see text.

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