



Land system change in Italy from 1884 to 2007: Analysing the North–South divergence on the basis of an integrated indicator framework[☆]

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ABSTRACT

Over the past centuries, land systems in Italy experienced fundamental shifts, owing to the availability of new energy forms, population surges, and technological progress. The 20th century was characterized by massive productivity increases, accompanied by gradual land abandonment and the return of forest land. We here analyze 120 years of land system change in Italy, applying the human appropriation of net primary production (HANPP) framework, a metric for socio-economic pressures on terrestrial ecosystems. HANPP allows integrating ecological with societal perspectives, by systematically quantifying (a) biomass harvest and (b) the difference between potential productivity of ecosystems and current productivity induced by land use processes, such as land conversion, or land degradation. Besides assessing national trends we calculated HANPP separately for the Italian North and South between 1934 and 2007, in order to scrutinize if high regional discrepancies in terms of natural and socio-economic preconditions translate into diverging land system trajectories. Our results show that national HANPP has been declining from 78% of natural productivity before WWII to 56% in 2007, indicating a declining land -use induced pressure on biomass flows over time. Simultaneously, biomass harvest increased by around 26% due to agricultural intensification, despite shrinking croplands. Although we found a significant difference between the Northern and Southern region in the absolute levels of several land use indicators related to biomass appropriation, the overarching trends of land system change were remarkably similar in both regions. This suggests that underlying drivers of land system change, such as policies aimed at land-use intensification and structural change were equally dominating land system trajectories in the North and South of Italy, not withstanding their socio-ecological divergences.

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Introduction

Land use provides essential resources to society and at the same time is one of the most central factors for accelerating global environmental change, which increasingly jeopardizes human well-being (Foley et al., 2005). This dilemma of land use is expected to intensify in the coming decades, owing to accelerating biomass demand of a rising and prospering world population (Nonhebel & Kastner, 2011; Kastner et al., 2012; Bruinsma, 2003). This calls for in depth analysis of the trade-offs between societal gains and ecological costs related to land use (Turner et al., 1977; Tilman, 1999; Foley

et al., 2005; Lambin & Geist, 2006; Galloway et al., 2008). Satisfying increasing biomass demand while concurrently avoiding potential environmental pitfalls requires interdisciplinary understanding of the complex society-nature interactions that lead to specific land use patterns and their dynamics over time (Rindfuss et al., 2004; GLP, 2005; Turner et al., 2007).

Large knowledge gaps persist on how socio-economic processes (economic growth, political shifts, demographic change) and natural constraints and endowments (e.g. water availability, climate, soils) co-determine trajectories of land system change. Analysing how land systems have reacted to changing underlying drivers in the past has been highlighted as key to tackle these knowledge gaps and as a precondition for preparing for future land system changes (Dearing et al., 2010). Long-term case studies have proven a powerful approach for scrutinizing the general principles of land system change (Krausmann et al., 2013, 2012; Singh et al., 2013; DeFries et al., 2004), particularly in terms of analysing effects of rapid change and megatrends such as urbanization or the increasing

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relevance of telecouplings in the land system (Hostert et al., 2011; Seto et al., 2012; Meyfroidt et al., 2013). Historic studies on land use change are rare though, mainly due to a lack of data sets on land system dynamics and their underlying drivers (Singh et al., 2013).

We here present a long time series analysis of land system change in the Republic of Italy, employing the analytical framework “human appropriation of net primary production” (HANPP; Haberl et al., 2007; Erb et al., 2009a,b). This framework allows to comprehensively assess changes in land systems (Vitousek et al., 1997; Haberl et al., 2007; Erb et al., 2009a,b; Niedertscheider et al., 2012), by discerning changes in the extent of land-use types, which is often associated with land cover change, and changes in the intensity of land use (Lambin & Meyfroidt, 2010; Erb et al., 2013; Kuemmerle et al., 2013).

HANPP quantifies socio-economic biomass flows, e.g. agricultural harvest, and relates these flows consistently to ecological biomass flows, i.e. net primary production (NPP). NPP is defined as the biomass produced annually through photosynthesis. It represents the trophic basis of almost all living organisms on earth and thus is a key parameter of ecosystem functioning (Roy et al., 2001). A central feature of HANPP is its ability to refer directly either to human consumption patterns, or to the impacts of land use on natural systems, allowing to put land use change in a socio-economic (e.g. resource economic; Alvarenga et al., 2013), as well as an ecological perspective (e.g. land use impacts on biodiversity, Dullinger et al., 2013; Haberl et al., 2007).

The Republic of Italy is an interesting country for quantifying changes in biomass flows related to changing socio-economic determinants due to its unique history of repeated major political and economic shifts, encompassing a major energy transition, a shift from democracy to fascism, two world wars and the accession to the European Union. While until far into the 20th century the level of industrialization was low to moderate compared to northern European countries, Italy became one of the leading industrial players after WWII (Malanima, 2006a,b), entailing rapid industrialization and economic growth. Thus after 1950 the role of agriculture changed completely (Malanima & Zamagni, 2010) along with structural change of the economy, technological advancement, market integration and the accession to the European Union, all of which are likely to have affected land system trajectories at different scales. Data availability allowed assessing land system changes for the Republic of Italy between 1884 and 2007.

A second interesting aspect about Italy as a study example is its pronounced North/South gradient in terms of biophysical and socio-economic conditions, which are expected to have affected land systems differently in the North compared to the South. Natural preconditions are more favourable for biomass production in the North, while the South is prone to lower annual precipitation rates (701 mm/year in the North versus 453 mm in the South in 2011, ISTAT, 2012), high temperature peaks in the summer, and dry-land degradation (Zika & Erb, 2009). In addition land use was determined by entirely different socio-economic frameworks in both regions until far into the 20th century. Historically northern land use tended to be more dominated by market driven decisions of individual family farmers who aimed at optimizing economic returns of their lands, whereas in the South land tenure rights were more restrictive particularly until WWII, with a substantial share of the population being employed as day labourers on large land holdings which were cultivated under low land use intensity (Rossi-Doria, 1958; Dunnage, 2002; Del Monte & Pennacchio, 2011). As a consequence high North/South discrepancies in terms of the level of industrialization, structural change of agriculture and economic performance prevailed over the past decades and indeed have been persisting until today (Daniele & Malanima, 2007; ISTAT, 2013). Data availability allowed for separate HANPP and land system change calculation for North and South Italy between 1934 and 2007. In this period

an ongoing process of concentration of biomass production away from marginal and poorer regions into the most fertile areas, best suited for productivity increases, has been witnessed across many European regions (MacDonald et al., 2000). To our knowledge no study has so far analyzed if these processes are also reflected in the regional land use trajectories in Italy, e.g. leading to a gradual shift of harvest and HANPP from the South into the North, accompanied by a trend towards land abandonment in the South and land use intensification and production increases in the North.

Hence the overarching goals of this study are twofold: (1) We aim to analyze land system dynamics after 1884 in a consistent time-series approach and to put these trajectories in relation to long term socio-economic change, such as industrialization, market integration, and energy transition in order to scrutinize the role of these drivers in a long term perspective. (2) We will test the hypothesis if the high natural and socio-economic discrepancies between the Italian North and South led to different land system trajectories since 1934. From this analysis we expect insights into the role of climatic and socio-economic determinants for dynamics and patterns of land use in Italy.

Materials and methods

The period studied reaches from 1884 to 2007 for the entire Italian territory and is determined by the availability of land use and agricultural harvest statistics. Italian borders have changed slightly during this period, in particular after World War I (WWI) and World War II (WWII). However, in terms of the total territory, these changes were minor and were thus ignored. Between 1934 and 2007, data availability allowed analyzing land system trajectories separately for the Italian North and South. The South consists of eight provinces (Basilicata, Campania, Calabria, Puglia, Abruzzo, Molise, Sicily and Sardinia) and is often referred to as “Mezzogiorno”.

Our analysis of Italian HANPP trajectories is based on a wide range of datasets, which are shortly described below. A detailed description of the materials and methods is further provided in the Supplementary Online Material (SI).

We follow the definition of HANPP by Haberl et al. (2007) as the sum of productivity losses due to land use and land cover change ($\text{HANPP}_{\text{luc}}$) and biomass harvest ($\text{HANPP}_{\text{harv}}$; Fig. 1). High HANPP levels entail lower shares of NPP_{eco} , i.e. the share of biomass remaining in ecosystems after human land use, which is available for other food webs. Thus high HANPP indicates high pressure on ecosystems caused by human land use. NPP_{act} refers to the current, e.g. “human managed” levels of productivity and consists of harvested NPP ($\text{HANPP}_{\text{harv}}$) and remaining productivity (NPP_{eco}).

The ratio of $\text{HANPP}_{\text{harv}}$ to HANPP is denoted as HANPP efficiency; this metric illustrates the efficiency to which societies gain biomass resources out of their HANPP levels. High levels of HANPP efficiency imply that large fractions of the appropriated productivity directly enter the socio-economic system in the form of biomass harvest, and that smaller fractions are foregone in the course of land use. HANPP efficiency thus does not capture the level of HANPP or $\text{HANPP}_{\text{harv}}$ as such, but rather demonstrates the composition of HANPP.

HANPP as percentage of NPP_{pot} represents an indicator of the degree of human domination of ecosystems in terms of energy flows (Erb et al., 2009a,b). Low levels imply that high fractions of the natural productivity are left in ecosystems after harvest, and that the degree of human disturbance from a HANPP perspective is generally low. HANPP per person ($\text{HANPP}/\text{cap}/\text{year}$) relates biomass appropriation to population numbers.

The HANPP calculation for Italy is based on the following five datasets:

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