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The Ineffectiveness of Landscape Diversity Index in Biocontrol: An Evidence From Small Scale Farmland

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Abstract. Landscape diversity index behaves ineffective in small scale farmland. The correlation coefficients between Shannon's diversity index as well as Simpson's diversity index with the population density of ladybeetles are negative. This result is opposite with the results from large scale farmland in developed countries. Landscape pattern has significant influence on the population density of ladybeetles. Especially the cotton/wheat relay intercrops have significant influence on the population density of ladybeetles. Besides grassland are also beneficial to the population density of ladybeetles.

Introduction

Many research have shown that landscape diversity has obvious effects on biocontrol services in agriculture. The composition and structure of a landscape affect the population density of natural enemies which can suppress pests significantly.

However, previous research mainly concentrate on large scale farmland in the developed countries. For instance, there are many research concentrate on the main corn and soybean planting areas of America [1, 2]. Some research concentrate on agricultural landscape in Europe [3, 4]. However, there is little evidence on agricultural landscape with small scale farmland in developing countries.

The situation in China is quite different from that of the developed countries. The rural farmland in China is mainly characterized by a continuous mosaic of cultivated lands crisscrossed by irrigation canals and ditches in which several small patches of grasslands and small woods bounding the fields are the only elements that enhance diversity. Therefore, China is an interesting case.

Landscape diversity index intrinsically has several defects in reflecting the overall features of landscape as well as other ecological services in a certain spatial scale. Traditional applications of diversity measurements at landscape level often employ indices that represent the richness or evenness of a certain spatial scale. These indices vary in response to changes in landscape composition. Shannon's diversity index is influenced strongly by the changes in importance of the rarest class, while the Simpson's diversity index is influenced strongly by the changes in the proportional abundance of the most common class [5]. Besides, an opposite response of these indices was observed for two Indian landscapes with the same richness, differing only in evenness [6].

Methods and Sampling

We chose Langfang and Wuqing which are located in the North China Plain as our research area. North China Plain is one of the three main cotton planting regions in China.

We selected five villages from two countries each. The criteria that we chose these villages are (1) with large cotton area and (2) with grads of non-crop area. We interviewed 30-50 households randomly which planted cotton in 2010 in each village and recorded the times of insecticide they sprayed on cotton in 2010. We divided them into 4 groups based on the times of insecticide they sprayed(0-5; 6-10; 11-15; more than 15). At last, we randomly selected 4 households from each group. If there were less than 4 households in a group, then we chose from the neighboring group. Meanwhile, we focused on the largest cotton field of a household if they had more than one.

Landscape diversity analysis

We selected the centers of the plots of each village and digitized the land use patterns surrounding the villages to a radius of 1.5 km. We interpreted the high-precision remote sensing images in ArcGIS 9.3. An interactive visual interpretation approach was applied to decode the land cover and land use information [7]. We conducted ground trothing and validation in field survey. Finally, calibrated land cover and land use information were obtained to identify landscape diversity.

Ladybeetles sampling

Ladybeetles (*Coccinella septempunctata* L.) is a general arthropod predator in our study area [8]. We collected the population density of ladybeetles in the late July in 2011, for the reason that cotton aphid (*Aphis gossypii* Glover) threats cotton most in late July, meanwhile ladybeetles have a strong suppression on cotton aphid in our study area [8]. Whole-plant counts were used to estimate the population density of ladybeetles. In each plot an X-shape path covering the entire field and we counted five plants of the five spots each in the cotton fields.

Results and analysis

As is shown in Table 1, corn is the most widely planted crop which is 41.41 percent. Cotton is the second largest planted crop which is 14.76 percent. Other crops including beans, peanuts, sweet potato, et al., is 2.64 percent. Grassland occupied 1.36 percent. Water area which occupied 2.39 percent is mainly recognized as irrigation canals and ditches in our study area. The share of forestry area is 17.85 percent. The share of building area which are surrounded by farmland is 19.59 percent.

Table 1 The shares of agricultural landscape types of the ten villages

Landscape types	Corn	Cotton	Other Crops	Grassland	Water Area	Trees	Buildings Area
Percent (%)	41.41	14.76	2.64	1.36	2.39	17.85	19.59

We computed Shannon's diversity index and Simpson's diversity index with different radius using the formulae below:

Shannon's diversity index $=-\Sigma\,[P_{ij}*\log(P_{ij})]$ (1)

Simpson's diversity index $=1/\Sigma\,(P_{ij})^2$ (2)

Where P_{ij} is the share of landscape pattern i of household j within a certain spatial scale.

The Pearson correlation coefficients between the population density of ladybeetles and landscape diversity indices are shown in table 2. Landscape diversity indices are negative correlative with the population density of ladybeetles. This is opposite with the results under large scale farmland [2].

Table 2 Pearson correlation coefficients within different spatial scales

Radius(m)	300	400	500	600	700	800	900	1000
Shannon's Diversity Index	-0.40	-0.42	-0.43	-0.43	-0.44	-0.43	-0.42	-0.41
Simpson's Diversity Index	-0.40	-0.45	-0.45	-0.46	-0.47	-0.45	-0.44	-0.42

The multivariate econometric model

In order to reveal the relationship between landscape pattern and the population density of ladybeetles, we established a multivariate econometric model.

The multivariate econometric model is specified as follows:

$L_i = c_1 + c_2 * LP_i + c_3 * ln(D_i) + c_4 * Q_i + e_i$ (3)

Where the dependent variable, L_i, is the population density of ladybeetles of household i.

In this model, the key explain variables of interest are all included. The matrix *LP* is the percentage of the 6 types of landscape patterns including: corn, cotton, other crops, trees, grassland and water area. Building area is excluded from the model to avoid collinearity.

Besides, there are several control variables included in the model. The variable D_i is the days between the date of the last insecticide sprayed by household *i* and the date of surveying the population density of ladybeetles in the cotton field of household *i*. Here we use the logarithmic transformation. The variable Q_i is the amount of insecticide used on per hectare before the date that we surveyed the population density of ladybeetles of household *i*.

The regression results are showed in Table 3.

Table 3 Regression results with different radii

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Radius (m)	300	400	500	600	700	800	900	1000
Corn (%)	0.070*** (8.15)	0.073*** (8.79)	0.078*** (9.37)	0.081*** (8.61)	0.082*** (7.82)	0.078*** (6.18)	0.081*** (5.01)	0.084*** (4.37)
Cotton (%)	0.009 (0.83)	-0.007 (0.66)	-0.019* (1.70)	-0.020 (1.60)	-0.024 (1.61)	-0.033* (1.77)	-0.027 (1.14)	-0.028 (1.09)
Trees (%)	0.048*** (3.38)	0.031** (2.22)	0.025* (1.94)	0.027** (2.09)	0.027* (1.89)	0.019 (1.23)	0.018 (1.01)	0.017 (0.83)
Other Crops (%)	-0.025 (1.39)	-0.044** (2.53)	-0.056*** (3.39)	-0.059*** (3.47)	-0.061*** (3.44)	-0.064*** (3.31)	-0.065*** (3.03)	-0.065*** (2.76)
Grassland (%)	-0.056 (0.68)	0.112 (1.53)	0.177** (2.55)	0.209*** (2.73)	0.221** (2.31)	0.189 (1.56)	0.272* (1.76)	0.318** (2.03)
Water Area (%)	0.335*** (5.27)	0.173*** (2.71)	0.069 (1.24)	0.042 (0.81)	0.034 (0.67)	0.014 (0.25)	-0.047 (0.68)	-0.120 (1.46)
ln(D_i)	3.118*** (23.34)	3.070*** (23.78)	3.066*** (25.51)	3.065*** (24.82)	3.067*** (24.16)	3.052*** (22.94)	3.041*** (21.94)	3.029*** (21.27)
Q(kg/ha)	-0.019* (1.85)	-0.018* (1.89)	-0.019** (2.04)	-0.017* (1.86)	-0.017* (1.77)	-0.018* (1.73)	-0.018 (1.65)	-0.016 (1.36)
Cons	-4.358*** (5.46)	-3.713*** (4.99)	-3.521*** (4.94)	-3.714*** (4.77)	-3.718*** (4.17)	-3.219*** (2.96)	-3.482** (2.52)	-3.595** (2.28)
Adj R-squared	0.8294	0.8462	0.8626	0.8532	0.8459	0.8339	0.8244	0.8206

Absolute *t* statistics in parentheses; * $p < .10$, ** $p < .05$, *** $p < .01$

The coefficients of corn in the model with different radii are significant and positive. In North China Plain wheat/corn rotation is mainly adopted. Besides, farmers usually adopt cotton/wheat relay intercrops. In fact the impact of ladybeetles on aphids is the biggest in cotton/wheat relay intercrops [9]. The reason is that wheat fields harbor a lot of natural enemies including ladybeetles and these natural enemies are fed with cereal aphids. Consequently the intercropping system has a high land use efficiency and helps to suppress aphids [9].

The coefficients of cotton are negative but not significant with all the radii. This means that cotton field has no significant effect on ladybeetles.

The coefficients of trees are positive and significant with smaller radii. It suggests that trees may enhance landscape diversity and have positive effects on ladybeetles.

The coefficients of other crops are significant and negative in the model with all the radii except for the smallest one which means that other crops have negative effects on ladybeetles. In North China Plain, other crops mainly include beans, peanuts and vegetables which receive a lot of insecticide sprays and the population density of ladybeetles would be suppressed significantly.

The coefficients of grassland are positive with all the radii except for the smallest one. This means that grassland has positive influence on the population density of ladybeetles. Researches have shown that grassland have significant positive effects on ladybeetles [2]. Grassland is the main non-crop habitats which can provide ladybeetles with shelter and alternative foods [9].

Besides, the coefficients of water area are not consistent in this model with different radii. This is mainly because water area do not have significant influence on the population density of ladybeetles.

Moreover, the results also show that several other control variables affect the population density of ladybeetles in cotton fields. The coefficients of $ln(D_i)$ are all negative and significant as expected in all models. The quantity of insecticide sprayed has a significant negative influence on ladybeetles.

Conclusion

The impacts of agricultural landscape pattern on the population density of ladybeetles is significant in small scale farmland. The continuous mosaic of farm lands crisscrossed by irrigation canals and ditches benefits the population density of ladybeetles. The cotton/wheat relay intercrops provide shelters and foods for ladybeetles. Besides, grassland is an important source of alternate shelters and foods for ladybeetles.

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