



Agricultural landscape change in China's Yangtze Delta, 1942–2002: A case study

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ABSTRACT

Over the past 60 years, China's ancient agricultural village landscapes have been transformed by unprecedented changes in rural policy, population and agricultural technology. The village landscapes of China's Yangtze Plain are among the most ancient, densely populated and intensively managed in the world and have undergone extremely rapid development in recent decades, causing the wholesale transformation of traditional village landscape structure, primarily at fine spatial scales (< 30 m). Here we investigate the causes and consequences of these fine-scale changes, 1942–2002, using a case study of landscape change within a regionally representative sample of village landscapes in Yixing County. High-resolution mapping was coupled with historical data obtained by interviews with elder farmers and archival sources, with uncertainties quantified using Monte Carlo methods. The already dense agricultural populations of 1942 had increased by about 50% by 2002, and this was accompanied by an intensification of land management that caused 53% of land area to undergo a substantial change in landscape class. Paddy area declined by 22% from 1942 to 2002, and this was coupled with an 8% net increase in built surfaces, a 14% increase in aquaculture surface, and most surprisingly, by a 5% net increase in land cover by closed canopy woody vegetation. Most of this change was caused by fine-scale land transformations that fragmented larger managed features into smaller features that incorporated a wider variety of management practices, thereby simultaneously increasing both landscape heterogeneity and complexity. Population growth, agricultural policy changes and market-oriented land management strategies combined to produce these significant long-term agricultural landscape changes. By coupling detailed analysis of fine-scale local landscape transformation processes with land use history across three time periods, this study identified the causes of ecologically significant landscape changes and may also help to indicate future change trends within some of the most densely populated and productive agricultural landscapes in the world.

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1. Introduction

Home to more than half a billion rural people, densely populated agricultural village landscapes cover approximately 2 million square kilometers across China's Eastern plains and Central and Southern hilly regions, accounting for about 20% of China's total land area and more than a quarter of village landscapes globally (Ellis, 2004; Ellis and Ramankutty, 2008). Though China's villages have been cultivated for centuries, some of the most significant ecological changes in their history have likely occurred since the 1940s, as a result of population growth, the adoption of

industrial technologies such as chemical fertilizers and pesticides, and changes in rural policy and its implementation (Han, 1989; Ellis and Wang, 1997; Tong et al., 2003).

The ecological impacts of long-term changes in population, policy and land management practices in agricultural China have been studied in terms of fertilizer use and other alterations of agricultural management practices (Li, 1993; Lindert et al., 1996; Meng et al., 2005), but the role of changes in landscape structure associated with these remain poorly understood, in part because of the challenges of measuring fine-scale landscape changes over long time periods using conventional land change measurement systems based on regional remote sensing platforms dating to the 1970s, such as Landsat and SPOT (Ellis et al., 2006; Ozdogan and Woodcock, 2006).

The lower reaches of China's Yangtze River Plain, also known as the Yangtze Delta and the Tai Lake Region, has long been one of the most densely populated agricultural regions on Earth and is

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legendary in China for its many centuries of productive rice-based agriculture and for its long history as one of China's most economically developed regions (Ellis and Wang, 1997; Li, 2000; Long et al., 2007a). While village landscapes of the Yangtze Delta have undergone a variety of changes over the centuries, in the past half century this region has witnessed unprecedented changes in population, land tenure, and technology, nearly tripling the agricultural productivity of the region while generating a variety of negative environmental consequences (Ellis and Wang, 1997).

This study investigates the causes and potential consequences of fine-scale changes in landscape structure between 1942 and 2002 in a sample of village landscapes in China's Yangtze Delta. To accomplish this, we combine field-validated high-resolution ecological mapping from current and historical imagery with elder interviews and historical research across a regionally selected sample of village landscapes across a field research site in Yixing County, Jiangsu Province.

2. Background and methods

2.1. Site description

The Yangtze Delta Region comprises the fertile deltaic plains at the mouth of the Yangtze River and surrounding Tai Lake (Ellis and Wang, 1997). The region has a Northern Subtropical Monsoon climate that is ideal for rice, with 1100–1400 mm of annual precipitation, annual mean temperatures around 16 °C and a 290 day growing season (Xu et al., 1980). The region has a long history of high-yielding subsistence rice production, and is believed by many to be a center of rice domestication (Ellis and Wang, 1997). For centuries and during the period of the current study, the region's farming system has been dominated by flooded paddy rice production in summer, rotated with wheat or rapeseed (*Brassica napus*) in winter, supplemented by mulberry production (*Morus alba*) on artificially elevated rainfed fields (to supply fodder for household silkworms), and by aquaculture in wetter areas near population centers (Ellis and Wang, 1997). With the exception of the communal period from the 1950s to 1970s, the agriculture of

this region has long been famed for its labor intensity, high productivity, and very small scale of management (King, 1911), with paddy fields usually being the largest and ranging in size from about 0.067 to 0.2 ha, and the full landholdings of pre-revolutionary households averaging 1.5 ha, with some land owned, some rented (Buck, 1937). Until the 1990s, most households also cultivated small vegetable gardens near their houses, raised pigs in tiny stalls within housing units, and reared a few caged and free-ranging chickens, ducks and geese.

2.2. Site, landscape samples and imagery

A single 100 km² rectangular (7 km × 14.25 km) field research site in Yixing County was selected for study in the Yangtze Delta Region of China from a total of three potential field sites examined across the region in the field together with regional experts during an extended site selection period as described by Ellis (2004; Fig. 1; centered on 31.37 Lat., 119.56 Lon.). The site was selected based on the availability of historical aerial photographs, historical agriculture surveys and the confirmed absence of any anomalous environmental, economic or social conditions compared with the region as a whole (Ellis, 2004).

Following site selection, a regionally stratified sample of 12 500 m × 500 m square landscape sample cells was selected for detailed study within the site as described by Ellis (2004). This was accomplished by first imposing a 500 m grid across the region, stratifying the grid cells thus formed into three regionally dominant land cover patterns identified by applying K-means cluster analysis to land cover derived from a Landsat ETM+ scene across the region (land cover clusters; Fig. 1), and finally by selecting a total of 12 of these grid cells within the site in proportion to the regional area of each of these land cover clusters (Ellis, 2004).

IKONOS 4 band pan-sharpened 1 m resolution GEO imagery was acquired across the entire Yixing site on 26 September 2002 and orthorectified using ground control points obtained by submeter accuracy Global Positioning Systems (GPS; Wang and Ellis, 2005). Aerial photographs covering the site in the 1940s

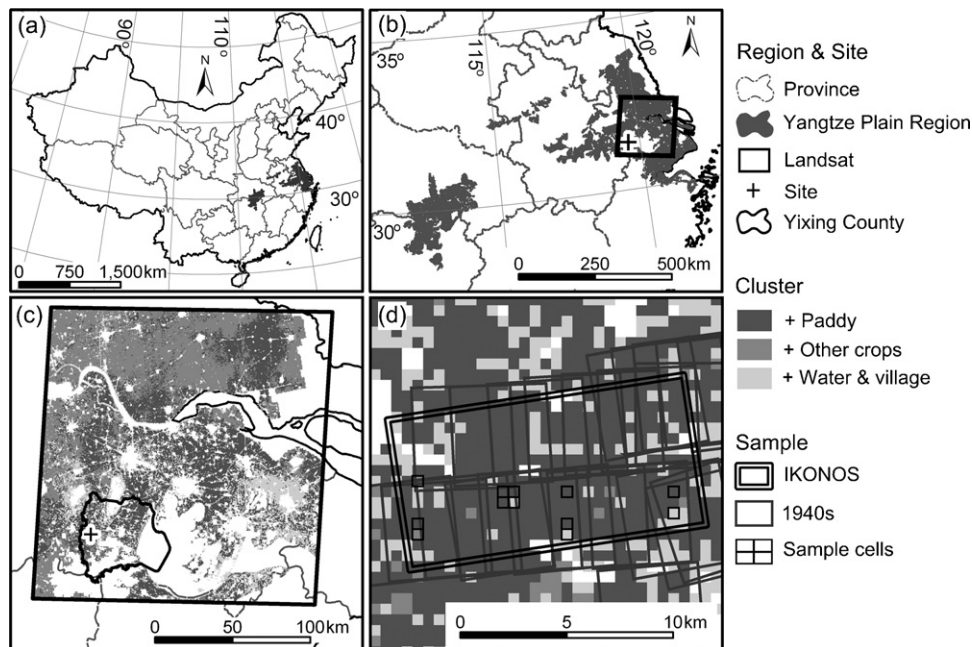


Fig. 1. Site and sample selection. (a) The Yangtze Plain Region of China. (b) Region with Landsat scene and site. (c) Landsat scene with land cover clusters (+paddy = mostly paddy, +other crops = mostly other crops, +water and village = mostly water and village builtup area), with site location and Yixing County boundary. (d) Site, with land cover clusters and boundaries of 12 landscape sample cells (IKONOS = IKONOS image footprint, 1940s = cover by 1940s aerial photographs).

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