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The Effects of Land Use Diversity on Pest Pressure and Insecticide Application in Cotton: A County Level Analysis for China

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1. Introduction

Despite a population of 1.3 billion, China has been able to produce nearly all of its food demand from a very limited land endowment. This achievement has been accomplished primarily by increasing the level of modern inputs and the intensity of the farming systems (Huang and Rozelle, 1995; Rozelle et al., 1997). For instance, as the world's largest pesticide producer and consumer, China uses 1.3 million tons of pesticides annually, 2.5 times the global average usage per unit area (China Daily, 2011). With a rising demand for food, Chinese agricultural productivity will have to continue to grow. But continued growth based on intensification and unsustainable land use practices would be difficult. Since the late 1990s, stagnant yield potential has come to characterize Chinese agriculture (see Figure 1), and environmental stress and ecosystem degradation, including productivity constraints from factors such as deterioration of soil and water quality, reduced access to irrigation water, and imbalanced nutrient use (Cassman et al., 2003), are among the main drivers of the slowdown in yield growth (Huang and Rozelle, 1995). Furthermore, the rapid growth of Chinese economy has led to dramatic land use changes that affect both agricultural and natural ecosystems. Remote sensing data shows that urbanization accounted for more than half of the conversion of cropland to other land uses in China by 2000, whereas the increase in cultivated land was primarily due to deforestation and the reclamation of grassland in the western Inner Mongolia region (Liu et al, 2005). These changes further led to a net reduction in agricultural productivity as "new" cropland is often of lower quality than the land withdrawn from agricultural production (Liu et al., 2005).

Agricultural ecosystems are actively managed by humans to optimize the provisioning ecosystem services (ES) of food, forage, fiber, and biofuel (MA, 2005). In the process, they depend on a wide variety of supporting and regulating services (e.g., biological pest control, pollination, maintenance of soil structure and fertility, and nutrient cycling) that determine the underlying biophysical capacity of agricultural ecosystems (Wood et al., 2000; Zhang et al., 2007). The value of these ES to agriculture is enormous and often underappreciated (Power, 2010). Research is needed to understand how to sustainably manage ES provided to agriculture and to minimize agriculture's negative externalities. As agricultural growth strategies based on intensification and unsustainable resource use have been increasingly questioned, investments are required in key areas of the rural sector to protect the resource base (Huang and Rozelle, 1995; Huang et al., 2002), including natural ecosystems that provide vital habitats and alternative food sources for beneficial insects within the agricultural landscapes.

Agricultural land use interacts with the landscape structure in important ways (Garrett, 2008). Structurally complex landscapes enhance local diversity in agricultural ecosystems, which may compensate for local high-intensity management and provide supporting and regulating ES that are important for agriculture (Tscharntke et al., 2005). Empirical evidence shows that increased landscape complexity, which typically means the increased availability of food sources and habitats for insects when compared to mono-culture landscapes, is correlated with diversity and the abundance of natural enemy populations (e.g., Kruess and Tscharntke, 1994), and, in many cases, enhanced pest control (Thies et al., 2003). A meta-analysis by Bianchi et al. (2006) finds that, in 74% of the studies reviewed, natural enemy populations were lower in simple landscapes versus complex landscapes. One of the most profound consequences of land use changes has been the simplification of agricultural landscapes with little natural habitat and its relation to the flows of ES that support agriculture. Resources that beneficial organisms rely on within landscapes are increasingly threatened by habitat and biodiversity loss (Wilby and Thomas, 2002), modern agricultural practices (Naylor and Ehrlich, 1997), and human alterations of natural ecosystems, many of which are attributed to dramatic land use changes.

A pervasive concern is that landscape simplification results in an increase in insect pest pressure, and thus an increased need for insecticides (Meehan et al., 2011).We test this hypothesis at the Chinese county scale across a range of insect pests, using remotely sensed land cover data, data from a survey of counties in the national pest monitoring network, and data from a national census of the agricultural sector. Specifically, we investigate the empirical relationships between land use (measured in diversity indices and proportional area of six land use categories), pest pressure, and insecticide application in rice and cotton. Understanding the relationship is critical if we want science-based policy to guide future landscape change (Meehan et al., 2011).

Our study contributes to the literature in three fundamental aspects. First, while the literature has been focused on the role of landscape structure in the provision of pest regulation ES, this study tests the hypothesis regarding the link between land use, pest pressure, and insecticide use at the county scale.[1] A broad correlative support for the hypothesized relationships at the county level offers further evidence of the important role of landscape diversity in the provision of pest regulation ES, assuming land use diversity in the county stems from diversity within individual landscapes as opposed to diversity between landscapes, which is very likely the case in China because of the prevalence of highly diverse agro-ecosystems at small plot level. The analysis is the first one to provide empirical evidence on the connection between land use diversity and pest pressure in China, where empirical studies on the role of landscape context in pest control ES is non-existent. In addition to the value to concept-proving, establishing the correlative link at the county scale provides options to local (county) governments to make land use policy to guide future landscape change.

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[1] On average, the sizes of counties are 890 km^2, 2,020 km^2 and 9,134 km^2 for small, medium and large counties, respectively, while the national average size is 4,013 km^2.

Second, we use a unique dataset of pest pressure and number of insecticide application collected through a survey of counties in the national pest monitoring network for rice and cotton. The panel data, covering 1996-2010 for cotton and 1991-2010 for rice, include 5 main insect pests, cotton aphid (CA, *Aphis gossypii*), cotton miridae (CM, mainly including *Apolygus lucorum*, *Adelphocoris suturalis*, *Adelphocoris lineolatus* and *Adelphocoris fasciaticollis*), cotton bollworm (CB, *Helicoverpa armigera*), rice planthoppes (RP, including *Nilaparvata lugens*, *Sogatella furcifera* and *Laodelphax striatellus*), and rice stem borers (RSB, mainly including *Tryporyza incertulas* and *Chilo suppressalis*), and one plant disease, rice blast (RB, *Magnaporthe sea*). This dataset, coupled with a county-level land cover/use dataset, which classifies land use in six categories including cultivated land, forest, grassland, man-made built-up (thereafter referred as “built-up”), unused land, and water body, and a county-level socio-economic dataset from the Chinese Academy of Agricultural Sciences, enables us to examine the empirical relationships between land use diversity indices, proportional area of different types of land use, pest pressure, and the number of insecticide use.

Third, the existing literature has been focused on limited geographic regions (i.e., Europe and North America). The hypothesis regarding the role of landscape diversity in pest control has yet to be tested in a developing country context. China offers a unique case to study in that, smallholder farming is the predominant agricultural land use and cropping decisions are highly decentralized. In addition, Chinese agricultural production has been characterized by intensive chemical insecticide use. These two factors imply very disturbed agro-ecosystems but also diverse land use at small plot level.

Meehan et al. (2011), the only study that exists in the literature which examines the relationships between landscape simplification, pest pressure, and insecticide use, using county level data for seven states of the Midwestern United States in 2007, found that independent of several other factors, the proportion of harvested cropland treated with insecticides increased with the proportion and patch size of cropland and decreased with the proportion of semi-natural habitat in a county. They also found a positive relationship between the proportion of harvested cropland treated with insecticides and crop pest abundance, and a positive relationship between crop pest abundance and the proportion cropland in a county. While results from Meehan et al. (2011) provide broad correlative support for the hypothesized link between landscape simplification, pest pressure, and insecticide use, and it was able to use crop-specific land use data, the study mainly focused on cropland and semi-natural land without differentiating different types of semi-natural land (e.g., forest, grassland, and unused land). In addition, although proportion of cropland treated with insecticides might be a good indicator for insecticide application for the US case study because of the wide adoption of economic threshold as well as the existence of alternative control methods, it may not work as well as the number of insecticide application, as the current study uses, for a Chinese study because of the heavy and injudicious practice of insecticides, and the lack of alternative control methods by smallholder farmers.

2. Methods

2.1 Data

We conducted a survey of counties in the national pest monitoring network to collect data on pest pressure, number of insecticide application, and estimated percentage yield loss for each pest in rice and cotton. The dataset covers 48 counties in 8 provinces for the period of 1996-2010 for cotton and 107 counties in 12 provinces for the period of 1991-2010 for rice. It was possible to collect the panel data because counties have been keeping these records for their annual report to provincial government. Pest pressure is measured in level of pest infestation following the national standard for categorizing pest pressure: 1 (no pest occurrence or very low level), 2 (slight infestation), 3 (moderate infestation), 4 (severe infestation), and 5 (extremely severe infestation).

Our county-level land use data were drawn from a national land use/cover dataset developed by the Institute of Geographic Sciences and Natural Resources Research (IGSNRR), Chinese Academy of Sciences (CAS). Developed based on satellite remote sensing data from the Landsat Thematic Mapper (TM)/Enhanced Thematic Mapper (ETM) images with a spatial resolution of 30 by 30 meters, the dataset has been used in a number of publications (e.g., Liu et al., 2010; Deng et al., 2008; Dent et al., 2011). The dataset, which includes a hierarchical classification system of 25 land cover classes, offers the most comprehensive coverage of China's land use for four time periods: i) the late 1980s (1986-1989), ii) the mid-1990s (1995-1996), iii) the late 1990s (1999-2000), and iv) the mid-2000s. This study uses data for the first hierarchy of classification, including cultivated land, forest, grassland, water body, built-up area and unused land (Table x). Based on the data, we computed the proportional area for each land use as well as land use diversity indices for each county.

2.2 Analysis methods

2.2.1 *Land use diversity metrics*

Among the most popular of metrics used to quantify landscape composition are the Shannon index, believed to emphasize the richness component of diversity, and the Simpson index, emphasizing the evenness component and more responsive to the dominant cover type (Nagendra, 2002).The Shannon index, also known as Shannon-Wiener index or Shannon entropy, has been a popular diversity index in the ecological literature:

$$I = -\sum_{i=1}^{m} P_i ln P_i \qquad (1)$$

where P_i is the probability of the i^{th} investigation object, and m is the total number of investigation objects (Shannon, 1948). The Simpson index measures the degree of concentration when individuals are classified into types (Simpson, 1949):

$$S = \sum_{i=1}^{m} P_i^2 \qquad (2)$$

To get the true diversity of diversity indices, we translate them back to the scale of "effective number of species" (MacArthur, 1965). The “effective number of species” is given as $\exp(-\sum_{i=1}^{m} P_i ln P_i)$for the Shannon index is and $(\sum_{i=1}^{m} P_i^2)^{-1}$ for the Simpson index. While the Shannon index is recommended for landscape management within an ecological framework by Nagendra (2002) and this study gives greater attention to the Shannon index when interpreting the results, we also consider the Simpson index for reference purpose.

2.2.2 *Econometric analysis*

To examine the relationship between land use and pest pressure, we constructed a two-stage econometric model. In the 1ststage, the model (M1) focuses on examining the effect of land use diversity (measured in Shannon and Simpson diversity indices converted to “effective number of species”) on pest pressure. A negative relationship implies that the more diverse the land uses are, the lower the level of pest infestation in rice and cotton is, based on the panel data collected at the county scale. In the 2nd stage, the model (M2) examines the effects of proportional area of different land uses on pest pressure. Since the diversity indices are computed from the proportional area of different land uses, they are not included in the same model to avoid multicolinearity.

For the ordinal dependent variable of pest pressure, we used the Stata program “gllamm” to estimate an ordered probit model. The program gllamm, written by Rabe-Hesketh, Skrondal and Pickles (2004 and 2005), runs in the statistical package Stata and estimates GLLAMMs (Generalized Linear Latent And Mixed Models) by maximum likelihood (www.gllamm.org).

Eventually, we are interested in the change in the response probabilities as a result of the change in each of the explanatory variables. Since we estimated an ordered probit model, interpretation of the estimated coefficients is not straightforward. In general, relative to the signs of the coefficients, only the signs of the changes in the probability of the lowest and highest categories, i.e., *Prob*(y=1) and *Prob*(y=5), are unambiguous. The signs of coefficients do not always determine the directions of the effects for the intermediate outcomes (i.e., categories 2, 3 and 4). In addition, the marginal effects of the explanatory variables on the probabilities are not equal to the coefficients and need to be calculated.

The ordered probit model is built around a latent regression (Greene, 2000):

$$y^* = \mathbf{x}\boldsymbol{\beta} + \varepsilon \tag{3}$$

$$\varepsilon \mid \mathbf{x} \sim N(0,1)$$

where y^* is unobserved. What we do observe is

$$\begin{aligned} y &= 1 \text{ if } y^* \leq \alpha_1 \\ &= 2 \text{ if } \alpha_1 < y^* \leq \alpha_2 \\ &= 3 \text{ if } \alpha_2 < y^* \leq \alpha_3 \\ &= 4 \text{ if } \alpha_3 < y^* \leq \alpha_4 \\ &= 5 \text{ if } y^* > \alpha_4 \end{aligned} \tag{4}$$

where the α's are called cutoff points or threshold parameters that are important determinants of the magnitudes of the estimated probabilities and partial effects and can be estimated by maximum likelihood. The marginal effects of changes in explanatory variable x_k are computed as:

$$\frac{\partial Prob(y=1)}{\partial x_k} = -\beta_k \phi(\alpha_1 - \mathbf{x}\boldsymbol{\beta}) \tag{5}$$

$$\frac{\partial Prob(y=2)}{\partial x_k} = -\beta_k[\emptyset(\alpha_2 - \mathbf{x}\boldsymbol{\beta}) - \emptyset(\alpha_1 - \mathbf{x}\boldsymbol{\beta})] \tag{6}$$

… …

$$\frac{\partial Prob(y=5)}{\partial x_k} = \beta_k\emptyset(\alpha_4 - \mathbf{x}\boldsymbol{\beta}) \tag{7}$$

where ø denotes standard normal density.

Reference

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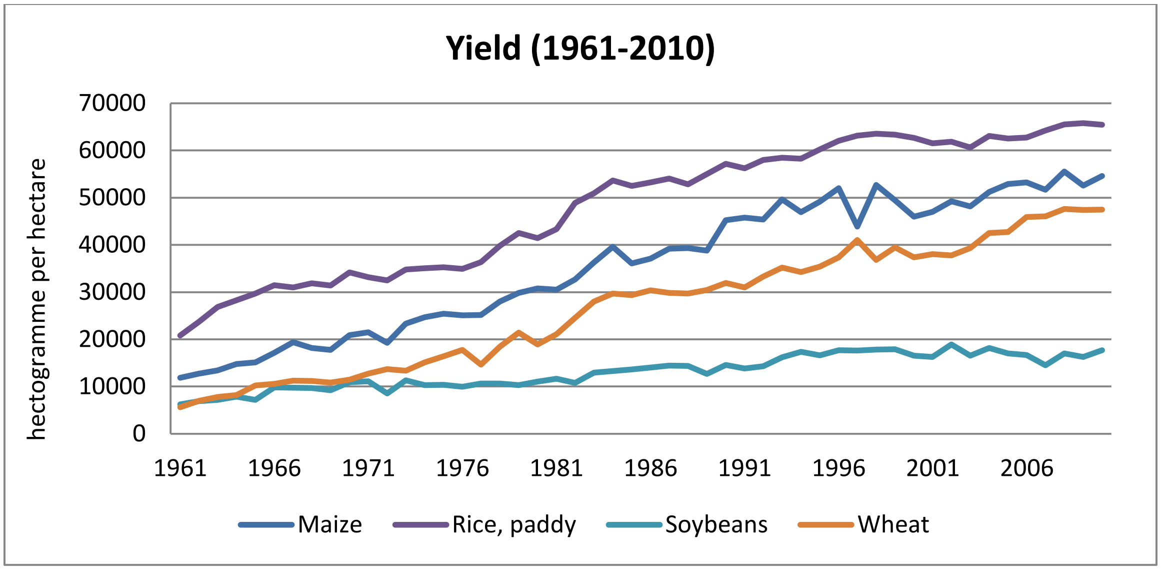


Figure 1: Yield of maize, rice, soybean and wheat in China from 1961 to 2010. Source: FAOSTAT.

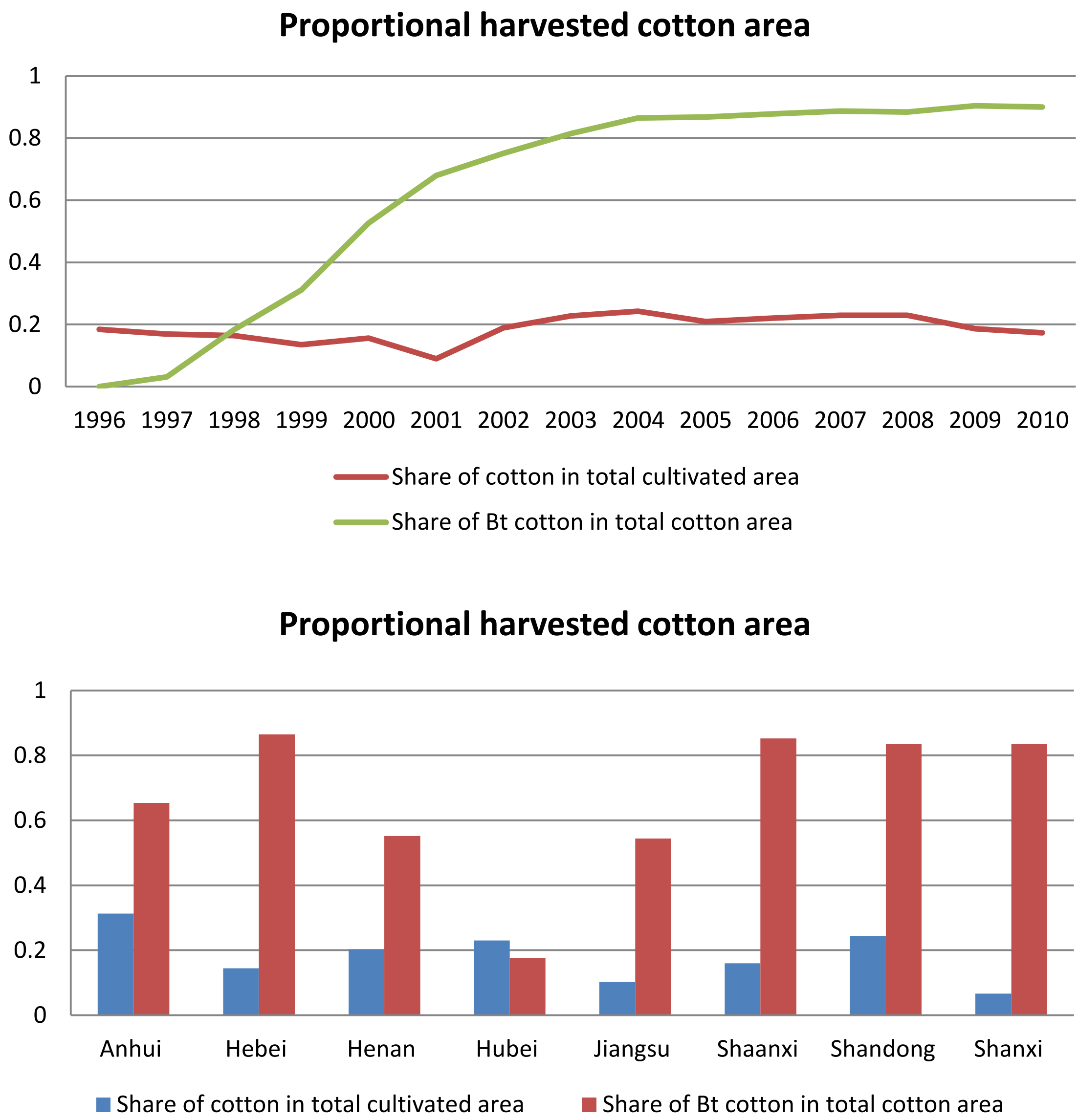
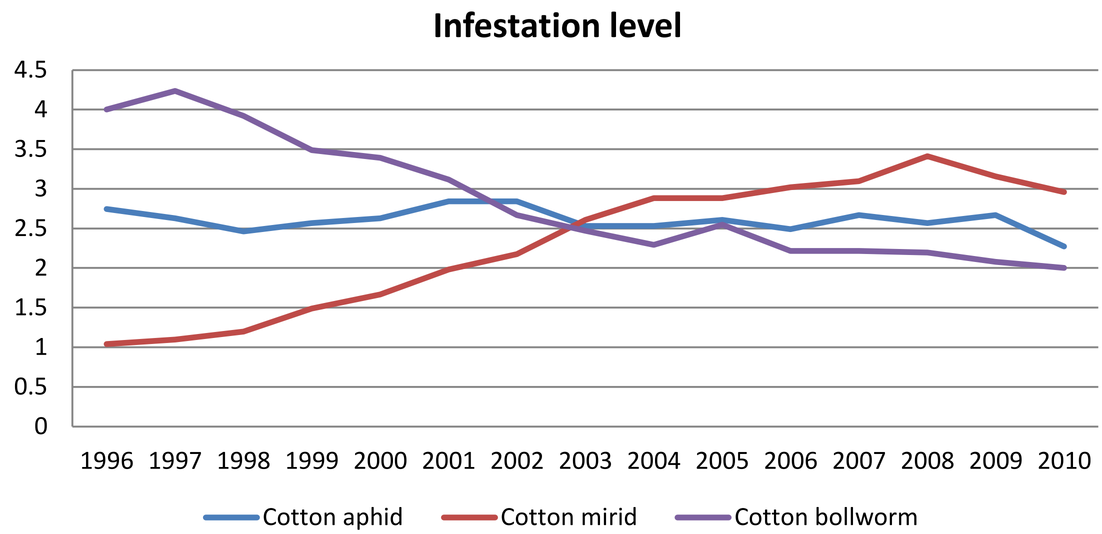


Figure 2: Proportion of harvested cotton area in total cultivated area and proportion of harvested Bt cotton area in total harvested cotton area by year and province



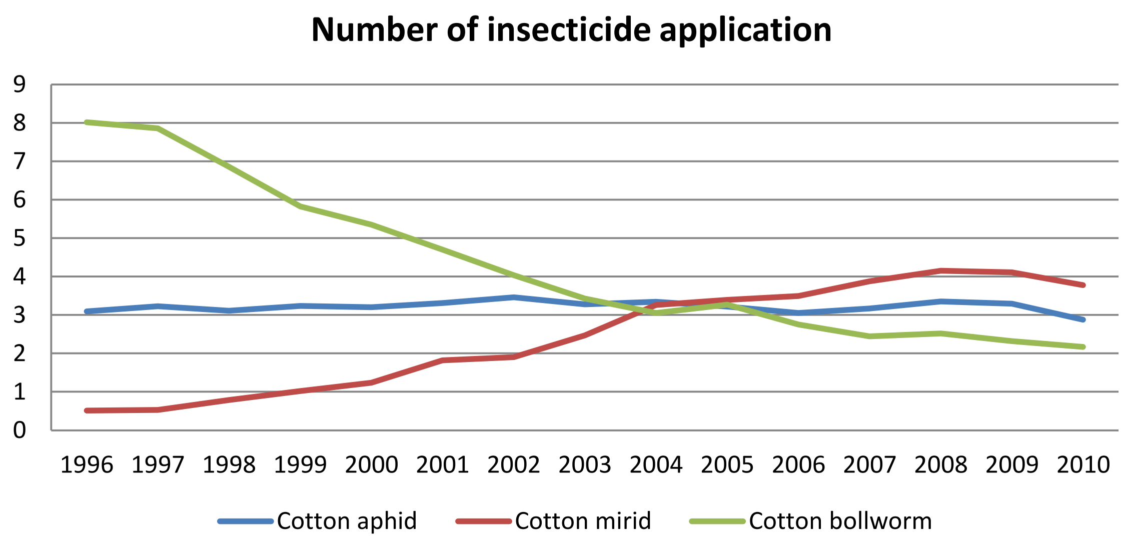
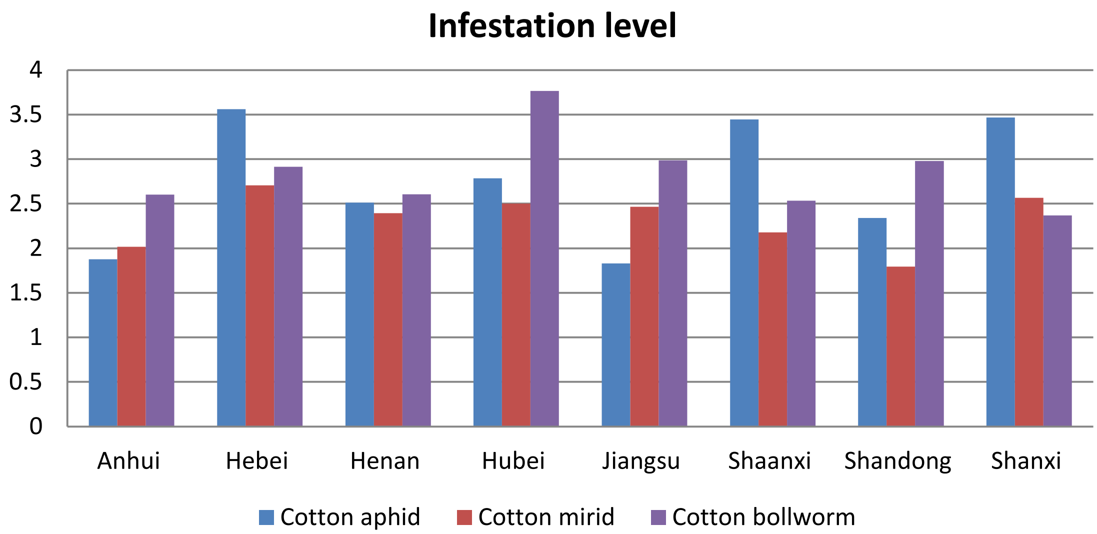


Figure 3: Pest pressure and insecticide use for each cotton pest by year



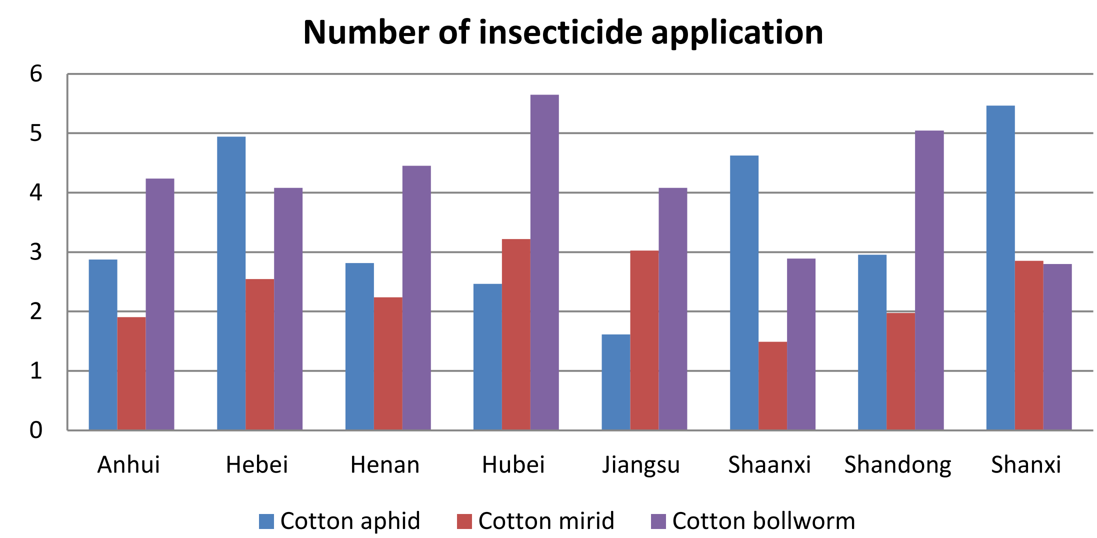
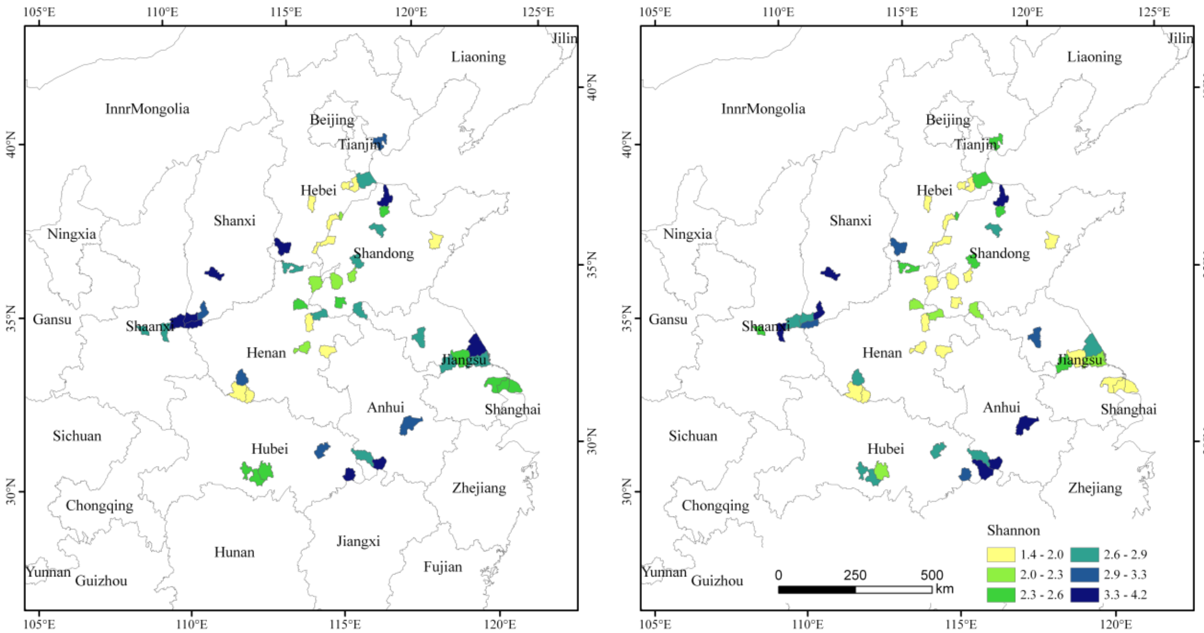


Figure 4: Pest pressure and insecticide use for each cotton pest by province



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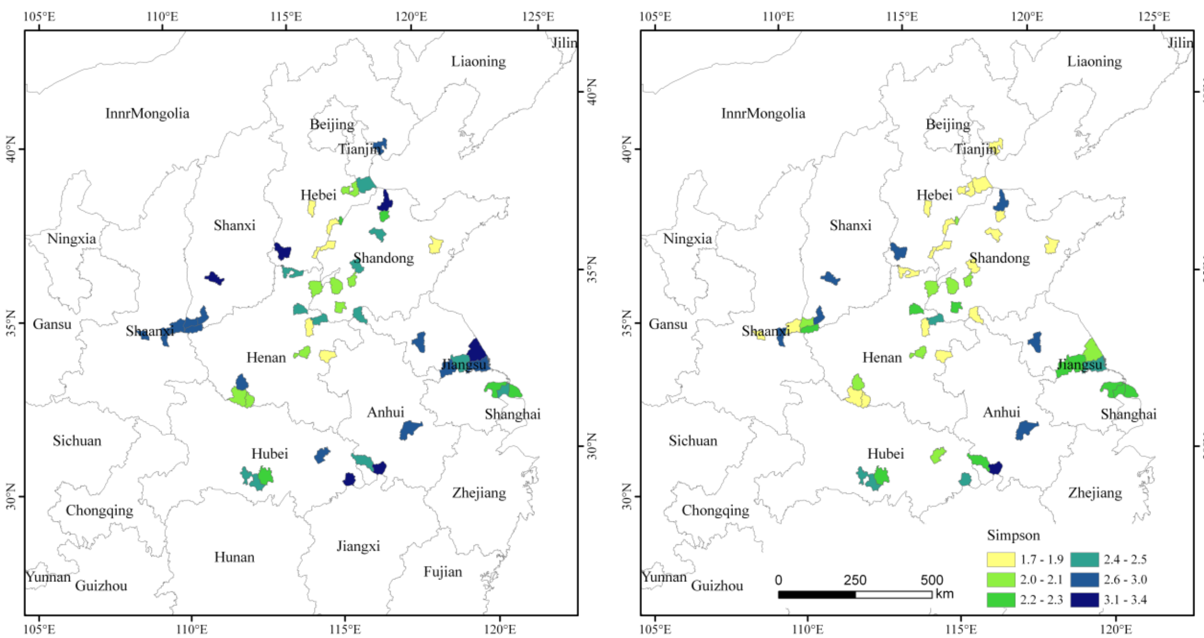

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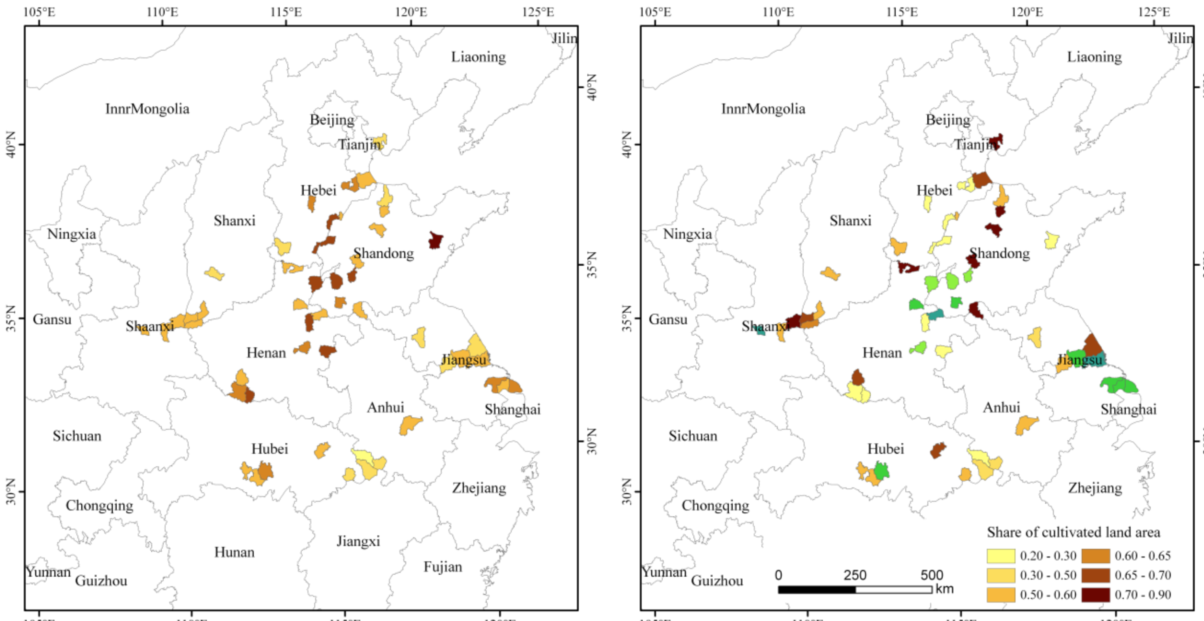
Figure 5: Shannon and Simpson diversity indices for cotton counties in 1990 (a) and 2005 (b)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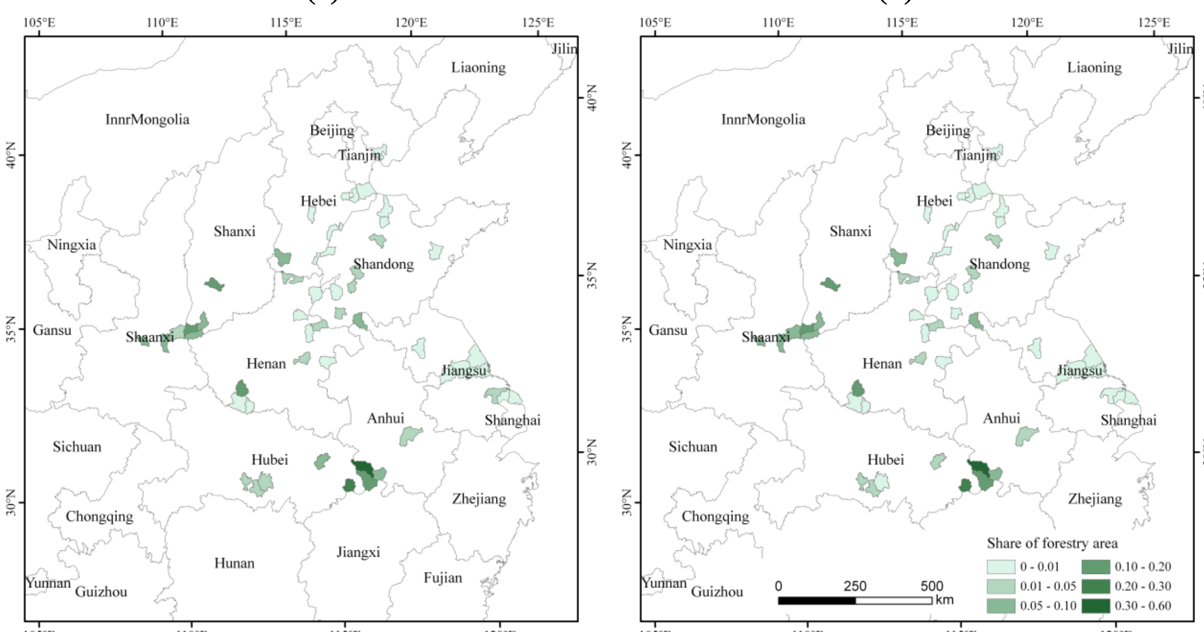
Yunnan
Guizhou
105°E
110°E
115°E
120°E
125°E
30°N
35°N
40°N
Share of cultivated land area
0.20 - 0.30
0.30 - 0.50
0.50 - 0.60
0.60 - 0.65
0.65 - 0.70
0.70 - 0.90
0
250
500
km

(a) (b)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105°E
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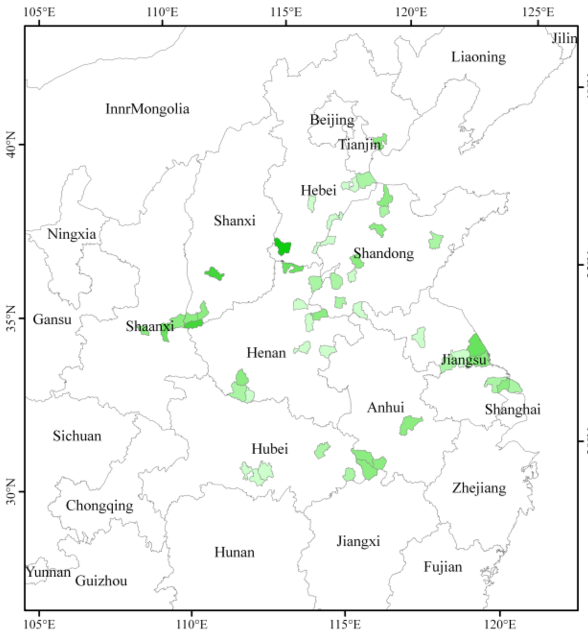
115°E
120°E
125°E
30°N
35°N
40°N
Share of forestry area
0 - 0.01
0.01 - 0.05
0.05 - 0.10
0.10 - 0.20
0.20 - 0.30
0.30 - 0.60
0
250
500
km

(a) (b)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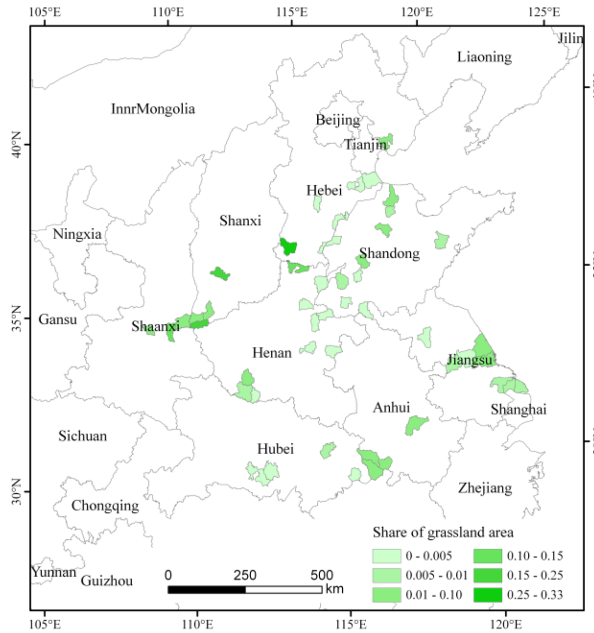
(a)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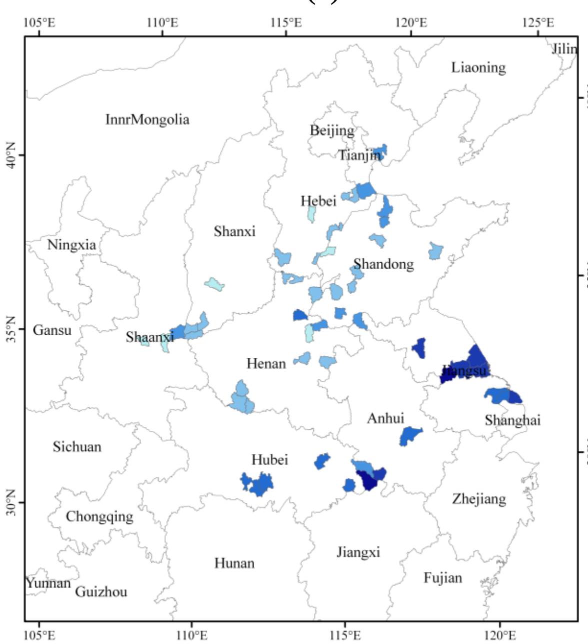
Hubei
Zhejiang
Chongqing
Yunnan
Guizhou
Share of grassland area
0 - 0.005
0.005 - 0.01
0.01 - 0.10
0.10 - 0.15
0.15 - 0.25
0.25 - 0.33
0
250
500
km

(b)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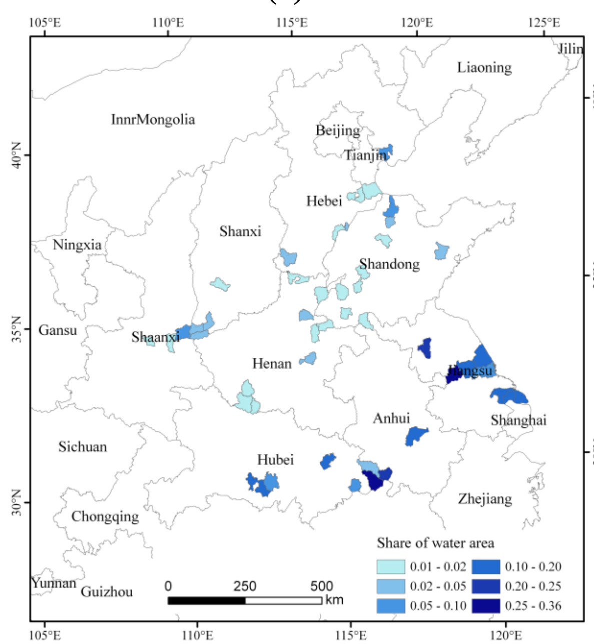
(a)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Anhui
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Hubei
Zhejiang
Chongqing
Yunnan
Guizhou
Share of water area
0.01 - 0.02
0.02 - 0.05
0.05 - 0.10
0.10 - 0.20
0.20 - 0.25
0.25 - 0.36
0
250
500
km

(b)

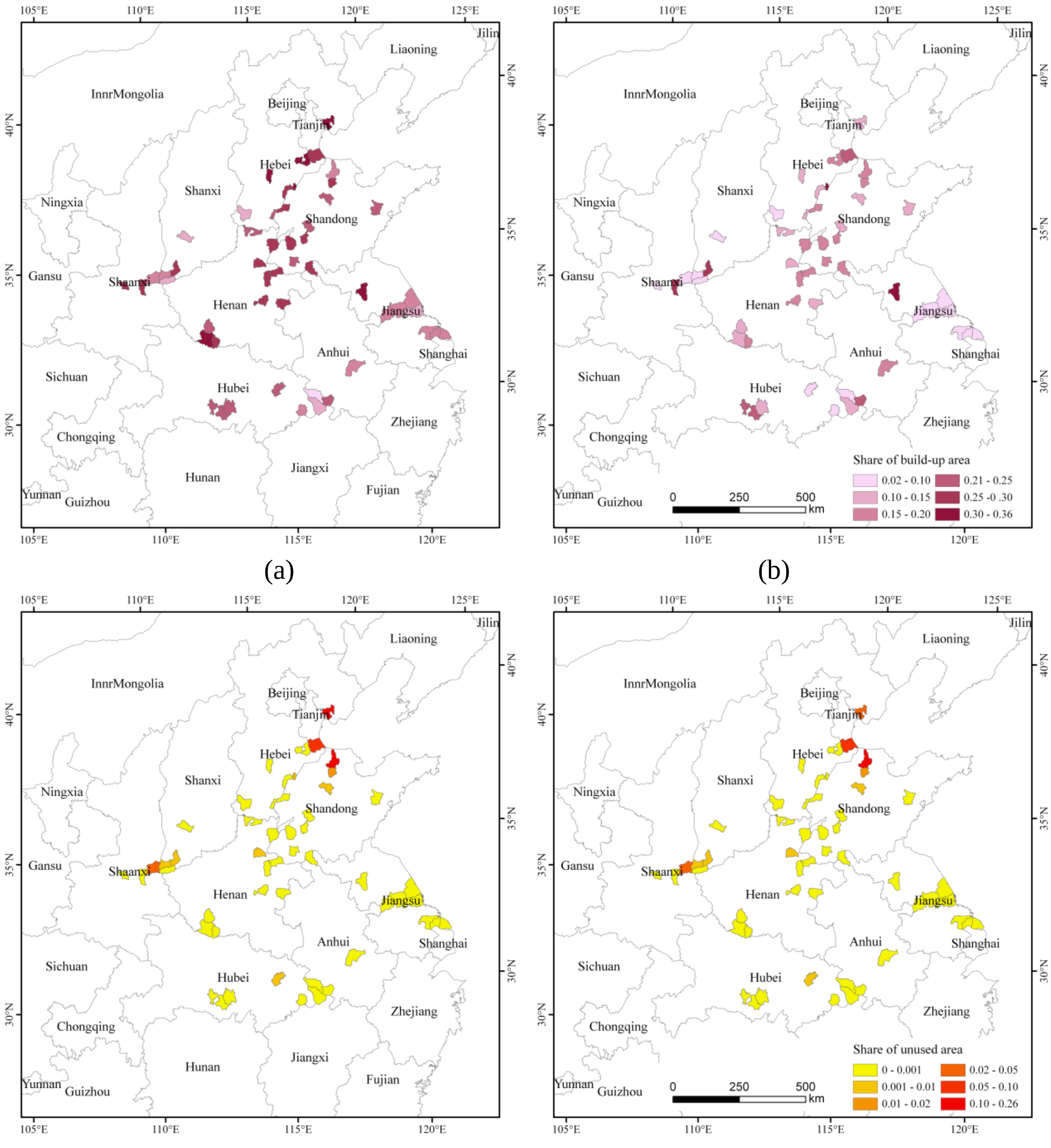


Figure 6: Proportional area of cultivated land, forest, grassland, water body, build-up and unused land for cotton counties in 1990 (a) and 2005 (b)

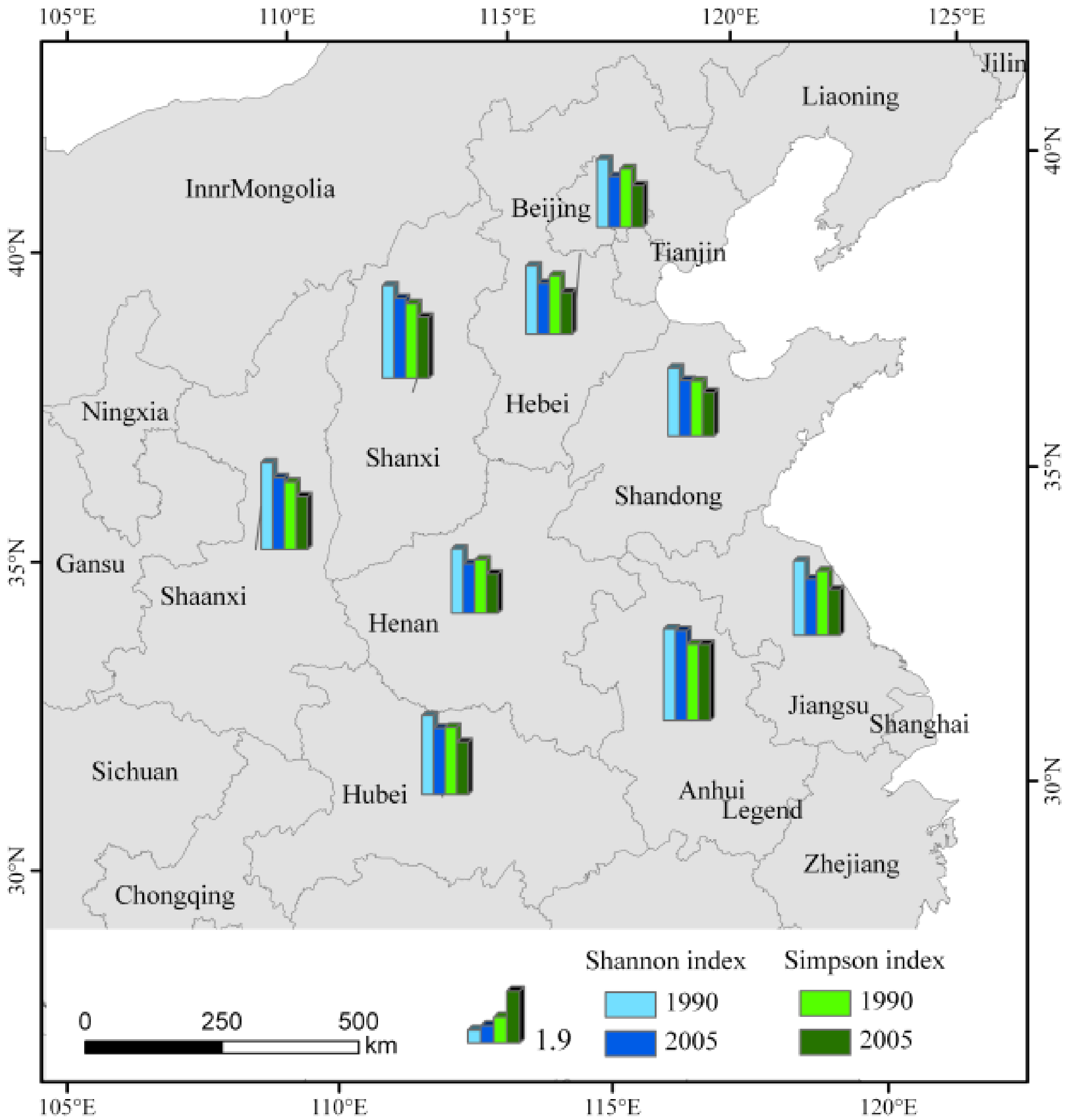
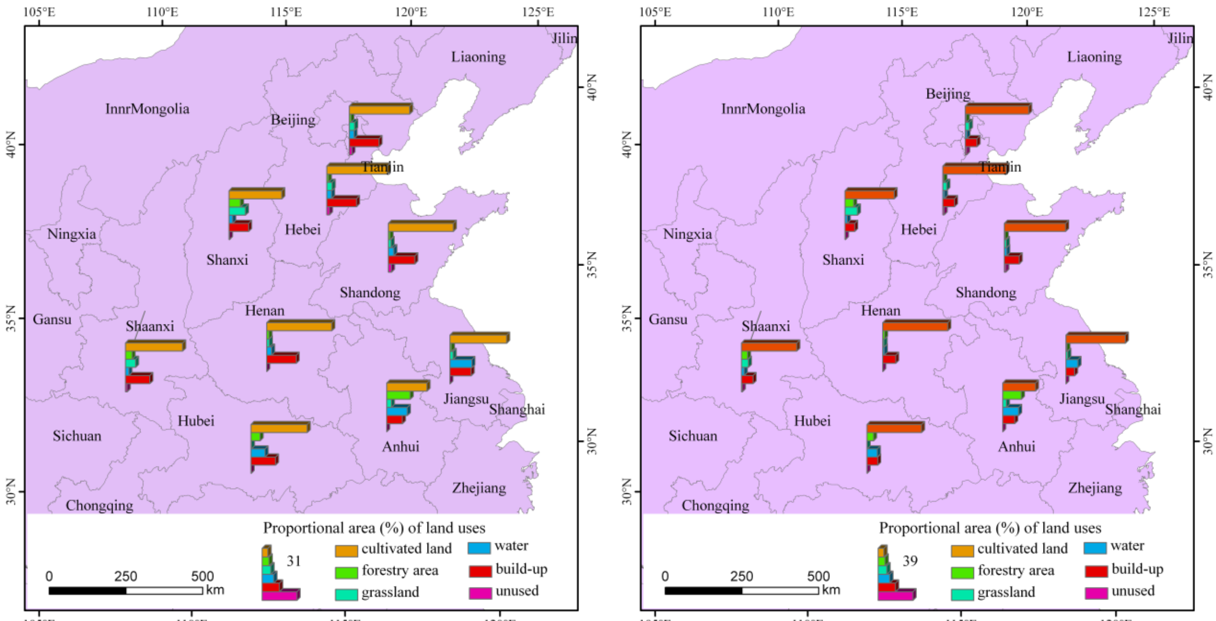


Figure 7: Shannon and Simpson indices for cotton counties in 1990 and 2005 by province



(a) (b)

Figure 8: Proportional area of cultivated land, forest, grassland, water body, build-up and unused land for cotton counties in 1990 (a) and 2005 (b) by province

Table 1. The hierarchical classification applied to the national land use/cover dataset of China

	Level 1	Level 2
1	Farmland	Paddy
		Dry farming
2	Forest	Forest
		Shrub
		Woods
		Others
3	Grassland	Dense grass
		Moderate Grass
		Sparse grass
4	Water body	Rivers
		Lakes
		Reservoir and ponds
		Permanent Ice and Snow
		Beach and Shore
		Bottomland
5	Man-made Built-up	City built-up
		Rural settlements
		others
6	Unused	Sand
		Gobi
		Salina
		Wetland
		Bare Soil
		Bare Rock
		Others

Table 1: Estimated coefficients for the model of the effect of land use diversity on pest infestation level in cotton

	Cotton aphid (CA)		Cotton miridae (CM)		Cotton bollworm (CB)	
	(1)	(2)	(3)	(4)	(5)	(6)
Shannon	-0.644***		-0.637***		-0.210	
	(0.150)		(0.226)		(0.169)	
Simpson		-0.600***		-0.139		-0.173
		(0.195)		(0.249)		(0.211)
ShrCotton_TotCulti	0.120	-0.636	-0.562	-1.097	-1.964***	-1.873***
	(0.543)	(0.684)	(0.730)	(0.699)	(0.673)	(0.683)
ShrBt_Cotton	0.335	0.308	-0.185	-0.225	-0.901***	-0.906***
	(0.259)	(0.290)	(0.330)	(0.303)	(0.254)	(0.254)
cb_PestiUse	0.0588***	0.0616**	-0.0846**	-0.0945***		
	(0.0228)	(0.0286)	(0.0336)	(0.0324)		
mtemp51	13.03*	9.786	21.10**	22.59**	-1.141	-1.132
	(7.247)	(7.605)	(9.028)	(8.965)	(7.597)	(7.577)
mtemp61	4.022	10.17	-8.060	-4.628	-4.636	-4.550
	(8.205)	(8.621)	(9.725)	(9.667)	(8.410)	(8.467)
mtemp71	17.46*	13.52	-29.23**	-32.06**	-5.626	-5.583
	(9.618)	(9.783)	(12.58)	(12.56)	(9.977)	(9.999)
mtemp81	-35.31***	-36.95***	13.60	18.56	2.286	2.394
	(10.93)	(11.18)	(13.17)	(13.21)	(11.21)	(11.29)
mprecip51	-0.00456	-0.122	0.102	0.0987	0.00312	0.00549
	(0.146)	(0.162)	(0.171)	(0.169)	(0.149)	(0.150)
mprecip61	0.122	0.0912	0.0460	0.0344	-0.141*	-0.140*
	(0.0825)	(0.0824)	(0.0947)	(0.0953)	(0.0818)	(0.0819)
mprecip71	-0.0350	-0.0538	0.111	0.0947	0.0832	0.0849
	(0.0638)	(0.0656)	(0.0745)	(0.0741)	(0.0660)	(0.0655)
mprecip81	-0.162**	-0.182**	0.00272	0.0218	-0.0394	-0.0369
	(0.0703)	(0.0719)	(0.0908)	(0.0902)	(0.0720)	(0.0723)
d_Anhui	-1.591**	-1.135	-0.379	-0.561	-0.452	-0.469
	(0.772)	(0.737)	(1.270)	(1.255)	(0.879)	(0.866)
d_Hebei	-0.861	-0.382	1.394	1.816	-0.325	-0.226
	(0.698)	(0.628)	(1.167)	(1.115)	(0.801)	(0.775)
d_Henan	-2.104***	-1.711***	0.707	1.249	-0.745	-0.669
	(0.717)	(0.641)	(1.204)	(1.123)	(0.842)	(0.811)
d_Hubei	-1.034	-0.340	1.481	1.469	1.746*	1.756**
	(0.790)	(0.763)	(1.234)	(1.175)	(0.895)	(0.867)
d_Jiangsu	-2.416***	-1.843***	0.697	0.771	0.109	0.163
	(0.766)	(0.715)	(1.190)	(1.137)	(0.837)	(0.812)
d_Shandong	-1.977***	-1.661**	-0.556	-0.148	0.0642	0.114
	(0.705)	(0.654)	(1.190)	(1.135)	(0.805)	(0.776)
d_Shanxi	-0.0690	0.0358	2.080*	1.698	-0.803	-0.787
	(0.698)	(0.629)	(1.177)	(1.126)	(0.808)	(0.787)
d_1997	0.0673	0.111	0.756	0.645	0.667**	0.666**

	(0.261)	(0.266)	(0.560)	(0.556)	(0.280)	(0.281)
d_1998	-0.156	-0.0158	1.533***	1.537***	0.141	0.139
	(0.298)	(0.303)	(0.568)	(0.563)	(0.308)	(0.308)
d_1999	-0.278	-0.256	2.030***	1.994***	-0.641**	-0.632**
	(0.263)	(0.266)	(0.518)	(0.516)	(0.268)	(0.268)
d_2000	-0.306	-0.237	2.391***	2.357***	-0.439	-0.433
	(0.296)	(0.309)	(0.551)	(0.540)	(0.301)	(0.301)
d_2001	-0.378	-0.357	3.209***	3.247***	-0.801**	-0.793**
	(0.361)	(0.385)	(0.597)	(0.591)	(0.363)	(0.366)
d_2002	0.110	0.138	3.700***	3.776***	-1.593***	-1.583***
	(0.347)	(0.376)	(0.588)	(0.584)	(0.361)	(0.365)
d_2003	-0.588*	-0.538	3.720***	3.889***	-1.964***	-1.952***
	(0.334)	(0.378)	(0.567)	(0.569)	(0.345)	(0.350)
d_2004	-0.891**	-0.728*	4.188***	4.469***	-2.177***	-2.158***
	(0.376)	(0.427)	(0.621)	(0.624)	(0.392)	(0.401)
d_2005	-0.828**	-0.827*	4.339***	4.586***	-1.737***	-1.710***
	(0.383)	(0.440)	(0.616)	(0.619)	(0.400)	(0.409)
Constant - cut11	-5.760***	-5.744***	-0.726	2.344	-7.662***	-7.324***
	(1.654)	(1.795)	(2.281)	(2.249)	(1.876)	(1.921)
Constant - cut12	-4.019**	-4.011**	0.594	3.658	-5.996***	-5.659***
	(1.641)	(1.778)	(2.282)	(2.258)	(1.870)	(1.915)
Constant - cut13	-2.795*	-2.796	1.729	4.786**	-4.195**	-3.861**
	(1.637)	(1.774)	(2.279)	(2.264)	(1.864)	(1.908)
Constant - cut14	-1.414	-1.421	3.379	6.443***	-2.590	-2.260
	(1.634)	(1.773)	(2.269)	(2.273)	(1.861)	(1.905)
Constant - cnt_1	1.092***	0.940***	1.184***	1.132***	1.016***	1.003***
	(0.108)	(0.112)	(0.140)	(0.128)	(0.0887)	(0.0893)
Observations	457	457	457	457	457	457
ll	-519.9	-520.5	-372.8	-373.0	-470.2	-470.7

Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1)

Table 2: Estimated average partial effects of different land use types on pest infestation level in cotton

		Estimated coefficient	Average Partial Effects				
			I	II	III	IV	V
Cotton aphid (CA)							
(1)	*Shannon*	-0.644***	0.088	0.070	-0.035	-0.084	-0.039
	cb_PestiUse	0.0588***	-0.008	-0.006	0.003	0.008	0.004
	mtemp51	13.03*	-1.771	-1.423	0.717	1.689	0.788
	mtemp71	17.46*	-2.373	-1.907	0.961	2.264	1.056
	mtemp81	-35.31***	4.799	3.856	-1.943	-4.578	-2.134
	mprecip81	-0.162**	0.022	0.018	-0.009	-0.021	-0.010
(2)	*Simpson*	-0.600***	0.084	0.064	-0.033	-0.078	-0.037
	cb_PestiUse	0.0616**	-0.009	-0.007	0.003	0.008	0.004
	mtemp81	-36.95***	5.146	3.945	-2.044	-4.796	-2.251
	mprecip81	-0.182**	0.025	0.019	-0.010	-0.024	-0.011
Cotton miridae (CM)							
(3)	*Shannon*	-0.637***	0.103	-0.011	-0.028	-0.046	-0.018
	cb_PestiUse	-0.0846**	0.014	-0.001	-0.004	-0.006	-0.002
	mtemp51	21.10**	-3.408	0.361	0.926	1.527	0.595
	mtemp71	-29.23**	4.722	-0.500	-1.283	-2.115	-0.824
(4)	*Simpson*	-	-	-	-	-	-
	cb_PestiUse	-0.0945***	0.015	-0.002	-0.004	-0.007	-0.003
	mtemp51	22.59**	-3.677	0.412	0.991	1.639	0.635
	mtemp71	-32.06**	5.221	-0.585	-1.407	-2.327	-0.902
Cotton bollworm (CB)							
(5)	*Shannon*	-	-	-	-	-	-
	ShrCotton_TotCulti	-1.964***	0.134	0.172	0.054	-0.108	-0.253
	ShrBt_Cotton	-0.901***	0.062	0.079	0.025	-0.049	-0.116
	mprecip61	-0.141*	0.010	0.012	0.004	-0.008	-0.018
(6)	*Shannon*	-	-	-	-	-	-
	ShrCotton_TotCulti	-1.873***	0.128	0.165	0.052	-0.103	-0.242
	ShrBt_Cotton	-0.906***	0.062	0.080	0.025	-0.050	-0.117
	mprecip61	-0.140*	0.010	0.012	0.004	-0.008	-0.018

Table 3: Estimated coefficients for the proportional area of different land uses in relation to cotton aphid (CA) infestation level by reference land use type

	Reference land use type					
	(1)	(2)	(3)	(4)	(5)	(6)
	Shr_Bldup	Shr_Culti	Shr_Frst	Shr_Grld	Shr_Unused	Shr_Wat
ShrCotton_TotCulti	-0.229	0.185	0.185	-1.155	-0.229	-0.229
	(0.542)	(0.576)	(0.576)	(0.706)	(0.542)	(0.542)
ShrBt_Cotton	0.410	0.175	0.175	0.262	0.410	0.410
	(0.295)	(0.249)	(0.249)	(0.269)	(0.295)	(0.295)
Shr_Bldup		-1.827	1.016	-3.668**	11.00***	-2.420
		(1.814)	(1.532)	(1.602)	(2.849)	(2.159)
Shr_Culti	3.064		2.843**	-4.986***	14.06***	0.644
	(2.149)		(1.145)	(1.781)	(2.826)	(1.621)
Shr_Frst	1.180	-2.843**		-5.707***	12.18***	-1.241
	(1.776)	(1.145)		(1.969)	(2.852)	(1.292)
Shr_Grld	2.641*	0.901	3.743**		13.64***	0.221
	(1.495)	(1.426)	(1.604)		(2.816)	(2.018)
Shr_Unused	-11.00***	-14.02***	-11.17***	-15.54***		-13.42***
	(2.848)	(2.587)	(2.761)	(3.111)		(3.151)
Shr_Wat	2.420	-4.840***	-1.998	-10.82***	13.42***	
	(2.159)	(1.753)	(1.365)	(2.842)	(3.151)	
cb_PestiUse	0.0574**	0.0611**	0.0611**	0.0760***	0.0574**	0.0574**
	(0.0231)	(0.0249)	(0.0249)	(0.0288)	(0.0231)	(0.0231)
mtemp51	16.09**	11.85	11.85	10.92	16.09**	16.09**
	(7.259)	(7.279)	(7.277)	(7.465)	(7.258)	(7.258)
mtemp61	6.715	5.933	5.933	7.029	6.715	6.715
	(8.413)	(8.338)	(8.330)	(8.921)	(8.414)	(8.409)
mtemp71	19.90**	14.04	14.04	13.16	19.90**	19.90**
	(9.607)	(9.560)	(9.544)	(9.744)	(9.602)	(9.606)
mtemp81	-38.65***	-39.78***	-39.78***	-42.02***	-38.65***	-38.65***
	(10.99)	(10.95)	(10.93)	(11.07)	(10.98)	(10.99)
mprecip51	-0.0219	0.0226	0.0226	-0.0834	-0.0219	-0.0219
	(0.143)	(0.146)	(0.146)	(0.160)	(0.143)	(0.143)
mprecip61	0.114	0.102	0.102	0.0980	0.114	0.114
	(0.0817)	(0.0813)	(0.0813)	(0.0841)	(0.0816)	(0.0817)
mprecip71	-0.0607	-0.0719	-0.0719	-0.0676	-0.0607	-0.0607
	(0.0637)	(0.0635)	(0.0635)	(0.0645)	(0.0637)	(0.0637)
mprecip81	-0.170**	-0.178**	-0.178**	-0.198***	-0.170**	-0.170**
	(0.0725)	(0.0708)	(0.0708)	(0.0716)	(0.0725)	(0.0725)
d_Anhui	-2.335***	-0.803	-0.803	0.260	-2.335***	-2.335***
	(0.809)	(1.346)	(1.347)	(0.941)	(0.809)	(0.809)
d_Hebei	-0.370	0.151	0.151	0.635	-0.370	-0.370
	(0.656)	(1.237)	(1.237)	(0.724)	(0.656)	(0.656)
d_Henan	-1.576**	-1.034	-1.034	-0.444	-1.576**	-1.576**
	(0.674)	(1.256)	(1.256)	(0.753)	(0.674)	(0.674)

d_Hubei	-1.063	0.699	0.699	1.242	-1.063	-1.063
	(0.767)	(1.321)	(1.321)	(0.908)	(0.767)	(0.767)
d_Jiangsu	-2.564***	-1.731	-1.731	-0.238	-2.564***	-2.564***
	(0.763)	(1.328)	(1.328)	(0.905)	(0.763)	(0.763)
d_Shandong	-1.397**	-0.702	-0.702	-0.369	-1.397**	-1.397**
	(0.694)	(1.254)	(1.254)	(0.739)	(0.694)	(0.694)
d_Shanxi	-0.570	-0.0757	-0.0757	-0.0842	-0.570	-0.570
	(0.659)	(1.246)	(1.246)	(0.750)	(0.659)	(0.659)
d_1997	0.0163	0.141	0.141	0.194	0.0163	0.0163
	(0.260)	(0.261)	(0.261)	(0.264)	(0.260)	(0.260)
d_1998	-0.151	-0.0987	-0.0987	0.0118	-0.151	-0.151
	(0.299)	(0.299)	(0.299)	(0.310)	(0.299)	(0.299)
d_1999	-0.341	-0.249	-0.249	-0.253	-0.341	-0.341
	(0.268)	(0.266)	(0.266)	(0.273)	(0.268)	(0.268)
d_2000	-0.425	-0.148	-0.148	-0.145	-0.425	-0.425
	(0.307)	(0.295)	(0.294)	(0.310)	(0.307)	(0.307)
d_2001	-0.590	-0.254	-0.254	-0.202	-0.590	-0.590
	(0.368)	(0.361)	(0.361)	(0.377)	(0.368)	(0.368)
d_2002	-0.00539	0.169	0.169	0.378	-0.00539	-0.00539
	(0.371)	(0.370)	(0.370)	(0.399)	(0.371)	(0.371)
d_2003	-0.689*	-0.498	-0.498	-0.240	-0.689*	-0.689*
	(0.371)	(0.364)	(0.364)	(0.401)	(0.371)	(0.371)
d_2004	-0.994**	-0.766*	-0.766*	-0.397	-0.994**	-0.994**
	(0.433)	(0.426)	(0.426)	(0.483)	(0.433)	(0.433)
d_2005	-1.008**	-0.697	-0.697	-0.344	-1.008**	-1.008**
	(0.469)	(0.459)	(0.459)	(0.500)	(0.469)	(0.469)
Constant - cut11	-0.840	-5.996***	-3.153	-10.27***	10.16***	-3.260*
	(1.801)	(1.992)	(1.945)	(2.339)	(2.815)	(1.903)
Constant - cut12	0.904	-4.255**	-1.412	-8.527***	11.90***	-1.517
	(1.803)	(1.985)	(1.941)	(2.311)	(2.832)	(1.895)
Constant - cut13	2.118	-3.033	-0.190	-7.321***	13.12***	-0.302
	(1.807)	(1.979)	(1.941)	(2.299)	(2.838)	(1.899)
Constant - cut14	3.513*	-1.626	1.217	-5.943***	14.51***	1.093
	(1.821)	(1.971)	(1.938)	(2.295)	(2.848)	(1.898)
Constant - cnt_1	1.160***	1.096***	1.096***	0.947***	1.160***	1.160***
	(0.120)	(0.120)	(0.120)	(0.120)	(0.120)	(0.120)
Observations	457	457	457	457	457	457
ll	-517.1	-518.0	-518.0	-519.9	-517.1	-517.1
cmd	gllamm	gllamm	gllamm	gllamm	gllamm	gllamm

Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1)

Table 4: Estimated coefficients for the proportional area of different land uses in relation to cotton miridae (CM) infestation level by reference land use type

	Reference land use type					
	(1)	(2)	(3)	(4)	(5)	(6)
	Shr_Bldup	Shr_Culti	Shr_Frst	Shr_Grld	Shr_Unused	Shr_Wat
ShrCotton_TotCulti	-1.373*	-1.373*	-1.373*	-1.472**	-1.373*	-1.373*
	(0.741)	(0.741)	(0.741)	(0.709)	(0.741)	(0.741)
ShrBt_Cotton	-0.189	-0.189	-0.189	-0.146	-0.189	-0.189
	(0.305)	(0.305)	(0.305)	(0.303)	(0.305)	(0.305)
Shr_Bldup		-2.137	0.00770	4.584**	-1.497	-5.068*
		(2.094)	(2.203)	(1.781)	(4.212)	(2.989)
Shr_Culti	2.137		2.145	7.396***	0.640	-2.931
	(2.094)		(1.827)	(2.119)	(3.680)	(2.160)
Shr_Frst	-0.00767	-2.145		4.479*	-1.505	-5.076**
	(2.203)	(1.827)		(2.362)	(4.165)	(2.345)
Shr_Grld	-2.634	-4.771***	-2.627		-4.132	-7.702***
	(1.731)	(1.845)	(2.418)		(4.067)	(2.965)
Shr_Unused	1.497	-0.640	1.505	7.336*		-3.571
	(4.210)	(3.679)	(4.164)	(4.111)		(4.687)
Shr_Wat	5.068*	2.931	5.076**	10.13***	3.571	
	(2.988)	(2.160)	(2.345)	(3.134)	(4.688)	
cb_PestiUse	-0.0675**	-0.0675**	-0.0675**	-0.0607*	-0.0675**	-0.0675**
	(0.0326)	(0.0326)	(0.0326)	(0.0318)	(0.0326)	(0.0326)
mtemp51	21.17**	21.17**	21.17**	19.41**	21.17**	21.17**
	(9.049)	(9.053)	(9.051)	(8.921)	(9.053)	(9.052)
mtemp61	-2.354	-2.354	-2.354	-2.016	-2.354	-2.354
	(9.888)	(9.895)	(9.892)	(9.741)	(9.894)	(9.895)
mtemp71	-31.92**	-31.92**	-31.92**	-31.57**	-31.92**	-31.92**
	(12.65)	(12.67)	(12.66)	(12.55)	(12.67)	(12.67)
mtemp81	15.11	15.11	15.11	13.15	15.11	15.11
	(13.42)	(13.44)	(13.43)	(13.42)	(13.43)	(13.44)
mprecip51	0.0886	0.0886	0.0886	0.0456	0.0886	0.0886
	(0.170)	(0.170)	(0.170)	(0.169)	(0.170)	(0.170)
mprecip61	0.0247	0.0247	0.0247	0.0178	0.0247	0.0247
	(0.0960)	(0.0960)	(0.0960)	(0.0957)	(0.0960)	(0.0960)
mprecip71	0.110	0.110	0.110	0.110	0.110	0.110
	(0.0748)	(0.0748)	(0.0748)	(0.0739)	(0.0748)	(0.0748)
mprecip81	0.0233	0.0233	0.0233	0.0152	0.0233	0.0233
	(0.0913)	(0.0913)	(0.0913)	(0.0909)	(0.0913)	(0.0913)
d_Anhui	-1.091	-1.091	-1.091	-0.928	-1.091	-1.091
	(1.295)	(1.295)	(1.295)	(1.297)	(1.295)	(1.295)
d_Hebei	1.487	1.487	1.487	1.263	1.487	1.487
	(1.094)	(1.094)	(1.094)	(1.130)	(1.094)	(1.094)
d_Henan	0.808	0.808	0.808	0.714	0.808	0.808

	(1.120)	(1.120)	(1.120)	(1.139)	(1.121)	(1.120)
d_Hubei	0.820	0.820	0.820	0.832	0.820	0.820
	(1.195)	(1.196)	(1.196)	(1.214)	(1.196)	(1.196)
d_Jiangsu	0.0556	0.0556	0.0557	-0.00261	0.0557	0.0557
	(1.205)	(1.205)	(1.205)	(1.233)	(1.205)	(1.205)
d_Shandong	-0.493	-0.493	-0.493	-0.638	-0.493	-0.493
	(1.121)	(1.121)	(1.121)	(1.148)	(1.121)	(1.121)
d_Shanxi	1.983*	1.983*	1.983*	2.268**	1.983*	1.983*
	(1.112)	(1.112)	(1.112)	(1.153)	(1.112)	(1.112)
d_1997	0.670	0.670	0.670	0.717	0.670	0.670
	(0.557)	(0.557)	(0.557)	(0.560)	(0.557)	(0.557)
d_1998	1.551***	1.551***	1.551***	1.604***	1.551***	1.551***
	(0.559)	(0.560)	(0.559)	(0.562)	(0.560)	(0.560)
d_1999	1.997***	1.997***	1.997***	2.020***	1.997***	1.997***
	(0.515)	(0.515)	(0.515)	(0.517)	(0.515)	(0.515)
d_2000	2.370***	2.370***	2.370***	2.400***	2.370***	2.370***
	(0.542)	(0.542)	(0.542)	(0.544)	(0.542)	(0.542)
d_2001	3.256***	3.256***	3.256***	3.251***	3.256***	3.256***
	(0.600)	(0.601)	(0.600)	(0.601)	(0.601)	(0.601)
d_2002	3.767***	3.767***	3.767***	3.750***	3.767***	3.767***
	(0.597)	(0.597)	(0.597)	(0.597)	(0.597)	(0.597)
d_2003	3.871***	3.871***	3.871***	3.825***	3.871***	3.871***
	(0.588)	(0.588)	(0.588)	(0.589)	(0.588)	(0.588)
d_2004	4.463***	4.463***	4.463***	4.415***	4.463***	4.463***
	(0.653)	(0.653)	(0.653)	(0.652)	(0.653)	(0.653)
d_2005	4.484***	4.484***	4.484***	4.399***	4.484***	4.484***
	(0.676)	(0.676)	(0.676)	(0.674)	(0.676)	(0.676)
Constant - cut11	3.452	1.315	3.459	7.706***	1.955	-1.616
	(2.363)	(2.061)	(2.276)	(2.502)	(4.100)	(2.746)
Constant - cut12	4.775**	2.639	4.783**	9.043***	3.278	-0.292
	(2.373)	(2.063)	(2.290)	(2.520)	(4.100)	(2.742)
Constant - cut13	5.909**	3.772*	5.916**	10.17***	4.411	0.841
	(2.388)	(2.066)	(2.302)	(2.535)	(4.103)	(2.745)
Constant - cut14	7.567***	5.430***	7.575***	11.83***	6.070	2.499
	(2.414)	(2.066)	(2.313)	(2.562)	(4.100)	(2.741)
Constant - cnt_1	1.138***	1.138***	1.138***	1.195***	1.138***	1.138***
	(0.129)	(0.129)	(0.129)	(0.139)	(0.129)	(0.129)
Observations	457	457	457	457	457	457
ll	-372.0	-372.0	-372.0	-372.3	-372.0	-372.0
cmd	gllamm	gllamm	gllamm	gllamm	gllamm	gllamm

Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1)

Table 5: Estimated coefficients for the proportional area of different land uses in relation to cotton bollworm (CB) infestation level by reference land use type

	Reference land use type					
	(1)	(2)	(3)	(4)	(5)	(6)
	Shr_Bldup	Shr_Culti	Shr_Frst	Shr_Grld	Shr_Unused	Shr_Wat
ShrCotton_TotCulti	-2.531***	-0.988*	-2.488***	-1.107*	-1.422**	-1.382**
	(0.695)	(0.596)	(0.804)	(0.640)	(0.641)	(0.631)
ShrBt_Cotton	-1.153***	-1.019***	-1.060***	-1.128***	-1.089***	-1.236***
	(0.259)	(0.247)	(0.263)	(0.259)	(0.243)	(0.256)
Shr_Bldup		0.907	5.955***	-3.632**	-17.65***	12.94***
		(1.659)	(1.712)	(1.696)	(3.876)	(2.372)
Shr_Culti	-1.218		4.642***	-4.956***	-19.13***	9.584***
	(1.835)		(1.229)	(1.704)	(3.632)	(1.825)
Shr_Frst	-6.104***	-4.522***		-10.52***	-26.13***	4.102***
	(1.628)	(1.122)		(2.257)	(3.989)	(1.538)
Shr_Grld	0.107	4.005***	8.308***		-16.47***	15.25***
	(1.653)	(1.507)	(1.942)		(3.772)	(2.712)
Shr_Unused	4.857	5.228*	10.03**	-0.591		15.16***
	(3.747)	(2.683)	(3.923)	(2.948)		(3.326)
Shr_Wat	-6.268***	-5.134***	2.289	-11.89***	-27.30***	
	(2.353)	(1.909)	(1.651)	(2.793)	(4.628)	
mtemp51	-1.571	-3.432	0.0761	-1.192	-3.814	0.793
	(7.527)	(7.373)	(7.482)	(7.340)	(7.380)	(7.432)
mtemp61	-5.336	-6.769	-5.444	-2.562	-11.24	-1.482
	(8.939)	(8.536)	(8.699)	(8.736)	(8.488)	(8.845)
mtemp71	-8.835	-7.029	-6.366	-6.694	-9.331	-6.564
	(10.20)	(10.00)	(10.06)	(10.00)	(10.25)	(10.00)
mtemp81	-0.937	0.243	2.513	5.132	6.312	1.350
	(11.67)	(11.45)	(11.39)	(11.94)	(11.50)	(11.85)
mprecip51	-0.0675	-0.00901	-0.0554	-0.0397	-0.0104	-0.00842
	(0.150)	(0.146)	(0.148)	(0.152)	(0.143)	(0.154)
mprecip61	-0.175**	-0.164**	-0.155*	-0.156*	-0.173**	-0.134
	(0.0837)	(0.0819)	(0.0829)	(0.0826)	(0.0859)	(0.0832)
mprecip71	0.0536	0.0930	0.0649	0.0933	0.0690	0.102
	(0.0648)	(0.0648)	(0.0650)	(0.0660)	(0.0697)	(0.0669)
mprecip81	-0.0600	-0.0617	-0.0388	-0.0387	-0.0365	-0.0646
	(0.0727)	(0.0715)	(0.0724)	(0.0719)	(0.0725)	(0.0733)
d_Anhui	1.953**	1.691**	1.289	1.711*	2.143***	2.338**
	(0.944)	(0.857)	(0.917)	(0.953)	(0.780)	(1.004)
d_Hebei	0.0561	0.428	0.0238	-0.204	0.172	-0.166
	(0.802)	(0.712)	(0.778)	(0.744)	(0.592)	(0.817)
d_Henan	0.195	-0.325	-0.0581	-0.781	0.800	-0.753
	(0.802)	(0.722)	(0.786)	(0.811)	(0.626)	(0.920)
d_Hubei	2.376***	2.314***	2.311***	3.014***	2.747***	3.453***
	(0.876)	(0.815)	(0.893)	(0.906)	(0.732)	(0.979)

d_Jiangsu	1.568*	1.902**	0.708	1.781**	2.483***	1.493
	(0.950)	(0.812)	(0.881)	(0.881)	(0.752)	(0.921)
d_Shandong	0.604	0.541	0.413	0.182	0.736	0.325
	(0.785)	(0.698)	(0.802)	(0.748)	(0.608)	(0.828)
d_Shanxi	-0.517	-0.676	-0.928	-0.983	-0.287	-0.895
	(0.761)	(0.705)	(0.762)	(0.752)	(0.598)	(0.822)
d_1997	0.749***	0.776***	0.669**	0.650**	0.723**	0.690**
	(0.284)	(0.281)	(0.281)	(0.283)	(0.283)	(0.287)
d_1998	0.310	0.222	0.239	0.235	0.187	0.269
	(0.311)	(0.308)	(0.308)	(0.312)	(0.306)	(0.313)
d_1999	-0.578**	-0.529**	-0.608**	-0.505*	-0.578**	-0.494*
	(0.267)	(0.265)	(0.269)	(0.265)	(0.267)	(0.265)
d_2000	-0.237	-0.252	-0.360	-0.293	-0.232	-0.259
	(0.304)	(0.297)	(0.301)	(0.297)	(0.297)	(0.297)
d_2001	-0.617	-0.642*	-0.696*	-0.664*	-0.550	-0.618*
	(0.376)	(0.367)	(0.370)	(0.373)	(0.366)	(0.370)
d_2002	-1.315***	-1.437***	-1.354***	-1.391***	-1.406***	-1.274***
	(0.370)	(0.364)	(0.374)	(0.365)	(0.371)	(0.370)
d_2003	-1.682***	-1.848***	-1.693***	-1.772***	-1.818***	-1.613***
	(0.362)	(0.354)	(0.366)	(0.356)	(0.364)	(0.361)
d_2004	-1.830***	-2.050***	-1.838***	-1.934***	-2.005***	-1.767***
	(0.423)	(0.413)	(0.427)	(0.413)	(0.431)	(0.420)
d_2005	-1.354***	-1.501***	-1.357***	-1.518***	-1.372***	-1.327***
	(0.463)	(0.447)	(0.467)	(0.456)	(0.470)	(0.473)
Constant - cut11	-10.05***	-8.320***	-2.225	-10.85***	-27.86***	3.936*
	(2.099)	(1.670)	(1.898)	(2.256)	(3.967)	(2.201)
Constant - cut12	-8.373***	-6.585***	-0.563	-9.115***	-26.12***	5.680**
	(2.072)	(1.653)	(1.895)	(2.248)	(3.934)	(2.221)
Constant - cut13	-6.577***	-4.790***	1.224	-7.312***	-24.31***	7.487***
	(2.059)	(1.643)	(1.898)	(2.242)	(3.908)	(2.237)
Constant - cut14	-4.964**	-3.185*	2.843	-5.708**	-22.69***	9.092***
	(2.048)	(1.636)	(1.898)	(2.235)	(3.890)	(2.243)
Constant - cnt_1	1.029***	1.091***	0.961***	1.092***	1.176***	1.162***
	(0.0881)	(0.0908)	(0.0828)	(0.0969)	(0.0956)	(0.0967)
Observations	457	457	457	457	457	457
ll	-465.8	-465.0	-466.1	-464.7	-467.2	-464.8
cmd	gllamm	gllamm	gllamm	gllamm	gllamm	gllamm

Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1)

Table 6: Estimated average partial effects of proportional area of different land uses in relation to cotton aphid (CA) infestation level by reference land use type

Reference land use type	Explanatory variables	Estimated coefficient	Average Partial Effects				
			I	II	III	IV	V
Shr_Bldup	Shr_Grld	2.641*	-0.349	-0.307	0.154	0.345	0.156
	Shr_Unused	-11.00***	1.452	1.277	-0.640	-1.439	-0.651
	cb_PestiUse	0.0574**	-0.008	-0.007	0.003	0.008	0.003
	mtemp51	16.09**	-2.124	-1.868	0.936	2.104	0.951
	mtemp71	19.90**	-2.627	-2.310	1.158	2.602	1.177
	mtemp81	-38.65***	5.102	4.487	-2.249	-5.055	-2.286
	mprecip81	-0.170**	0.022	0.020	-0.010	-0.022	-0.010
Shr_Culti	Shr_Frst	-2.843**	0.375	0.328	-0.166	-0.371	-0.166
	Shr_Unused	-14.02***	1.849	1.619	-0.818	-1.831	-0.819
	Shr_Wat	-4.840***	0.638	0.559	-0.283	-0.632	-0.283
	cb_PestiUse	0.0611**	-0.008	-0.007	0.004	0.008	0.004
	mtemp81	-39.78***	5.247	4.596	-2.322	-5.197	-2.325
	mprecip81	-0.178**	0.023	0.021	-0.010	-0.023	-0.010
Shr_Frst	Shr_Culti	2.843**	-0.375	-0.328	0.166	0.371	0.166
	Shr_Grld	3.743**	-0.494	-0.433	0.219	0.489	0.219
	Shr_Unused	-11.17***	1.474	1.291	-0.652	-1.460	-0.653
	cb_PestiUse	0.0611**	-0.008	-0.007	0.004	0.008	0.004
	mtemp81	-39.78***	5.247	4.596	-2.322	-5.197	-2.325
	mprecip81	-0.178**	0.023	0.021	-0.010	-0.023	-0.010
Shr_Grld	Shr_Bldup	-3.668**	0.496	0.416	-0.214	-0.475	-0.222
	Shr_Culti	-4.986***	0.674	0.566	-0.291	-0.646	-0.302
	Shr_Frst	-5.707***	0.771	0.648	-0.333	-0.740	-0.346
	Shr_Unused	-15.54***	2.101	1.763	-0.908	-2.013	-0.942
	Shr_Wat	-10.82***	1.463	1.228	-0.632	-1.402	-0.656
	cb_PestiUse	0.0760***	-0.010	-0.009	0.004	0.010	0.005
	mtemp81	-42.02***	5.681	4.768	-2.455	-5.445	-2.549
	mprecip81	-0.198***	0.027	0.022	-0.012	-0.026	-0.012
Shr_Unused	Shr_Bldup	11.00***	-1.452	-1.277	0.640	1.439	0.651
	Shr_Culti	14.06***	-1.857	-1.633	0.818	1.839	0.832
	Shr_Frst	12.18***	-1.608	-1.414	0.709	1.593	0.720
	Shr_Grld	13.64***	-1.801	-1.584	0.794	1.784	0.807
	Shr_Wat	13.42***	-1.772	-1.558	0.781	1.755	0.794
	cb_PestiUse	0.0574**	-0.008	-0.007	0.003	0.008	0.003
	mtemp51	16.09**	-2.124	-1.868	0.936	2.104	0.951
	mtemp71	19.90**	-2.627	-2.310	1.158	2.602	1.177
	mtemp81	-38.65***	5.102	4.487	-2.249	-5.055	-2.286
	mprecip81	-0.170**	0.022	0.020	-0.010	-0.022	-0.010
Shr_Wat	Shr_Unused	-13.42***	1.772	1.558	-0.781	-1.755	-0.794
	cb_PestiUse	0.0574**	-0.008	-0.007	0.003	0.008	0.003

mtemp51	16.09**	-2.124	-1.868	0.936	2.104	0.951
mtemp71	19.90**	-2.627	-2.310	1.158	2.602	1.177
mtemp81	-38.65***	5.102	4.487	-2.249	-5.055	-2.286
mprecip81	-0.170**	0.022	0.020	-0.010	-0.022	-0.010

Table 7: Estimated average partial effects of proportional area of different land uses in relation to cotton miridae (CM) infestation level by reference land use type

Reference land use type	Explanatory variables	Estimated coefficient	Average Partial Effects I	II	III	IV	V
Shr_Bldup	ShrCotton_TotCulti	-1.373*	0.224	-0.026	-0.059	-0.100	-0.038
	Shr_Wat	5.068*	-0.826	0.097	0.219	0.369	0.142
	cb_PestiUse	-0.0675**	0.011	-0.001	-0.003	-0.005	-0.002
	mtemp51	21.17**	-3.450	0.403	0.914	1.539	0.593
	mtemp71	-31.92**	5.202	-0.608	-1.378	-2.321	-0.894
Shr_Culti	ShrCotton_TotCulti	-1.373*	0.224	-0.026	-0.059	-0.100	-0.038
	Shr_Grld	-4.771***	0.777	-0.091	-0.206	-0.347	-0.134
	cb_PestiUse	-0.0675**	0.011	-0.001	-0.003	-0.005	-0.002
	mtemp51	21.17**	-3.450	0.403	0.914	1.539	0.593
	mtemp71	-31.92**	5.202	-0.608	-1.378	-2.321	-0.894
Shr_Frst	ShrCotton_TotCulti	-1.373*	0.224	-0.026	-0.059	-0.100	-0.038
	Shr_Wat	5.076**	-0.827	0.097	0.219	0.369	0.142
	cb_PestiUse	-0.0675**	0.011	-0.001	-0.003	-0.005	-0.002
	mtemp51	21.17**	-3.450	0.403	0.914	1.539	0.593
	mtemp71	-31.92**	5.202	-0.608	-1.378	-2.321	-0.894
Shr_Grld	ShrCotton_TotCulti	-1.472**	0.238	-0.028	-0.062	-0.106	-0.042
	Shr_Bldup	4.584**	-0.742	0.086	0.195	0.331	0.130
	Shr_Culti	7.396***	-1.197	0.139	0.314	0.534	0.209
	Shr_Frst	4.479*	-0.725	0.084	0.190	0.323	0.127
	Shr_Unused	7.336*	-1.187	0.138	0.311	0.529	0.208
	mtemp51	19.41**	-3.141	0.366	0.824	1.401	0.550
	mtemp71	-31.57**	5.109	-0.595	-1.341	-2.279	-0.894
	ShrCotton_TotCulti	-1.373*	0.224	-0.026	-0.059	-0.100	-0.038
	cb_PestiUse	-0.0675**	0.011	-0.001	-0.003	-0.005	-0.002
	mtemp51	21.17**	-3.450	0.403	0.914	1.539	0.593
Shr_Unused	mtemp71	-31.92**	5.202	-0.608	-1.378	-2.321	-0.894
Shr_Wat	ShrCotton_TotCulti	-1.373*	0.224	-0.026	-0.059	-0.100	-0.038
	Shr_Bldup	-5.068*	0.826	-0.097	-0.219	-0.369	-0.142
	Shr_Frst	-5.076**	0.827	-0.097	-0.219	-0.369	-0.142
	Shr_Grld	-7.702***	1.255	-0.147	-0.332	-0.560	-0.216
	cb_PestiUse	-0.0675**	0.011	-0.001	-0.003	-0.005	-0.002

Table 8: Estimated average partial effects of proportional area of different land uses in relation to cotton bollworm (CB) infestation level by reference land use type

Reference land use type	Explanatory variables	Estimated coefficient	Average Partial Effects				
			I	II	III	IV	V
Shr_Bldup	ShrCotton_TotCulti	-2.531***	0.171	0.223	0.071	-0.139	-0.326
	ShrBt_Cotton	-1.153***	0.078	0.102	0.033	-0.063	-0.149
	Shr_Frst	-6.104***	0.412	0.537	0.172	-0.335	-0.786
	Shr_Wat	-6.268***	0.423	0.552	0.177	-0.344	-0.808
	mprecip61	-0.175**	0.012	0.015	0.005	-0.010	-0.023
Shr_Culti	ShrCotton_TotCulti	-0.988*	0.066	0.085	0.030	-0.054	-0.127
	ShrBt_Cotton	-1.019***	0.068	0.088	0.031	-0.056	-0.131
	Shr_Frst	-4.522***	0.302	0.391	0.136	-0.247	-0.583
	Shr_Grld	4.005***	-0.267	-0.346	-0.121	0.218	0.516
	Shr_Unused	5.228*	-0.349	-0.452	-0.158	0.285	0.674
	Shr_Wat	-5.134***	0.343	0.444	0.155	-0.280	-0.662
	mprecip61	-0.164**	0.011	0.014	0.005	-0.009	-0.021
Shr_Frst	ShrCotton_TotCulti	-2.488***	0.169	0.222	0.067	-0.139	-0.318
	ShrBt_Cotton	-1.060***	0.072	0.095	0.028	-0.059	-0.136
	Shr_Bldup	5.955***	-0.404	-0.532	-0.160	0.333	0.762
	Shr_Culti	4.642***	-0.315	-0.414	-0.125	0.260	0.594
	Shr_Grld	8.308***	-0.563	-0.742	-0.223	0.464	1.063
	Shr_Unused	10.03**	-0.680	-0.896	-0.269	0.561	1.284
	mprecip61	-0.155*	0.010	0.014	0.004	-0.009	-0.020
Shr_Grld	ShrCotton_TotCulti	-1.107*	0.073	0.096	0.033	-0.060	-0.143
	ShrBt_Cotton	-1.128***	0.075	0.098	0.034	-0.061	-0.145
	Shr_Bldup	-3.632**	0.240	0.316	0.110	-0.198	-0.468
	Shr_Culti	-4.956***	0.328	0.431	0.150	-0.270	-0.639
	Shr_Frst	-10.52***	0.695	0.916	0.318	-0.573	-1.356
	Shr_Wat	-11.89***	0.786	1.035	0.359	-0.647	-1.533
	mprecip61	-0.156*	0.010	0.014	0.005	-0.008	-0.020
Shr_Unused	ShrCotton_TotCulti	-1.422**	0.093	0.124	0.041	-0.078	-0.180
	ShrBt_Cotton	-1.089***	0.071	0.095	0.032	-0.060	-0.138
	Shr_Bldup	-17.65***	1.158	1.543	0.513	-0.974	-2.240
	Shr_Culti	-19.13***	1.254	1.671	0.556	-1.055	-2.426
	Shr_Frst	-26.13***	1.713	2.283	0.759	-1.441	-3.315
	Shr_Grld	-16.47***	1.080	1.439	0.479	-0.909	-2.090
	Shr_Wat	-27.30***	1.791	2.386	0.794	-1.506	-3.464
	mprecip61	-0.173**	0.011	0.015	0.005	-0.010	-0.022
Shr_Wat	ShrCotton_TotCulti	-1.382**	0.091	0.120	0.042	-0.077	-0.177

ShrBt_Cotton	-1.236***	0.081	0.108	0.038	-0.068	-0.158
Shr_Bldup	12.94***	-0.848	-1.127	-0.396	0.716	1.655
Shr_Culti	9.584***	-0.628	-0.835	-0.293	0.531	1.226
Shr_Frst	4.102***	-0.269	-0.357	-0.125	0.227	0.525
Shr_Grld	15.25***	-1.000	-1.328	-0.467	0.844	1.950
Shr_Unused	15.16***	-0.993	-1.320	-0.464	0.839	1.938

Table 9: Estimated effect of cotton pest infestation level on the number of pesticide application

Cotton	Nr. of insecticide sprays on aphid	Nr. of insecticide sprays on miridae	Nr. of insecticide sprays on bollworm
Level II	0.476	0.963	0.803
Level III	0.979	1.551	2.132
Level IV	1.984	2.862	3.475
Level V	3.03	3.816	6.028