Tea Plantation Expansion in Hangzhou, China: Process, Related factors & Ecological Effect

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Introduction

Land Use/Cover Change (LUCC) as one of the major directive signals for the influence of human activities on terrestrial ecosystem, make a huge impact on interchanging between biosphere and atmosphere, biodiversity, and sustainable utilization of natural resource.

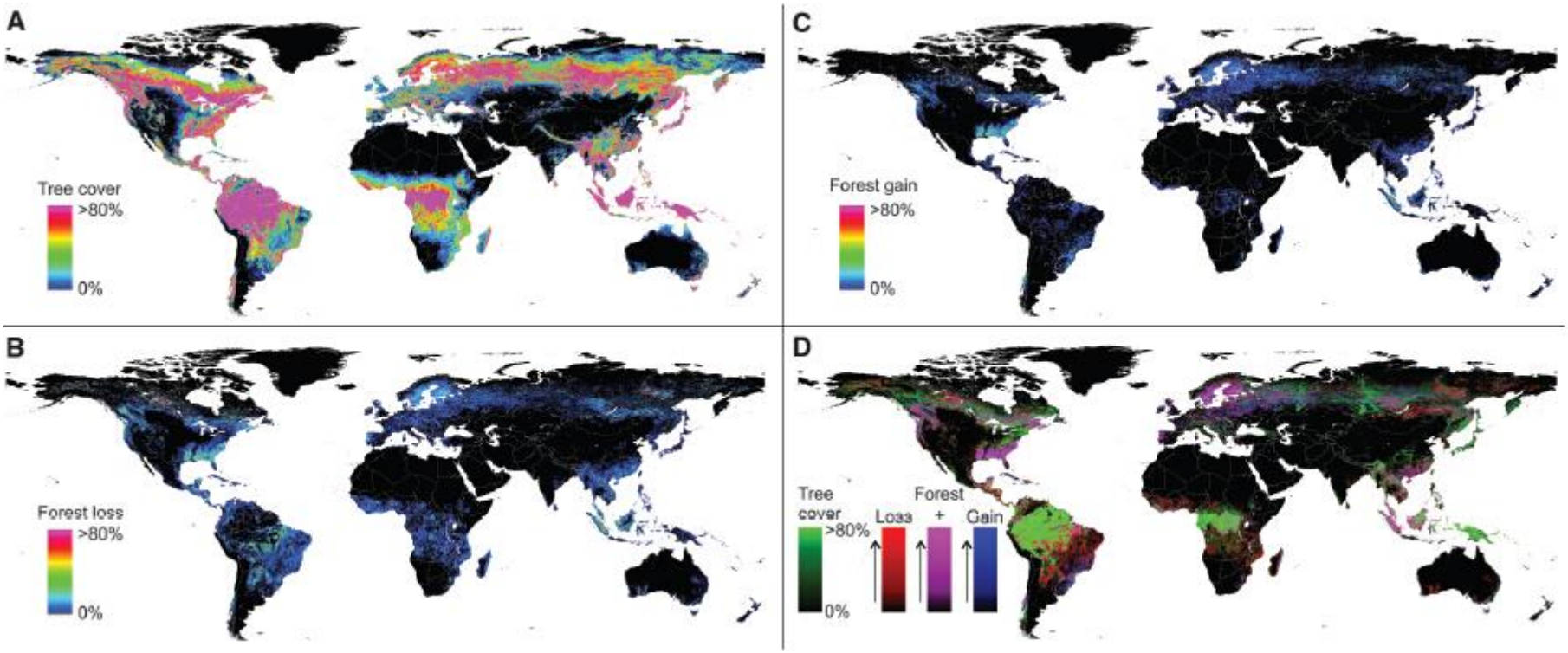


Fig. 1. forest cover change worldwide (2000-2010) [1]

[1] M. C. Hansen, P. V. Potapov, R. Moore, et al. High-Resolution Global Maps of 21st-Century Forest Cover Change[J]. Science, 2013, 342 : 850–853.

Introduction

As market-oriented agriculture crops, the expansion/development of cash crop expansion becomes a major component of land use change worldwide, especially in developing countries in subtropical/tropical regions.

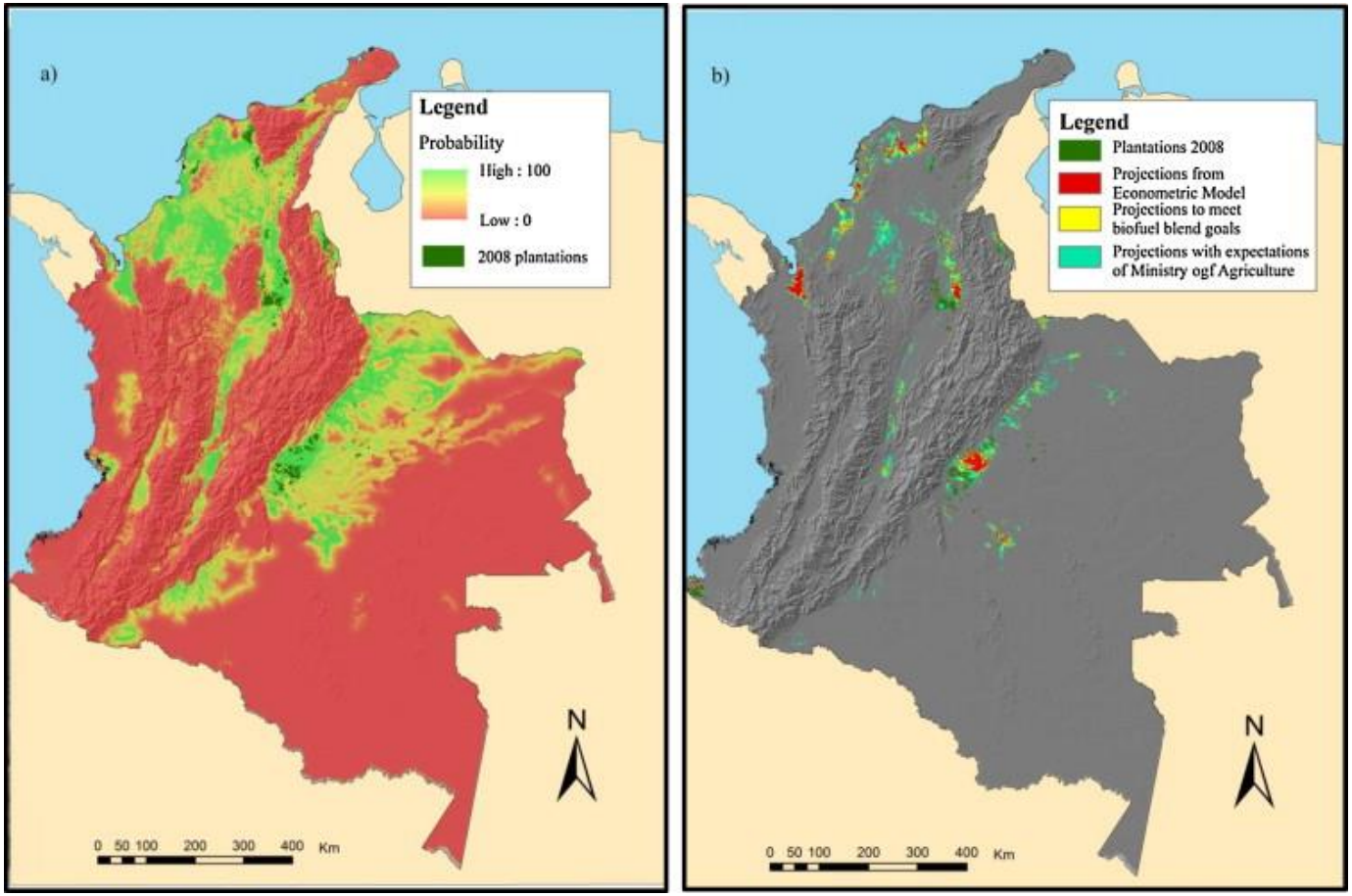


Fig. 2. Spatial model of future oil palm plantations expansion in Colombia:
(a) expansion probabilities (b) most probable spatial expansion of oil palm in 2020 [2]

[2] Castiblanco, C., Etter, A., Aide, T.M., 2013. Oil palm plantations in Colombia: a modelof future expansion. Environ. Sci. Policy 27, 172–183.

Introduction

Since the implication of ‘Household Responsibility’ policy in 1980s, many Chinese farmers changed their farmland to cash crop plantations to obtain higher economic benefits. Hangzhou has witnessed a huge cash crop expansion since 1985.

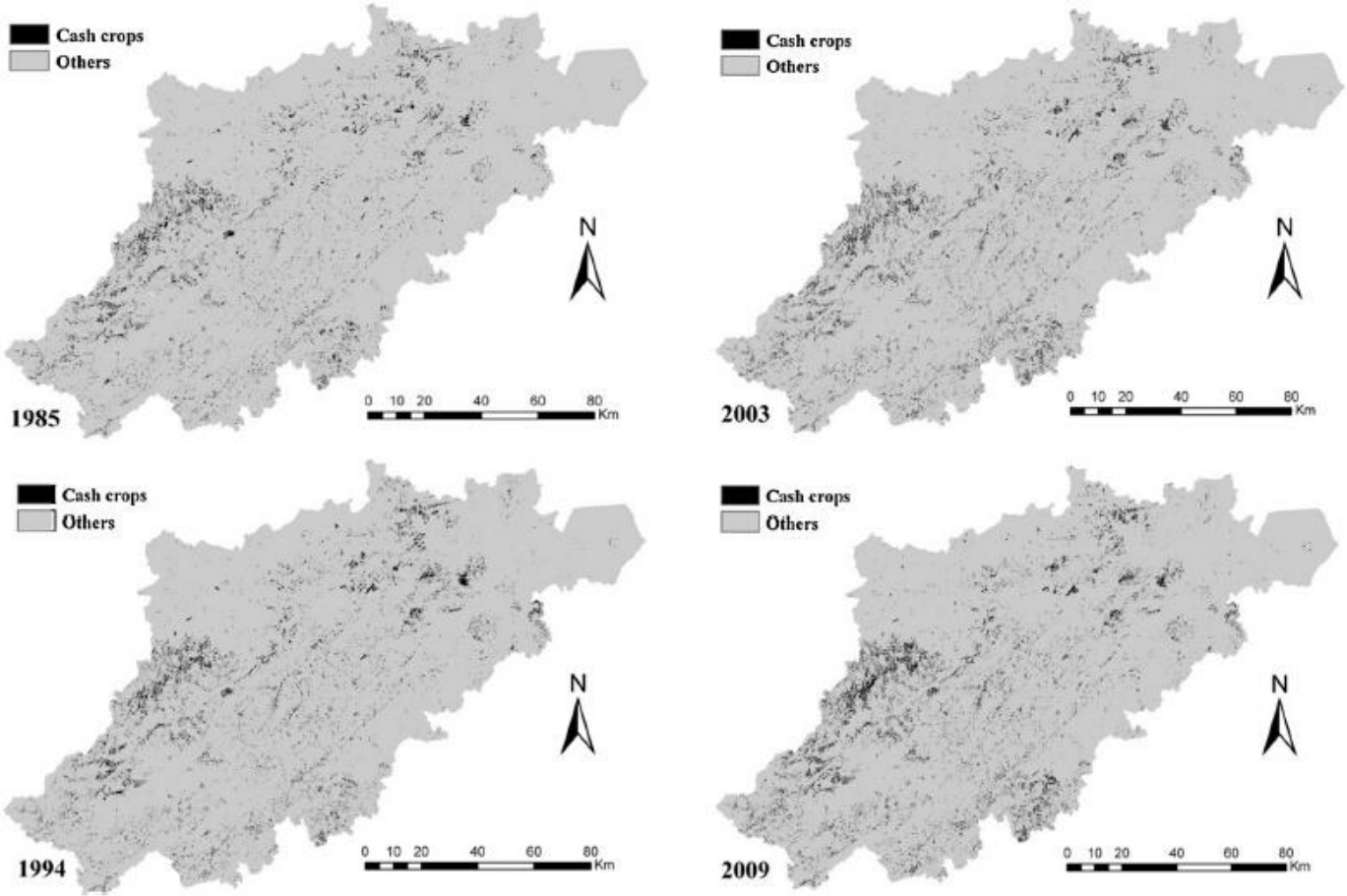


Fig. 3. Cash crop expansion in Hangzhou, China(2000-2010)

Introduction

Tea is a major component of cash crop products in China. China has undergone a huge increase on total area, total yield, and per unit area yield of tea plantation since the 1950s.

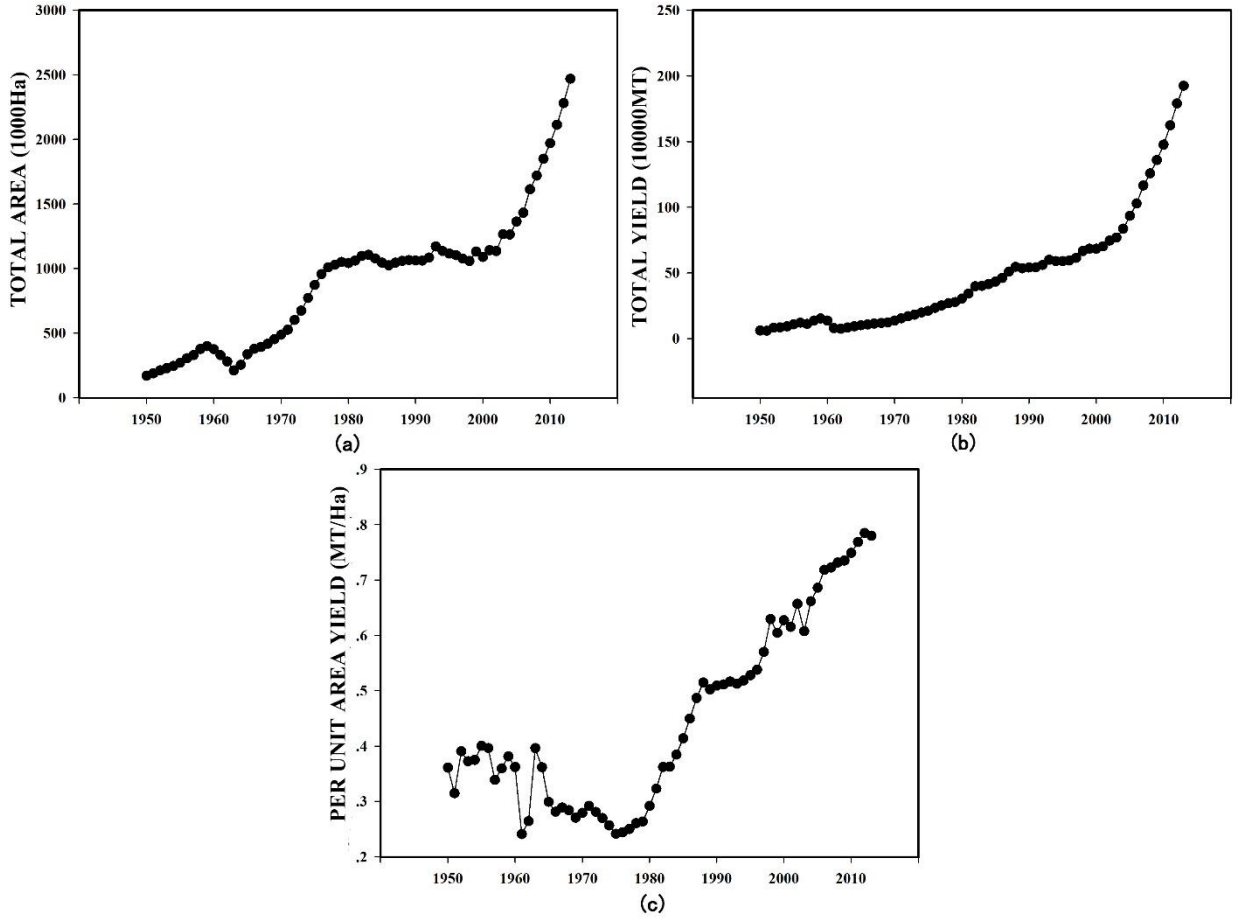


Fig. 4. the change of total area (a), total yield(b), and per unit area yield (c) of tea plantation (1950 - 2013)

Introduction

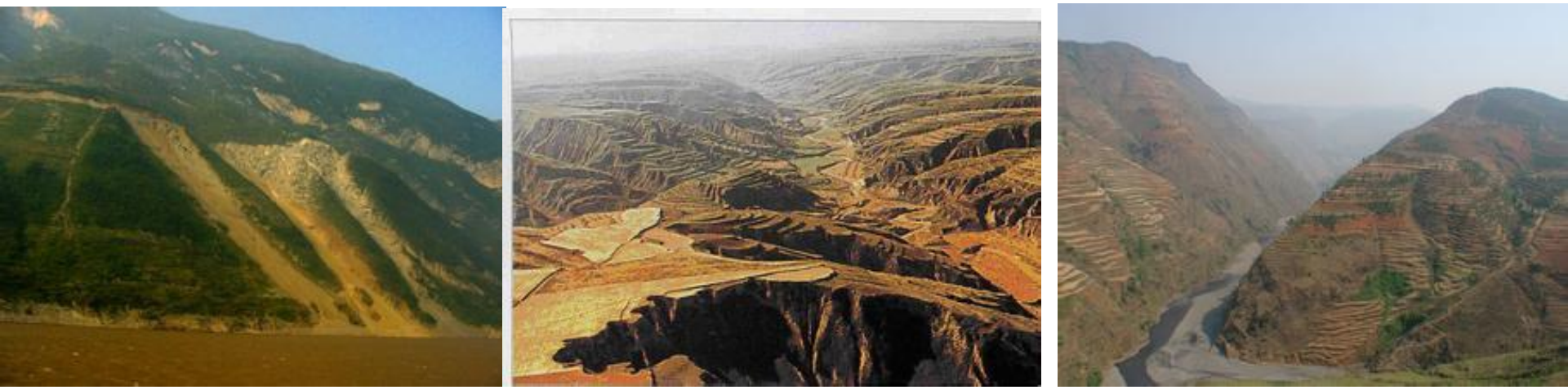


Fig. 5. The destruction of ecological environment

While tea plantation expansion (TPE) brings more economical interest, we will expect that expansion without supervision and management will leads to many negative effects on the local ecosystem and ecological environment, such as landscape fragmentation, water/soil loss and pollution, biodiversity loss.

Question:

1. **What are the related factors of tea plantation expansion? / What factors contribute to TPE? (Related factors)**
2. **How tea plantation expansion affects ecological environment? (Ecological Effect)**

Data

Hangzhou is called as “the tea capital of China”, with total area of tea plantations of 35900Ha and total yield of 20000MT. The climate, topographical and soil conditions make Hangzhou a ideal place for tea plantation.

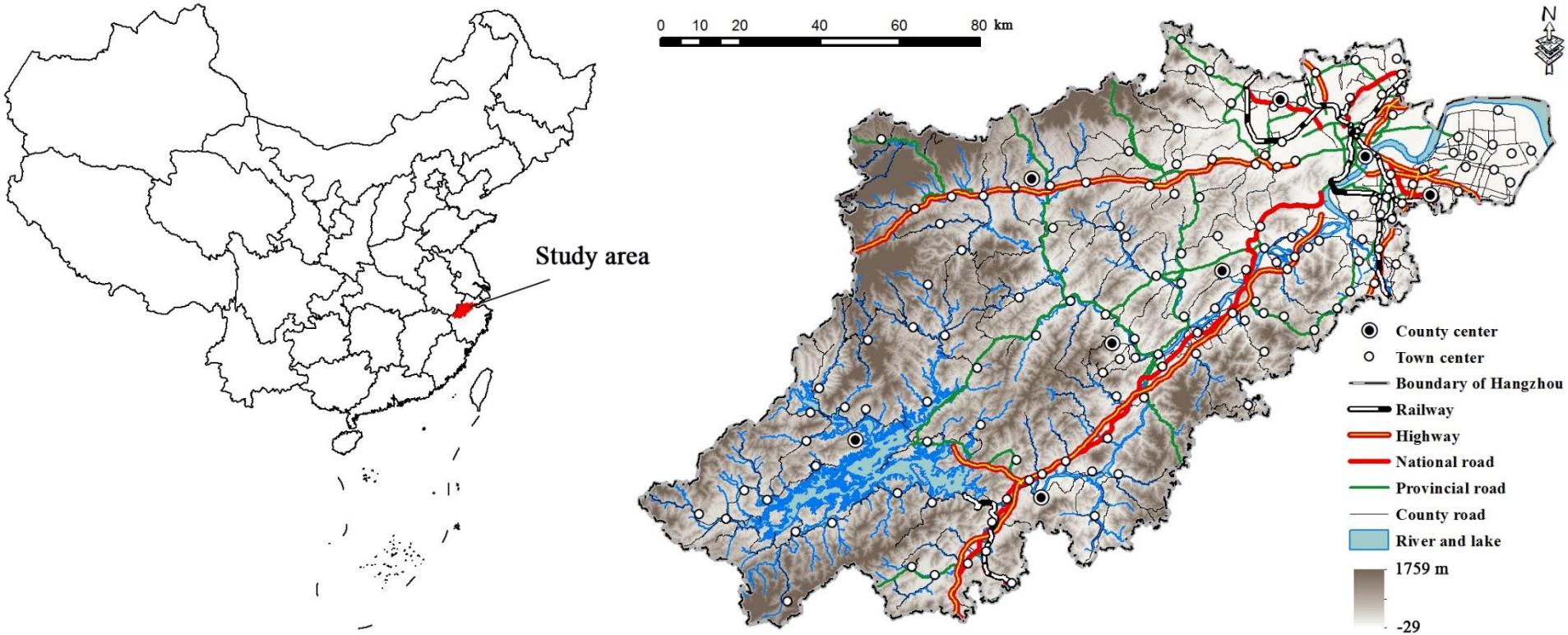


Fig. 6. Study Area

Data

Hangzhou underwent a large amount of tea plantation expansion from 2004 to 2013.

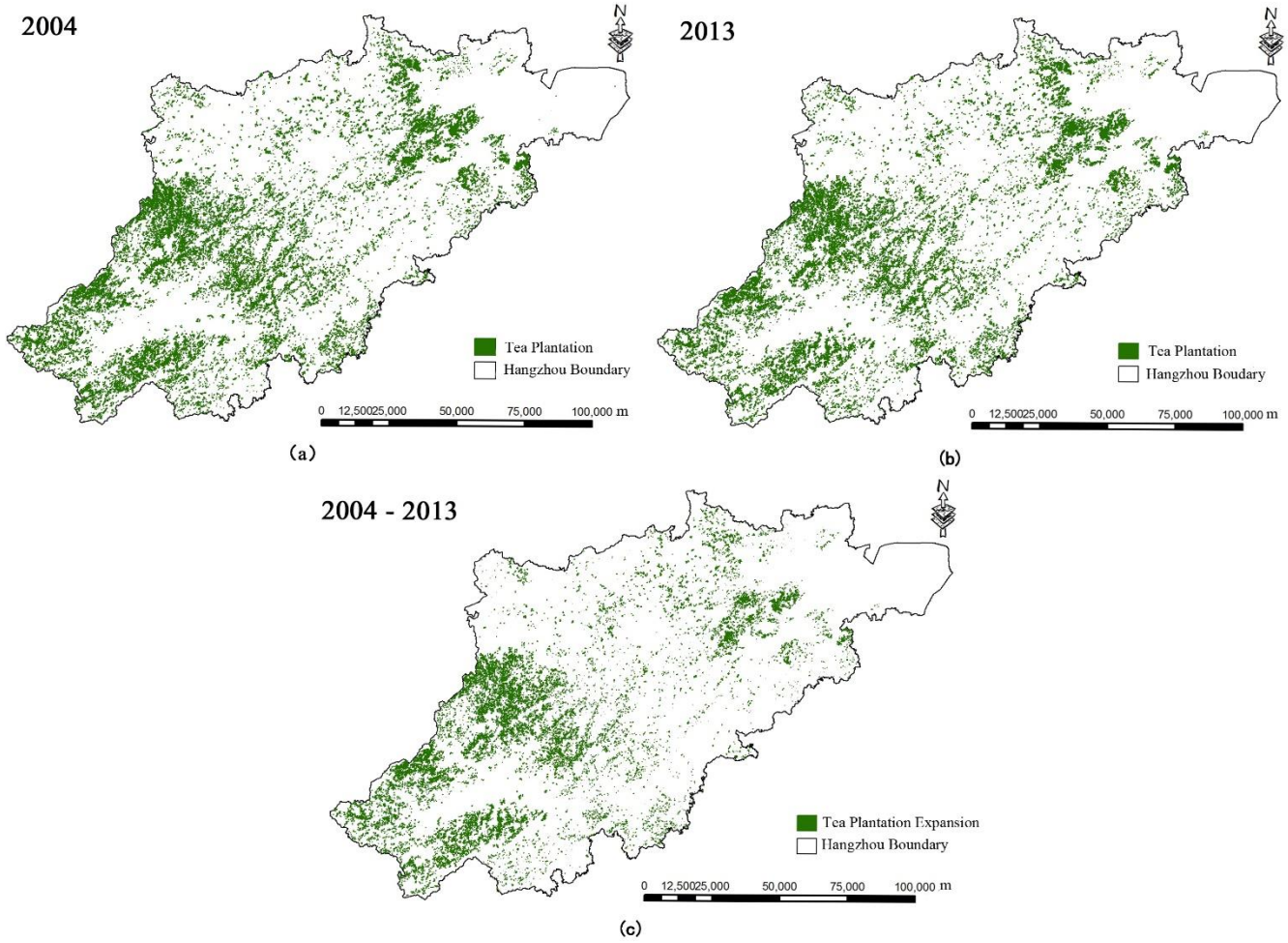


Fig. 6. (a) Tea Plantation in 2004
(b) Tea Plantation in 2013
(c) Expanded area of Tea Plantation

Method: Part 1 - Related Factors

1. **Exploring the relationship between area of TPE and physical, proximity, and Socioeconomic factors:**

Type of Factors	Factor Name
Physical	Slope (°)
	Elevation (m)
Proximity	Distance to all roads (km)
	Distance to national roads (km)
	Distance to provincial roads (km)
	Distance to county roads (km)
	Distance to highways (km)
	Distance to railways (km)
	Distance to town centers (km)
	Distance to village centers (km)
	Distance to waterbodies (km)
Socioeconomic	Changing rate of public financial income (km)
	Changing rate of public financial expense (km)
	Changing rate of Population (km)
	Changing rate of employment figure (km)
	Changing rate of per capita net rural income (km)

Method: Part 1 - Related Factors

For physical and proximity factors,:

- Using histograms to show how area of tea plantation expansion vary according to different factors.
- Using appropriate regression model if the histogram shows a strong correlation between this factor and TPE.

For socioeconomic factors:

- Because these census data are obtained in village level, using spatial lag model to get the relationship between socioeconomic factors and TPE:

$$Y = \alpha + \beta X + \gamma W_Y + \varepsilon$$

X、Y are dependent and independent variables； α is intercept； β is coefficient of X； ε is error； γ is the coefficient of spatial atuocorrelation； W_Y is spatial weight matrix.

Method: Part 2 - Ecological Effect

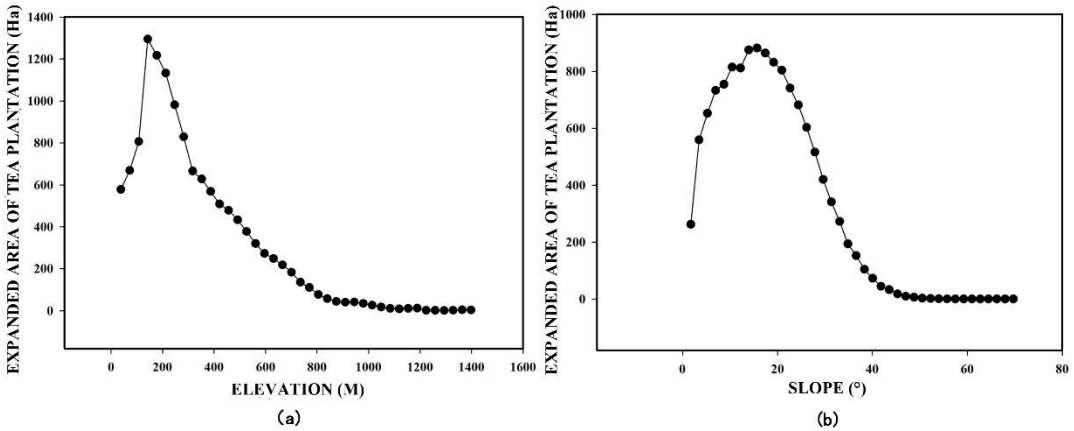
2. Evaluating ecological effect of tea plantation expansion:

- Selecting and calculating 15 landscape metrics of each village in 2004, 2013.
- Calculating the changing rate of these 15 metrics from 2004 to 2013:
- Using Pearson correlation analysis to select metrics ($p < 0.05$).
- Using spatial lag model to evaluate the ecological effect of TPE on the landscape.

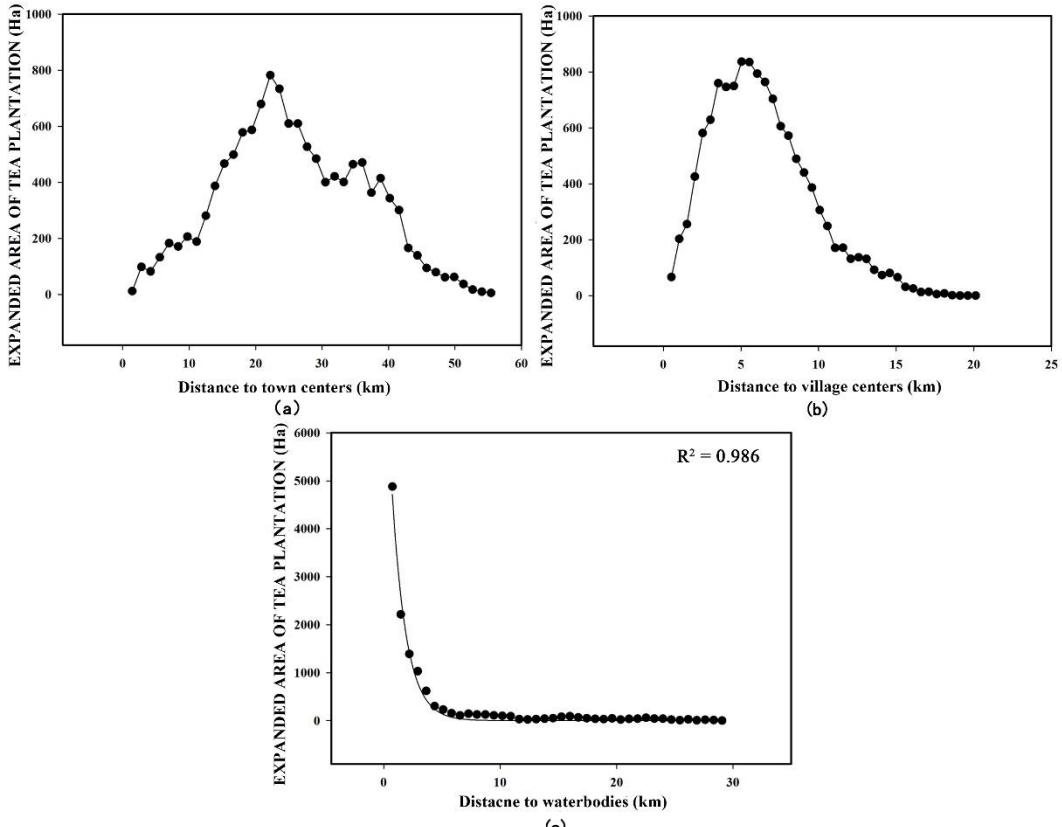
Metric	Full name of metrics	Equation
PD	Patch Density	$PD = \frac{N}{A}(10000)(100)$
ED	Edge Density	$ED = \frac{E}{A}(10000)$
LSI	Landscape Division Index	$LSI = \frac{E^*}{A}$
SHAPE	Area-Weighted Mean of Shape Index	$SHAPE = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}\frac{P_{ij} \times A_{ij}}{\sqrt{A_{ij}}}}{A}$
PAFRAC	Perimeter-Area Fractal Dimension	$PAFRAC = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}\frac{P_{ij} \times A_{ij}}{\sqrt{A_{ij}}}}{\frac{[N\sum_{i=1}^{m}\sum_{j=1}^{n}(\ln P_{ij} - \ln A_{ij})] - [(\sum_{i=1}^{m}\sum_{j=1}^{n}\ln P_{ij})(\sum_{i=1}^{m}\sum_{j=1}^{n}\ln A_{ij})]}{(N\sum_{i=1}^{m}\sum_{j=1}^{n}\ln P_{ij}^{2}) - (\sum_{i=1}^{m}\sum_{j=1}^{n}\ln P_{ij})^{2}}}$
AI	Aggregation Index	$AI = \frac{\sum_{i=1}^{m} A_i\left[\frac{g_{ii}}{\max \rightarrow g_{ii}}\right]}{A}(100)$

Result: Part 1 – Related Factors

Physical factors:



Proximity factors:



Result: Part 1 – Related Factors

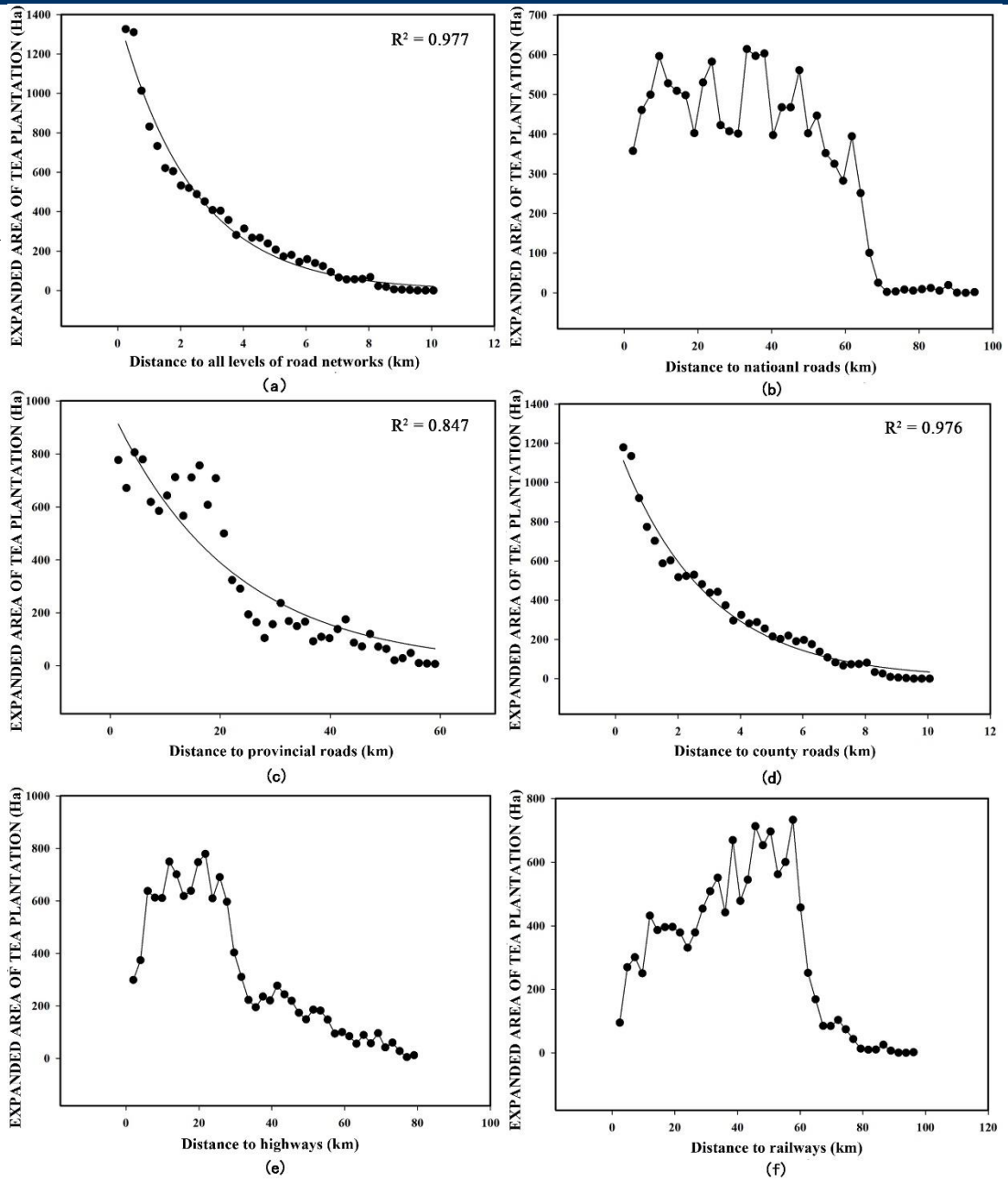
Proximity factors :

Exponential Regression applied on

Dis. To All roads

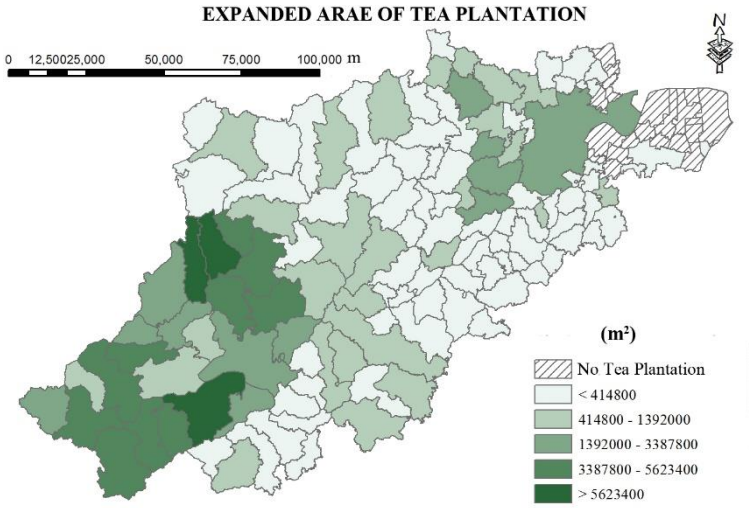
Dis. To provincial roads

Dis. To county roads



Result: Part 1 – Related Factors

The factors related to TPE:



Y	X	Regression Model	R^2
	Proximity		
	Dis. To all roads(km)	$Y^a = 1405.96 \times exp(-0.42X)$	.98**
	Dis. To provincial roads(km)	$Y^a = 976.72 \times exp(-0.05X)$	.85**
	Dis. To county roads(km)	$Y^a = 1214.97 \times exp(-0.36X)$	.98**
	Dis. To waterbodies (km)	$Y^a = 8614.01 \times exp(-0.82X)$	.99**
TPE(ha)	**Socioeconomic**		
	Public income	$Y^b = -533.98X + 0.71W_Y + 435724.2$	.55*
	Public expense	*NS*	
	Population	*NS*	
	Employment	*NS*	
	rural income	$Y^b = 11539.35X + 0.63W_Y + 291512.1$	.56**

Abbreviations: TPE (Area of Tea Plantation Expansion), Public income (Changing rate of public financial income), Public expense (Changing rate of public financial expense), Population (Changing rate of Population), Employment (Changing rate of employment figure), rural income (Changing rate of per capita net rural income)

[a] Exponent Regression Model

[b] Spatial Lag Model

** $p < 0.01$

* $p < 0.05$

Result: Part 2 – Ecological Effect

The ecological effects of TPE on landscape:

Y	*X*	Regression Model	R^2
PD	**TPE(ha)**	$Y^b = 2.08 \times 10^{-6}X + 0.72W_Y - 1.43$	$.37^{**}$
ED		$Y^b = 7.07 \times 10^{-7}X + 0.82W_Y - 0.23$	$.43^{*}$
LSI		$Y^b = 8.67 \times 10^{-7}X + 0.80W_Y - 0.18$	$.42^{*}$
SHAPE		$Y^b = 1.57 \times 10^{-6}X + 0.26W_Y - 3.40$	$.07^{*}$
PAFRAC		$Y^b = 2.53 \times 10^{-7}X + 0.64W_Y - 0.35$	$.44^{**}$
AI		*NS*	

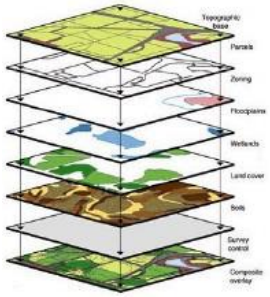
All the dependent variables means the changing rate of the corresponding landscape metrics.

^{b} Spatial Lag Model

** $p < 0.01$

* $p < 0.05$

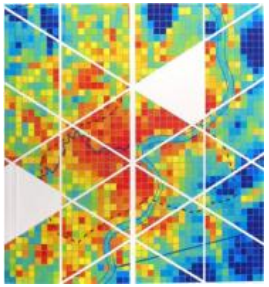
Conclusion



(1) Hangzhou has undergone great tea plantation expansion, about 54975.9 ha, from 2004 to 2013.

(2) Tea plantation expansion is highly related to some physical, proximity, and socioeconomic factors: slope, elevation, distance to water bodies, distance to roads, distance to settlement, public financial income and per capita rural income. Some relationships can be expressed by exponential regression, spatial lag model. But others (physical) factors have more complex relationship with Tea plantation expansion .

$$Y = \alpha + \beta X + \gamma W_Y + \varepsilon$$



(3) Tea plantation expansion would make the landscape become fragmentized, complex and irregular, which indicated that tea plantation expansion would lead to negative ecological effects.