

中国农户大豆品种选择影响因素分析

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摘要:品种改良与新品种推广是提高作物产量的重要途径。然而,在生产实践中,新品种能否被农民选用受制于许多因素。为明确中国北方春大豆区、黄淮海夏大豆区和南方多作大豆区农民采用大豆新品种的影响因素,国家大豆产业技术体系于2008-2010年,在上述三个大豆主产区共22个省份,对农民的受教育水平、务农时间长短、家庭人口数量等社会经济特征以及他们对大豆新品种性状的了解情况进行了调查。在此基础上,本文采用二元Logit模型分析了影响农民大豆品种选择的主要因素。结果显示:北方春大豆区、黄淮海夏大豆区和南方多作大豆区受访农户的新品种采用率分别是99.45%、93.40%和37.55%;在北方春大豆区和黄淮海夏大豆区,农民对改良品种的高产、稳产、抗倒和抗病性等特点的认可程度超过地方品种,而在南方地区,农民对地方品种的稳产、抗病、抗逆、加工品质、熟期、株高等品种特点认可度更高;在北方春大豆区,从事农业生产年限和非农劳动力数量是影响农民选择改良品种的主要因素,而在黄淮海夏大豆区和南方多作大豆区,除了农户的社会经济特征以及高产目标外,影响农民选择改良品种的主要因素分别是早熟和抗倒性。研究结果可为分区制定区域品种选育和推广策略,推动中国大豆生产发展提供依据。

关键词:中国;大豆;品种采用;品种特点;二元Logit模型
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Factors Influencing Variety Choice by Soybean Farmers in China: Analysis of an On-site Survey

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Abstract: Variety improvement and new variety adoption play dominant roles in enhancing crop productivity. However, in practice, successful adoption of improved varieties is influenced by multiple factors. This study aimed to investigate farmers' perception of soybean variety traits and identify factors determining farmers' variety choices in the three main soybean production regions of China, namely the Northern Spring Soybean Region (NSSR), the Huang-Huai-Hai Rivers Valley Summer Soybean Region (HHHR), and the Southern Multiple-Cropping Soybean Region (SMSR). During 2008-2010, farmers from 22 provinces covering the three main soybean production regions were surveyed by National Soybean Industry R & D System to obtain data about their socioeconomic characteristics and perceptions of variety traits. A binary logit model was applied to identify the factors influencing farmers' variety choices. The results indicated that high adoption rates of improved varieties of 99.45% in NSSR and 93.40% in HHHR, whereas that in SMSR was 37.55%. In NSSR and HHHR, improved varieties out-

performed landraces with respect to all the surveyed traits, particularly high yield, yield stability, lodging resistance, and disease resistance. In SMSR, in contrast, the landraces were superior to improved varieties in yield stability, disease resistance, stress tolerance, processing quality, maturity group, and plant height. Empirical results showed that in NSSR farming experience and off-farm labor strongly influenced variety adoption. With the exception of household socioeconomic factors and the aim of high yield, early maturity in HHHR and lodging resistance in SMSR were the main factors influencing farmers' variety choices. This study will assist the development of region-specific breeding and extension strategies and further advance of soybean production in China.

Keywords: China; Soybean; Variety choice; Variety traits; Binary logit

Introduction

Soybean is an important world crop, providing food, oil and feed. China, where soybean was first domesticated, was formerly the largest soybean producer. However, the supply of and demand for soybeans in China have changed dramatically since the mid-1990s. In 1996, imports of soybean exceeded exports, owing to increased demand for soybean oil and meal^[1]. From then on, the gap between imports and exports has grown yearly. Although China currently ranks fourth in soybean production worldwide, it has become the world's leading importer of soybean, raising strong concern about the future of the Chinese soybean industry^[2-5].

Several measures have been taken by Chinese government to boost soybean production, among which breeding improved varieties has been especially emphasized. With the aim of testing new varieties, regional soybean uniform trials were initiated in Northeast China in the 1950s. The national uniform trial for soybean started in 1960, followed by the establishment of more than 100 experimental sites^[6]. The number of released soybean varieties reached 1 800 by 2012^[7]. However, such a large number of released varieties neither increased the adoption rate of new varieties nor expanded the planting area of any individual soybean variety. This situation prompted us to investigate how farmers assess soybean varieties, and what are the limiting factors influencing their variety choice in the main soybean production areas of China. The results will help soybean breeders adjust their breeding aims based on farmers' variety requirements.

Although a large number of studies have previously been conducted to identify the factors that could influence farmers' variety choices, they have focused mainly on socioeconomic factors, including education level, farm size, credit availability, agroecological zone, household income, and farming experience^[8-10]. Few

have addressed farmers' perceptions and the attributes of the varieties themselves^[8,11]. Farmers' perception of the technological attributes of the varieties was found to be a major factor determining variety adoption and use intensity^[12]. An impact of variety characteristics on adoption has been identified on maize^[13]. Favorable production, processing, and consumption attribution were stressed for hybrid maize varieties^[14].

In view of the various farming practices and agroecological circumstances in the three main soybean production areas of China^[15], we hypothesized that there would be dramatic differences in farmers' perception of favorable soybean variety traits and that these would correspondingly affect their final variety choices. Accordingly, a national survey was conducted during 2008–2010, and a binary logit model was used to evaluate the key factors influencing farmers' variety choice.

Data source and study context

The study region

The research regions including three major soybean production areas of China, namely the Northern Spring Soybean Region (NSSR), the Huang-Huai-Hai Rivers Valley Summer Soybean Region (HHHR), and the Southern Multi-Cropping Soybean Region (SMSR)^[15]. The NSSR is characterized by single cropping, including provinces of Heilongjiang, Jilin, Liaoning, Inner Mongolia, Ningxia, and Xinjiang, and northern of Hebei, northern of Shanxi, northern of Shaanxi, and Gansu. The HHHR is characterized by summer planting of soybean after winter wheat, with a small part of spring-planted soybean. It covers mainly the middle and southern parts of Hebei and Shanxi provinces, Henan, Shandong, the middle part of Shaanxi, Beijing, Tianjin, northern of Anhui, and northern of Jiangsu. The SMSR is dominated by multi-cropping practice. Soybean is planted in relay or intercropped with other major crops including maize, wheat, rice, or

rapeseed, which are extensively grown across very large regions. The provinces of Hunan, Zhejiang, Jiangxi, Hubei, Sichuan, Fujian, Guangdong, Hainan, Guangxi, Guizhou, Yunnan, and southern of Anhui, southern of Jiangsu, and southern of Shaanxi belong to this region.

Data collection

We used a multi - stage sampling method to collect sample data from 2008 to 2010. The primary sampling units were the 22 provinces covering the typical soybean planting regions of China. Secondary sampling units were 142 counties of those 22 provinces, according to soybean planting areas. Then at least three villages were

surveyed in each county and at least three farmers were surveyed in each village. In total 1 627 farmers were interviewed, with 949 farmers from 61 counties in NSSR, 401 farmers from 44 counties in HHRH, and 277 farmers from 37 counties in SMSR. The final sample size was reduced to 1 549 farmers by deletion of samples with missing values. Soybean varieties were classified into two types: improved varieties and landraces. Improved varieties typically refer to the certified varieties released by provincial or national authorities. Landraces are traditional local varieties without official certificates. The sampling sites are summarized in Table 1.

Table 1 Sample site summary

NSSR			HHRH			SMSR		
Province	No. of sample farmers	Percentage /%	Province	No. of sample farmers	Percentage /%	Province	No. of sample farmers	Percentage /%
Heilongjiang	361	40.07	Henan	140	36.94	Guizhou	61	22.68
Liaoning	172	19.09	Anhui	102	26.91	Guangxi	58	21.56
Inner Mongolia	164	18.20	Shandong	46	12.14	Sichuan	43	15.99
Xinjiang	62	6.88	Jiangsu	40	10.55	Yunnan	37	13.75
Gansu	57	6.33	Shanxi	26	6.86	Jiangxi	34	12.64
Jilin	56	6.22	Hebei	25	6.60	Hubei	29	10.78
Shaanxi	25	2.77				Guangdong	5	1.86
Ningxia	4	0.44				Hainan	2	0.74
Total	901	100.00	Total	379	100.00	Total	269	100.00

Data were collected using questionnaires. Questions were designed based on literature searches and suggestions from experienced soybean breeders in different soybean production regions. Although other factors could affect variety adoption, such as soybean price and extension services for farmers, variety traits were considered to be the most important determinants of the variety choices of farmers. Farmers were asked to report the variety traits that might affect their choices of a specific variety. Thirteen attributes were listed. High yield, yield stability, pod number, plant type, plant height, and shattering resistance represented production characteristics. Lodging resistance, early maturity, disease resistance, insect resistance, and stress tolerance are associated with environmental adaptability^[16]. Seed appearance is a proxy for commodity attributes, including seed shape, seed size, and seed hilum color, which tends to affect the commercial grade of soybean. The evaluation of processing quality is based on oil content, protein content, and the taste of tofu.

Farmers’ socioeconomic characteristics surveyed including education level, farming experience, family size, off - farm labor, farm size, and seed source.

Model specification

A binary logit model was developed to identify the key factors influencing farmers’ variety choice^[9,17].

$$\text{Prob}[Y_{ij} = 1] = \frac{\exp(\beta' X_i)}{1 + \exp(\beta' X_i)} = \hat{(\beta' X_i)} \quad (1)$$

The subscripts *i* and *j* denote farmer and variety type (improved variety = 1; landrace = 0), respectively. $\hat{(\cdot)}$ denotes logistic cumulative distribution function. Equation (1) is a reduced form of the binomial logit model, where the *x_i* row vector of explanatory variables for the *i* th farmer are the independent variables and the unobserved ε is assumed to follow a distribution of logistic probability with a density function.

$$F'(\beta' X_i) = \hat{(\beta' X_i)} [1 - \hat{(\beta' X_i)}] \quad (2)$$

Empirically, the model was estimated as:

$$\text{Pr}[VAR_i = 1] = \beta_i \varepsilon_i + \varepsilon_i \quad (3)$$

Where *VAR_i* is the type of soybean variety adopted

by the i^{th} farmer (improved variety = 1 ; landrace = 0) ; X_i is a vector of socioeconomic factors and variety traits which are assumed to affect farmers’ variety choices; β_i is a vector of parameters to be estimated, and ε_i is the random term.

The binary logit model was fitted with IBM SPSS Statistics 19.0 software^[18].

Results and discussion

Use of improved varieties or landraces

We observed a very high diversity of soybean varieties grown in China (Tables 2, 3 and 4). Almost all the varieties reported in this survey are planted exclusively

in one of the three production regions. No individual variety played a dominant role in its growing region except for Zhonghuang 13 in HHHR, where 102 of 379 farmers planted Zhonghuang 13, with an adoption rate of 26.91% . Soybean is photoperiod - sensitive, and each soybean variety can adapt to a narrow range of latitude^[19]. But a few exceptions including Zhonghuang 13 and Zhonghuang 35 were reported to be planted in both NSSR and HHHR, and Kaiyu 12 was planted in both NSSR and SMSR. Jiang et al.^[20] found that low photoperiod sensitivity was the major reason allowing Zhonghuang 13 to adapt to wide areas.

Table 2 Varieties adopted by farmers in the Northern Spring Soybean Region

Order	Variety	Yield /kg · ha ⁻¹	Area /ha	No. of users	Order	Variety	Yield /kg · ha ⁻¹	Area /ha	No. of users
1	Jiangmodou 1	1259.90	522.43	62	94	Suinong 23	1500.00	2.80	2
2	Heihe 38	1883.59	534.84	55	95	Suinong 28	1800.00	13.33	2
3	Tiefeng 29	3060.65	15.17	46	96	Tadou	3000.00	0.47	2
4	Hefeng 50	2148.86	176.00	35	97	Tiefeng 33	3187.50	0.27	2
5	Liaodou 15	2704.55	17.16	33	98	Tiefeng 37	2970.00	0.12	2
6	Tiefeng 31	3080.50	33.20	30	99	Xindadou 5	3630.00	9.27	2
7	Shidadou 2	3549.38	66.90	24	100	Zhonghuang 35	3900.00	4.07	2
8	Heinong 38	3317.05	93.80	22	101	284	2250.00	1.67	1
9	Non - identified improved	2278.57	4.63	21	102	749	2250.00	3.33	1
10	Heinong 48	2606.25	30.67	20	103	811	1500.00	0.13	1
11	Kaiyu 12	2569.74	7.69	19	104	3053	2400.00	0.67	1
12	Mengdou 14	1725.00	27.67	15	105	5208	750.00	2.00	1
13	Beijiangjiu 1	1462.50	99.65	14	106	8502	2400.00	0.20	1
14	Suinong 22	1789.29	24.70	14	107	9395	2250.00	1.77	1
15	Baofeng 7	1837.50	146.53	12	108	85 - 15	1800.00	0.20	1
16	Jindou 19	1566.48	4.02	12	109	85 - 7	2175.00	0.67	1
17	Shennong 8	2926.25	1.83	12	110	97 - 174	2325.00	0.73	1
18	Dongnong 46	2635.91	11.23	11	111	Bei 91 - 95	2445.00	3.67	1
19	Fengdou 8	2611.36	1.10	11	112	Beian 570	1500.00	1.00	1
20	Kenfeng 16	1956.82	55.71	11	113	Beijiang 02 - 1198	799.50	1.73	1
21	Heihe 43	1411.05	55.19	10	114	Beijiang 193	3000.00	2.33	1
22	Heihe 31	1058.33	22.67	9	115	Dalidou (Landrace)	1800.00	12.67	1
23	Jindou 23	2131.67	2.93	9	116	Damin 168	3000.00	0.67	1
24	Kenjiandou 4	2301.67	17.27	9	117	Dan 304	3225.00	0.13	1
25	Xinbeifeng 4	1433.33	32.47	9	118	Dongbei 46	1650.00	8.00	1
26	Heihe 17	1387.50	14.00	8	119	Dongda 2	2250.00	0.09	1
27	Kenjiandou 25	1477.50	38.60	8	120	Dongnong 42	1800.00	1.33	1
28	Liaodou 10	2587.50	0.70	8	121	Dongnong 434	2250.00	2.00	1
29	Suinong 10	1831.88	45.13	8	122	Fengyuan 96 - 18	600.00	1.33	1

续表 2

Order	Variety	Yield /kg · ha ⁻¹	Area /ha	No. of users	Order	Variety	Yield /kg · ha ⁻¹	Area /ha	No. of users
30	Heinong 40	2121.43	0.55	7	123	Fuer 15	1950.00	3.33	1
31	Huajiang 4	1125.00	28.15	7	124	Fuer 3	1500.00	0.80	1
32	Jiunong 26	3428.57	25.70	7	125	Fuer 5	1800.00	2.00	1
33	Suinong 14	2078.57	6.73	7	126	Fuer 6	2250.00	1.33	1
34	Suinong 15	1703.57	11.67	7	127	Han 348	1650.00	0.20	1
35	Beifeng 4	1175.00	18.60	6	128	Hefeng 39	1800.00	2.67	1
36	Fengjiao 7607	3150.00	3.07	6	129	Hefeng 41	4500.00	0.67	1
37	Hefeng 25	1900.00	29.80	6	130	Hefeng 48	2100.00	20.00	1
38	Heihe 29	1420.00	19.67	6	131	Heihe 18	2325.00	1.33	1
39	Heihe 44	1905.00	16.67	6	132	Heinong 34	2250.00	0.08	1
40	Beidou 14	2149.02	8.87	5	133	Heinong 41	2175.00	15.00	1
41	Beidou 5	2280.00	16.07	5	134	Heinong 43	2400.00	6.67	1
42	Chidou 1	2430.00	2.31	5	135	Heinong 50	2250.00	2.00	1
43	Hefeng 51	1605.00	51.47	5	136	Heinong 54	2400.00	0.07	1
44	Heihe 25	1884.00	19.00	5	137	Heiqi (Landrace)	1200.00	0.03	1
45	Heihe 5	3060.00	7.20	5	138	Huajiang 3	2745.00	12.67	1
46	Heinong 37	2454.00	30.87	5	139	Huajiang 3053	2265.00	3.00	1
47	Heinong 51	3330.00	55.00	5	140	Huajiang 3349	1875.00	6.67	1
48	Jiangmodou 2	1020.00	14.33	5	141	Huajiang 4404	3150.00	3.20	1
49	Jindou	960.00	0.43	5	142	Jifeng 1	3600.00	2.00	1
50	Kangxian 4	1359.00	8.87	5	143	Jikedou 1	3150.00	2.00	1
51	Tiefeng 8	2595.00	0.87	5	144	Jilin 12	2100.00	0.20	1
52	Beijiang 01 - 296	927.38	7.03	4	145	Jilin 29	3000.00	0.20	1
53	Heihe 33	1916.25	18.13	4	146	Jilin 51	3750.00	5.00	1
54	Heihe 36	1691.25	16.67	4	147	Jiangfeng 22 - 3286	1500.00	3.00	1
55	Heihe 37	2070.00	18.00	4	148	Jintaiyang 1	1500.00	4.00	1
56	Heihe 48	3180.00	7.87	4	149	Jindou 15	2250.00	0.17	1
57	Heinong 44	1912.50	13.53	4	150	Jindou 18	2250.00	0.07	1
58	Jiyu 47	3843.75	7.77	4	151	Jindou 1	3000.00	0.33	1
59	Liaodou 23	2246.25	2.60	4	152	Jindou 24	1950.00	0.67	1
60	Tiedou 37	3262.50	5.40	4	153	Jiunong 29	4500.00	0.67	1
61	Xindadou 8	3187.50	4.67	4	154	Kangxianwang	1050.00	2.00	1
62	Datianfengyuan 88 - 2	2050.00	20.50	3	155	Kenfeng 17	2047.50	13.33	1
63	Hefeng 47	2300.00	13.20	3	156	Kenjiandou 14	1500.00	3.33	1
64	Hefeng 55	2240.00	36.67	3	157	Kenjiandou 28	1920.00	1.20	1
65	Heinong 39	3730.00	22.47	3	158	Kenjiandou 29	2250.00	3.13	1
66	Heinong 42	2080.00	13.00	3	159	Kenjiandou 7	2700.00	0.93	1
67	Jinda 53	2625.00	3.60	3	160	Kennong 10	1350.00	0.47	1
68	Jindou 20	2500.00	0.61	3	161	Kennong 18	1800.00	2.00	1
69	Kesuo	3850.00	40.00	3	162	Kennong 25	1350.00	4.67	1
70	Liaodou 18	2180.00	1.33	3	163	Liao 81	2250.00	0.33	1

续表 2

Order	Variety	Yield /kg · ha ⁻¹	Area /ha	No. of users	Order	Variety	Yield /kg · ha ⁻¹	Area /ha	No. of users
71	Mengdou 12	1900.00	6.27	3	164	Liaodou 24	2085.00	0.27	1
72	Miandou 2	2250.00	0.37	3	165	Liaodou 32	2160.00	0.33	1
73	Shidadou 1	3400.00	3.13	3	166	Liaodou 4	1740.00	0.20	1
74	Suinong 4	1550.00	2.47	3	167	Liaodou 8 - 5052	1530.00	0.40	1
75	Tiefeng 30	3050.00	0.87	3	168	Luyuandou 198	2250.00	0.40	1
76	Tiefeng 35	3125.00	0.33	3	169	Mengdou 16	2700.00	2.67	1
77	Xindadou 1	3750.00	16.73	3	170	Qingpi (Landrace)	2250.00	0.03	1
78	81 - 15	1950.00	0.73	2	171	Shuangqingdou (Landrace)	1950.00	0.67	1
79	Beifeng 01 - 8296	2437.50	2.33	2	172	Sui 99 - 735	2400.00	5.67	1
80	Fendou 17	2437.50	0.27	2	173	Suinong 17	1875.00	0.67	1
81	Habei 46 - 1	1575.00	7.20	2	174	Suinong 18	1800.00	0.93	1
82	Hai 193	2512.50	6.33	2	175	Suinong 24	2250.00	2.40	1
83	Hefeng 35	2437.50	1.87	2	176	Suinong 25	2250.00	2.00	1
84	Hefeng 40	2137.50	83.33	2	177	Suinong 48	2475.00	1.20	1
85	Hefeng 45	2137.50	16.67	2	178	Tiegan 1	2250.00	0.87	1
86	Hefeng 46	1762.50	7.33	2	179	Xindadou 2	3600.00	1.17	1
87	Hefeng 52	1725.00	20.47	2	180	Xinke 15	4500.00	4.00	1
88	Heinong 35	2175.00	10.03	2	181	Yiwofeng (Landrace)	3225.00	0.40	1
89	Jindou 4	2625.00	0.40	2	182	Yongfeng 8	4500.00	0.40	1
90	Liao 8864 - 1	1800.00	0.40	2	183	Changnong 16	3750.00	0.87	1
91	Mengdou 24	3225.00	0.40	2	184	Changnong 4	1350.00	0.20	1
92	Qingfeng 1	2175.00	0.73	2	185	Zhonghuang 13	2550.00	0.20	1
93	Suinong 14 - 3	1650.00	9.33	2		Average (weighted)	2001.61	3.51	

Table 3 Varieties adopted by farmers in the Huang - Huai - Hai Rivers Valley Summer Soybean Region

Order	Variety	Yield /kg · ha ⁻¹	Area /ha	No. of users	Order	Variety	Yield /kg · ha ⁻¹	Area /ha	No. of users
1	Zhonghuang 13	2268.82	59.81	102	37	Yuejin 10	2250.00	7.00	2
2	Jindou 25	1902.69	4.38	26	38	Zaoshudou (Landrace)	2175.00	0.23	2
3	Youbian 30	2153.57	32.93	14	39	Zhonghuang 25	2325.00	0.47	2
4	Yudou 29	2723.57	27.53	14	40	Zhonghuang 39	2550.00	0.87	2
5	Gaofeng 1	2886.92	3.03	13	41	Zhoudou 11	2625.00	0.73	2
6	Wandou 9	2067.69	2.79	13	42	88 - 60	2250.00	0.27	1
7	Shangdou 1099	2657.50	11.36	12	43	Baidou (Landrace)	2100.00	0.33	1
8	Yudou 25	2400.00	3.43	12	44	Beijing 140	2850.00	0.03	1
9	Suike 928	2307.27	9.01	11	45	Cangdou 5	1950.00	0.47	1
10	Zhudou 9715	2318.18	3.27	11	46	Caohuangdou (Landrace)	1350.00	0.10	1
11	Hedou 12	2979.00	1.89	10	47	Dabaike (Landrace)	1575.00	0.01	1
12	Yudou 22	2595.00	18.10	10	48	Dalyudou (Landrace)	3150.00	0.20	1
13	Huaidou 4	2741.67	7.13	9	49	Dishen	2940.00	0.87	1
14	Ludou 4	3096.56	1.97	9	50	Dongdou 17	3015.00	0.07	1
15	Zhoudou 12	2860.71	1.93	7	51	Fandou 5	3000.00	0.67	1

续表 3

Order	Variety	Yield /kg · ha ⁻¹	Area /ha	No. of users	Order	Variety	Yield /kg · ha ⁻¹	Area /ha	No. of users
16	Bayuezha (Landrace)	2250.00	2.02	6	52	Hedou 15	2475.00	0.11	1
17	Hongmaodou (Landrace)	1887.50	3.27	6	53	Hedou 16	2550.00	0.09	1
18	Kefeng 6	2175.00	2.00	6	54	Huaidou 5	2700.00	0.67	1
19	Non - identified landraces	2238.00	0.49	5	55	Huaidou 6	3900.00	0.33	1
20	Zheng 9525	3075.00	1.53	5	56	Jidou 10	2250.00	0.07	1
21	Lyuguang 75	3662.50	0.51	4	57	Jidou 17	1980.00	0.20	1
22	Zheng 92116	2737.50	0.90	4	58	Ludou 10	2850.00	0.10	1
23	Hedou 13	2590.00	0.90	3	59	Qiyuezha (Landrace)	2250.00	0.07	1
24	Zhonghuang 35	3450.00	0.27	3	60	Shanning 10	2535.00	0.06	1
25	Guandou 1	1500.00	0.47	2	61	Shangqiu 7608	2550.00	0.13	1
26	He 84 - 5	2250.00	1.67	2	62	Shennong 25104	2265.00	0.07	1
27	Hedou 11	2850.00	0.20	2	63	Shiyuezha (Landrace)	1500.00	0.03	1
28	Jihuang 13	2850.00	0.07	2	64	Wandou 10	1500.00	0.47	1
29	Ludou 11	2670.00	0.42	2	65	Yudou 11	1620.00	0.20	1
30	Qihuang 26	2497.50	1.00	2	66	Yudou 17	2400.00	0.20	1
31	Shangdou 6	1875.00	0.20	2	67	Yudou 19	2175.00	0.02	1
32	Wandou 15	1762.50	4.00	2	68	Zhonghuang 14	2100.00	0.20	1
33	Wandou 24	2587.50	0.62	2	69	Zhoudou 16	2700.00	0.93	1
34	Wandou 26	1650.00	3.64	2	70	Zhoudou 6	2775.00	2.81	1
35	Wandou 12	1912.50	3.12	2	71	Zhudou 9716	2175.00	0.60	1
36	Yudou 5	2475.00	0.33	2	Average (weighted)		2384.13	0.62	

Table 4 Varieties adopted by farmers in the Southern Multi - Cropping Soybean Region

Order	Variety	Yield /kg · ha ⁻¹	Area /ha	No. of users	Order	Variety	Yield /kg · ha ⁻¹	Area /ha	No. of users
1	Non - identified landraces	1606.40	9.95	87	29	Guichun 2	2062.50	0.13	2
2	Edou 8	2160.30	6.13	16	30	Guixia 2	2062.50	0.20	2
3	Edou 4	2228.63	5.67	13	31	Heidou (Landrace)	1575.00	0.15	2
4	Gongxuan 1	1309.09	0.93	11	32	Hualiandou (Landrace)	1012.50	0.07	2
5	Dongladou	1741.67	0.67	9	33	Qiyuehuang (Landrace)	937.50	0.15	2
6	Guixia 1	1303.13	1.34	8	34	Sanlidou (Landrace)	1800.00	2.25	2
7	Dedou 6171	1892.14	1.93	7	35	Baikehuangdou (Landrace)	1950.00	0.10	1
8	Kaiyu 12	3606.43	2.80	7	36	Dashuidou (Landrace)	1200.00	0.21	1
9	Qianjindou (Landrace)	848.57	0.55	7	37	Erjizao (Landrace)	1875.00	0.08	1
10	Dabaidou (Landrace)	1912.50	0.70	6	38	Guichun 1	2250.00	0.13	1
11	Huachun 2	2842.50	3.90	6	39	Guixia 3	1500.00	0.17	1
12	Liuyuebai (Landrace)	900.00	1.53	6	40	Huangpidou (Landrace)	1800.00	0.11	1
13	Jiuyuehuang (Landrace)	1494.00	0.55	5	41	Huikedou (Landrace)	2250.00	0.08	1
14	Wendou 1	1230.60	0.57	5	42	Huimaodou (Landrace)	2250.00	0.03	1
15	Zhechun 2	1740.00	1.13	5	43	Liuyuehuang (Landrace)	937.50	0.04	1
16	Non - identified improved	1312.50	0.19	4	44	Lyudou (Landrace)	1050.00	0.05	1
17	Guichun 8	1406.25	0.85	4	45	Pengxishiyuehuang	1800.00	0.10	1

续表 4

Order	Variety	Yield /kg · ha ⁻¹	Area /ha	No. of users	Order	Variety	Yield /kg · ha ⁻¹	Area /ha	No. of users
18	Huaxia 1	2456.25	1.33	4	46	Qiandou 6	1650.00	0.11	1
19	Xiaolidou (Landrace)	1743.75	0.32	4	47	Qingdadou (Landrace)	2550.00	0.07	1
20	Huaxia 2	2550.00	0.93	3	48	Qingpi (Landrace)	1200.00	0.03	1
21	Huangkedou (Landrace)	2150.00	0.44	3	49	Ribendadou	1575.00	0.05	1
22	Liudou 3	1625.00	0.97	3	50	Shiyuehuang (Landrace)	750.00	0.20	1
23	Nandou 12	2000.00	0.29	3	51	Xibaidou (Landrace)	1920.00	0.13	1
24	Qiandou 2	2200.00	0.29	3	52	Xiaohuangdou (Landrace)	825.00	0.80	1
25	Aituo 3	1125.00	0.07	2	53	Xiaolidongdou (Landrace)	1687.50	0.07	1
26	Baimaodou (Landrace)	2043.75	0.27	2	54	Zaohuangdou (Landrace)	2250.00	0.08	1
27	Baihuadou (Landrace)	2025.00	0.15	2		Average (weighted)	1971.23	0.19	
28	Dabaishuidou (Landrace)	810.00	0.04	2					

We found a very high adoption rate of improved varieties at national level, but apparent differences among the three regions (Table 5). In NSSR and HHHR almost all the surveyed soybean farmers used improved varieties, whereas in SMSR landraces were still widely adopted. In NSSR, 896 of 901 farmers adopted improved varieties, with an adoption rate of 99.45%, much higher than the national level of 87.22%. In total 185 varieties were used there, including 180 improved varieties and 5 landraces. In HHHR, the adoption rate of improved varieties reached 93.40%, and in total 354 of the 379 surveyed farmers chose improved varieties. The 71 varieties used there included 62 improved varieties and 9 landraces. In SMSR, 101

of 269 surveyed farmers adopted improved varieties, with an adoption rate of 37.55%. In this region 29 landraces were still planted by the investigated farmers, 53.70% of the 54 varieties sampled. North China is a traditional soybean growing region, where there are a large number of soybean research organizations. Governments give priority in financial support to soybean research in this area. This situation led to the release of more varieties in this region together with a relatively well-established soybean variety extension system. In contrast, the southern region lags behind not only in soybean research inputs, but also in number of released soybean varieties^[21].

Table 5 Use of improved varieties or landraces

Variety type	NSSR			HHHR			SMSR			Total		
	No. of varieties	No. of farmers	Percentage of farmers/%	No. of varieties	No. of farmers	Percentage of farmers/%	No. of varieties	No. of farmers	Percentage of farmers/%	No. of varieties	No. of farmers	Percentage of farmers/%
Landrace	5	5	0.55	9	25	6.60	29	168	62.45	43	198	12.78
Improved variety	180	896	99.45	62	354	93.40	25	101	37.55	267	1351	87.22
Total	185	901	100.00	71	379	100.00	54	269	100.00	310	1549	100.00

Farmers’ perceptions of soybean variety traits

The common concern for farmers in choosing a variety is whether it has high yield characteristic. This concern is consistent with the national long term breeding aim of improving yield potential. However, the regional differences in farmer’s perceptions of other variety traits are remarkable (Table 6).

In NSSR, farmers emphasized the traits of yield stability, lodging resistance, disease resistance, and

seed appearance for improved varieties. Most of the sampled farmers preferred large round seeds with yellow hilum. A small group of farmers chose to grow landraces for their good taste or high productivity of to-fu.

In HHHR, farmers had the same preference for variety traits as did those in NSSR, but the ranks were different. Lodging resistance was followed by disease resistance, seed appearance, and yield stability. The

improved varieties were superior in all the surveyed traits, including production characteristics, environmental adaptability, commodity attributes, and processing quality.

In SMSR, the improved varieties attracted farmers

mainly for production attributes such as pod number per plant and plant type. But landraces had better adaptability and were superior in stress tolerance, disease resistance, and early maturity as well as processing quality.

Table 6 Farmer’s perceptions of soybean variety traits

Trait	NSSR			HHHR			SMSR			Total		
	Landrace	Improved variety	Percentage /%	Landrace	Improved variety	Percentage /%	Landrace	Improved variety	Percentage /%	Landrace	Improved variety	Percentage /%
High yield	2	435	48.50	1	175	46.44	46	54	37.17	49	664	46.03
Lodging resistance	0	131	14.54	6	79	22.43	4	9	4.83	10	219	14.78
Yield stability	0	144	15.98	0	56	14.78	14	1	5.58	14	201	13.88
Disease resistance	1	122	13.65	1	64	17.15	26	7	12.27	28	193	14.27
Seed appearance	1	88	9.88	0	59	15.57	9	12	7.81	10	159	10.91
Stress tolerance	0	62	6.88	3	35	10.03	37	13	18.59	40	110	9.68
Processing quality	1	69	7.77	1	17	4.75	23	18	15.24	25	104	8.33
Early maturity	0	57	6.33	12	34	12.14	15	7	8.18	27	98	8.07
Pod number	0	26	2.89	0	41	10.82	5	8	4.83	5	75	5.16
Plant type	0	21	2.33	0	25	6.60	4	8	4.46	4	54	3.74
No shattering	0	15	1.66	2	21	6.07	0	0	0.00	2	36	2.45
Plant height	0	21	2.33	2	5	1.85	4	2	2.23	6	28	2.19
Insect resistance	0	8	0.89	1	1	0.53	3	3	2.23	4	12	1.03

Numbers in the table are number of farmers who reported that the specific traits lead them to adopt the varieties. Percentage denotes the number of farmers choosing a given variety trait (both for landraces and improved varieties) relative to the total number of farmers surveyed in the NSSR, HHHR, and SMSR, respectively.

The various scales of soybean production, cropping systems, management practices, and roles of soybean in local agriculture led to diverse demands in variety traits. For instance, high yield was considered the most important variety trait in all three regions, whereas farmers from NSSR and HHHR placed more emphasis on it (where 48.45% and 46.44% of surveyed farmers considered it important in variety adoption, respectively) compared with those of SMSR (where only 37.17% of sampled farmers considered it important in variety adoption) (Table 6). The reason is that soybean is a major crop in both NSSR and HHHR but only a supplementary crop in SMSR. With respect to stress tolerance, farmers in SMSR need varieties with better performance for this trait because soybean in this region is often planted in infertile fields, and frequently suffers from drought and high temperature during growing season.

Based on the above results, we concluded that farmers generally preferred improved varieties and that these outperformed landraces in many respects, especially in high yield, lodging resistance, yield stability,

and disease resistance. But this does not mean that the improved varieties are superior in all the important traits. Regional differences in farmers’ preference for variety traits and their rankings of these traits should be considered in soybean breeding.

Factors influencing variety choice

Table 7 describes variables included in the binary logit model. Only a few variety traits were included in the model as explanatory variables, owing to the high correlation between the variety trait dummies. Farmers were classified as adopters (dependent variable = 1) if they planted improved varieties and non - adopters (dependent variable = 0) otherwise. Education fell into 5 levels: no formal education = 1 ; primary education = 2 ; secondary education = 3 ; high school = 4 ; above high school = 5 ; Farming experience means famers’ experience in soybean farming in years ; Family size is number of family members ; Off - farm labor means number of family members who work off - farm ; Farm size is soybean planting area (ha) ; Seed source is the way by which farmers get the seed, it took the value of 1 if purchased, and 0 otherwise. A dummy variable for

each variety trait was created. The dummy took a value of 1 if farmers reported it led them to adopt the varieties, and 0 otherwise. Table 8 shows the binary logit regression results.

Table 7 Description of variables in the binary logit model

Variable	NSSR				HHHR				SMSR			
	Min.	Max.	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.	Mean	SD
Education	1	5	3.23	—	1	5	3.27	—	1	5	2.85	—
Farming experience	2	58	23.06	9.20	3	60	25.56	10.43	2	57	27.53	10.86
Family size	2	7	3.99	1.16	2	7	4.44	1.35	2	7	4.70	1.37
Off - farm labor	0	5	0.46	0.79	0	5	1.07	1.08	0	5	1.12	1.28
Farm size	0.01	80.00	3.51	6.87	0.01	6.67	0.62	0.98	0.01	2.13	0.19	0.22
Seed source	0	1	0.78	—	0	1	0.55	—	0	1	0.25	—
High yield	0	1	0.48	—	0	1	0.46	—	0	1	0.37	—
Lodging resistance	0	1	0.15	—	0	1	0.22	—	0	1	0.05	—
Early maturity	0	1	0.06	—	0	1	0.12	—	0	1	0.08	—
Disease resistance	0	1	0.14	—	0	1	0.17	—	0	1	0.12	—
Stress tolerance	0	1	0.07	—	0	1	0.10	—	0	1	0.19	—
Processing quality	0	1	0.08	—	0	1	0.05	—	0	1	0.15	—

Table 8 Binary logit estimates of factors influencing improved variety adoption in China

Variables	NSSR		HHHR		SMSR	
	Coefficient	<i>P</i> - value	Coefficient	<i>P</i> - value	Coefficient	<i>P</i> - value
Constant	0.142 * *	0.963	0.799	0.621	− 1.077	0.261
Education	0.299	0.643	0.146	0.623	0.183	0.272
Farming experience	0.142	0.028	− 0.030	0.208	− 0.032 * *	0.043
Family size	0.459	0.402	0.135	0.566	− 0.122	0.395
Off - farm labor	− 1.578 * * *	0.003	− 0.219	0.430	0.063	0.674
Farm size	− 0.019	0.832	2.153 * *	0.030	2.453 * * *	0.006
Seed source	0.839	0.396	2.323 * * *	0.000	1.483 * * *	0.000
High yield	0.801	0.426	2.803 * * *	0.010	1.032 * * *	0.001
Lodging resistance	16.309	0.996	− 0.207	0.742	1.832 * * *	0.009
Early maturity	16.830	0.997	− 1.822 * * *	0.005	0.081	0.888
Disease resistance	− 0.452	0.708	1.585	0.158	− 0.577	0.282
Stress tolerance	15.581	0.997	− 0.028	0.972	0.196	0.639
Processing quality	− 1.582	0.219	− 0.610	0.660	0.270	0.534

N - value, log - likelihood, pseudo - R² and percentage predicted correctly of NSSR are 901, 152.883, 0.381, and 97.2, respectively. N - value, log - likelihood, pseudo - R² and percentage predicted correctly of HHHR are 379, 72.621, 0.453, and 95.3, respectively. N - value, log - likelihood, pseudo - R² and percentage predicted correctly of SMSR are 269, 282.279, 0.327, and 74.3, respectively. * and * * * denote significant at the 0.05 and 0.01 probability level, respectively.

Socioeconomic factors influencing farmers’ variety choices

Education is considered to be one of the means of en-

hancing farmers’ ability to acquire and analyze information^[22]. Several studies have reported the positive impacts of farmer education on technology adop-

tion^[23-24]. However, our results indicated no relationship between education and variety choice.

Farming experience had mixed effects on technology adoption. A study of the adoption of conservation farming found that farming experience was not an important factor^[25], but that it negatively affected the adoption of more risky technologies (e. g. fertilization) and positively affected the adoption of less risky technology (e. g. pesticides)^[26]. Our results showed that farming experience had a positive impact on variety choice in NSSR, but a negative impact in SMSR.

Family size was not significant in influencing farmers' variety choices, a result similar to the finding that among rice farmers there was no relationship between family size and improved rice variety adoption^[27]. Family size usually serves as an indicator of labor supply. Although improved variety adoption is associated with high yield, it does not necessarily save labor. It is also possible that a larger family engages in off-farm activities if they think that off-farm work provides more economic returns than farm work^[28].

The significant negative coefficient between variety adoption and off-farm labor in NSSR indicated that improved variety adoption declined with the increase of off-farm labor. This finding is in contrast with a study on maize in which the adoption of improved maize varieties was found to be positively influenced by off-farm work^[29]. Adoption of herbicide-tolerant soybeans was positively related to off-farm employment income^[30-31].

Farm size positively affected improved variety adoption in HHHR and SMSR. Farm size is usually associated with farmers' ability to assume risk^[32]. Further, a large farm may take advantage of a possible scale effect of variety adoption^[13]. Positive effects of farm size on the adoption of improved maize have been reported^[33-34]. Table 7 shows the average soybean farm scale in China, ranging from 0.19 to 3.51 ha. The smallest soybean fields are located in SMSR, where some farmers planted soybean only on field bunds. Moreover, the comparative advantage of growing maize over soybean has resulted in a massive shift of planting area from soybean to maize. Although soybean/maize relay cropping is one of the ways to expand soybean planting areas in SMSR, greater effort should be made to increase farm sizes to achieve scale effects.

The significantly positive coefficients for seed purchase in HHHR and SMSR suggested that farmers preferred to choose improved varieties if the seed was purchased rather than recycled. Seed purchase is one of the ways in which farmers gain access to new varieties. However, seed saving is a traditional farming practice. Farmers keep some seed from the harvest for replanting in the following year, a practice that once served multiple purposes in farming practice, including helping farmers minimize dependence on commercial suppliers, reducing production cost, and contributing to genetic diversity^[35-37]. Soybean is a self-pollinated plant and the seeds are more readily saved and replanted than those of open-pollinated crops such as maize. In recent years the Chinese government has made great efforts to encourage farmers to adopt new agricultural technologies^[38]. Farmers have realized the importance of seed improvement. In addition, seed commercialization has been achieved in China since the first Seed Law was enacted^[39]. Seeds sold in the market are exclusively improved varieties developed by public research organizations or private companies. It is reasonable that the purchase of seeds leads to the higher adoption of improved varieties.

Variety traits influencing farmers' variety choices

High yield significantly increased the probability of adoption of improved varieties in HHHR and SMSR, a result in accord with that previous report for maize adoption^[13]. High yield is the primary aim of soybean breeding in China. Considering the limits in extending soybean planting to a larger area, continuous efforts have been devoted to high-yield breeding, which is expected to increase soybean production in China^[6]. This is also one of the best ways to enhance soybean self-sufficiency and to fill the gap between the soaring soybean imports and the stagnant domestic soybean production in China.

Lodging resistance significantly influenced farmers' decisions to choose improved varieties in SMSR. Lodging is one of the main causes of high yield loss in cereals^[40], but lodging resistance is seldom included in the variety adoption model. This result can be explained by the unique intercropping and relay-cropping system used in SMSR, which requires varieties with high levels of lodging resistance. For this system lodging-re-

sistant varieties are preferred by farmers.

Early maturity was significantly emphasized by farmers in HHHR. Maturity group is defined by the days from planting to maturity at specific latitudes^[41] and is important for determining the geographical adaptation of a variety. In general farmers in NSSR prefer early - maturing varieties to avoid early frost, and in HHHR summer soybean must be harvested before the planting of winter wheat, owing to the short farming season. In recent years more farmers work off - farm and must finish the soybean harvest during the National Day holiday, leading to a more urgent need for early - maturing varieties.

Soybean disease incurs great yield loss to soybean production worldwide^[42-43], and use of resistant varieties is the most effective and environmentally friendly method for controlling disease. However, our study found unexpectedly that disease resistance had no impact on farmers' variety choice in these three regions. Particularly in the north part of NSSR, soybean is continuously cultured, increasing numbers of soybean cyst nematodes and soybean fungal pathogens cause high yield losses^[44-45]. One explanation for the result is the development of disease resistant varieties nationwide^[6]. Moreover, the extensive use of seed coatings has effectively controlled soybean disease.

Stress tolerance and processing quality were important variety traits, but not determining factors for farmers' variety choices. This result indicated that the improved varieties are not superior in the traits of stress tolerance and processing quality. More attention should be given to these two traits in soybean breeding in the future. Further, climate change has been predicted to exert a strong influence on small - scale farmers in the developing countries^[46]. Dramatically fluctuating weather will pose great challenges to stress tolerance breeding.

Conclusions

We identified factors influencing farmers' soybean variety choices in China. Farmers' socioeconomic characteristics, seed sources, and variety traits were included as variables in a binary logit model. The results showed that farmers' preference for variety traits varied significantly across regions. Binary logit analysis also

showed obvious regional differences among factors controlling farmers' variety choices; farming experience and off - farm labor were the leading factors in NSSR; whereas farm size, seed source, high yield, and maturity group played key roles in HHHR; and farming experience, farm size, seed source, high yield, and lodging resistance dominated in SMSR.

We conclude that breeding programs should consider farmers' concerns about variety traits, and more soybean varieties adapted to local production environments should be developed. This study also suggests the necessity of developing large - scale soybean farms to realize economies of scale. Besides high yield, early maturity in HHHR, and lodging resistance in SMSR should be stressed in soybean breeding for those regions.

One major limitation of this study is the extremely small sample size of landrace - planting farmers in NSSR. Accordingly, the data were analyzed by regions, not by the three regions as a whole, in order to identify regional differences in soybean variety adoption.

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References

[1] Aubert C, Zhu X G. The changing role of soybean in China's food system: a study in its production, processing, consumption and trade [M]. Beijing: China Agriculture Press, 2002.

[2] Zhu X G. The difficulties faced by China's soybean industry and countermeasures for its development [J]. Chinese Rural Economy, 2003(1): 27 - 33. (in Chinese)

[3] Yu C L, Feng Z C. Quantitative analysis on comparative advantage and international competitiveness of soybean in China [J]. Research of Agricultural Modernization, 2005, 26 (1): 26 - 30. (in

- Chinese with English abstract)
- [4] Xing L. Estimating the non - commercial - commercial feed gap in China and its impact on future world demand for soybeans [D]. Urbana - Champaign, USA: University of Illinois, 2009.
 - [5] Masuda T, Goldsmith P D. China's meat and egg production and soybean meal demand for feed: An elasticity analysis and long - term projections [J]. International Food and Agribusiness Management Review, 2012, 15(3): 35 - 54.
 - [6] Institute of Crop Sciences of Chinese Academy of Agricultural Sciences, Soybean Research Center of Jilin Academy of Agricultural Sciences. China's Soybean Cultivars (1993 - 2004) [M]. Beijing: China Agriculture Press, 2007. (in Chinese)
 - [7] Wang C J, Sun S, Jin S J, et al. Genetic diversity analysis of widely - planted soybean varieties from different decades and major production regions in China [J]. Acta Agronomica Sinica, 2013, 39(11): 1917 - 1926. (in Chinese with English abstract)
 - [8] Kafle B. Determinants of adoption of improved maize varieties in developing countries: A review [J]. International Research Journal of Applied and Basic Sciences, 2010, 1(1): 1 - 7.
 - [9] Otieno D J. Market and non - market factors influencing farmers' adoption of improved beef cattle in arid and semi - arid areas of Kenya [J]. Journal of Agricultural Science, 2012, 5(1): 32 - 43.
 - [10] Namwata B, Lwelamira J, Mzirai O B. Adoption of improved agricultural technologies for Irish potatoes (*Solanum tuberosum*) among farmers in Mbeya Rural district, Tanzania: A case of Ilungu ward [J]. Journal of Animal & Plant Sciences, 2010, 8(1): 927 - 935.
 - [11] Just R, Silberman D, Feder G. Adoption of agricultural innovations in developing countries: A survey [Z]. World Bank Staff Working Paper, Number 444, 1981.
 - [12] Sall S, Norman D, Featherstone A M. Quantitative assessment of improved rice variety adoption: The farmer's perspective [J]. Agricultural Systems, 2000, 66(2): 129 - 144.
 - [13] Hintze L H, Renkow M, Sain G. Variety characteristics and maize adoption in Honduras [J]. Agricultural Economics, 2003, 29(3): 307 - 317.
 - [14] Lunduka R, Fisher M, Snapp S. Could farmer interest in a diversity of seed attributes explain adoption plateaus for modern maize varieties in Malawi? [J]. Food Policy, 2012, 37(5): 504 - 510.
 - [15] Bu M H, Pan T F. A study on the regionalization of soybean production area in China [J]. Soybean Science, 1982, 1(2): 105 - 121. (in Chinese with English abstract)
 - [16] Sleper D A, Poehlman J M. Breeding field crops [M]. USA: Blackwell Publishing, 2006.
 - [17] McFadden D. Conditional logit analysis of qualitative choice behavior [C]//Zarembka P. Frontiers in econometrics. New York: Academic Press, 1974.
 - [18] SPSS Incorporation. IBM SPSS Statistics 19.0 Core System Guide, 2010.
 - [19] Morse W J, Cartter J L, Williams L F. Soybeans: culture and varieties [M]. Washington D. C., USA: United States Department of Agriculture, 1949.
 - [20] Jiang Y, Leng J T, Fei Z H, et al. Photoperiod responses of a widely adapted soybean cultivar of Zhonghuang 13 [J]. Soybean Science, 2009, 28(3): 377 - 381. (in Chinese with English abstract)
 - [21] Peng Z. Study on the soybean research and development system in China [J]. Scientia Agricultura Sinica, 2009, 42(11): 3852 - 3862. (in Chinese with English abstract)
 - [22] Asfaw A, Admassie A. The role of education on the adoption of chemical fertilizer under different socioeconomic environments in Ethiopia [J]. Agricultural Economics, 2004, 30(3): 215 - 228.
 - [23] Strauss J, Barbosa M, Teixeira S, et al. Role of education and extension in the adoption of technology: A study of upland rice and soybean farmers in Central - West Brazil [J]. Agricultural Economics, 1991, 5(4): 341 - 359.
 - [24] Lin J Y. Education and innovation adoption in agriculture: Evidence from hybrid rice in China [J]. American Journal of Agricultural Economics, 1991, 73(3): 713 - 723.
 - [25] Mazvimavi K, Twomlow S. Socioeconomic and institutional factors influencing adoption of conservation farming by vulnerable households in Zimbabwe [J]. Agricultural Systems, 2009, 101(1 - 2): 20 - 29.
 - [26] Kebede Y, Gunjal K, Coffin G. Adoption of new technologies in Ethiopian agriculture: The case of Tegulet - Bulga district Shoa province [J]. Agricultural Economics, 1990, 4(1): 27 - 43.
 - [27] Shakya P B, Flinn J C. Adoption of modern varieties and fertilizer use on rice in the eastern Tarai of Nepal [J]. Journal of Agricultural Economics, 1985, 36(3): 409 - 419.
 - [28] Amaza P, Kwacha A, Kamara A. Farmers' perceptions, profitability, and factors influencing the adoption of improved maize varieties in the Guinea Savannas of Nigeria [C]//Proceedings of Tropentag 2008, October 7 - 9, 2008, Hohenheim, Germany.
 - [29] Tura M, Aredo D, Tsegaye W, et al. Adoption and continued use of improved maize seeds: Case study of Central Ethiopia [J]. African Journal of Agricultural Research, 2010, 5(17): 2350 - 2358.
 - [30] Fernandez - Cornejo J, Hendricks C. Off - farm work and the adoption of herbicide - tolerant soybeans [C]//Proceedings of Southern Agricultural Association Annual Meeting 2003, February 1 - 5, 2003, Alabama, USA.
 - [31] Fernandez - Cornejo J, Hendricks C, Mishra A. Technology adoption and off - farm household income: The case of herbicide - tolerant soybeans [J]. Journal of Agricultural and Applied Economics, 2005, 37(3): 549 - 563.
 - [32] Perrin R, Winkelmann D. Impediments to technical progress on small versus large farms [J]. American Journal of Agricultural Economics, 1976, 58(5): 888 - 894.
 - [33] Alene A D, Poonyth D, Hassan R M. Determinants of adoption and intensity of use of improved maize varieties in the Central Highlands of Ethiopia: A Tobit analysis [J]. Agrekon, 2000, 39(4): 633 - 643.
 - [34] Ayinde O E, Adewumi M O, Babalola O A. Determinants of adoption of downy mildew resistant maize by small - scale farmers in Kwara State, Nigeria [J]. Global Journal of Science Frontier Research, 2010, 10(1): 32 - 35.

善林业生态系统建设,发挥好林业生态对大豆等农业的促进作用,提升大豆产业化水平,以改善本区域林业生态系统建设与大豆产业发展耦合协调关系。

3 结 论

本文基于熵值法和耦合模型测度黑龙江林业生态系统建设与大豆产业发展间耦合关联度和耦合协调度,并选取 2008~2012 年的数据进行了实证分析,结果表明:黑龙江林业生态系统建设与大豆产业发展间耦合关联度和耦合协调度在 2008 年处于较低水平,在 2009~2012 年总体上呈现较高水平状态,但在这期间二者的耦合关联度均显著地高于二者的耦合协调度。因此,相关部门要进一步重视林业生态系统建设与大豆产业发展的协调发展,加大林业生态系统建设,以林业发展带动大豆产业发展,同时提升大豆产业化水平,使二者在协调中共同发展。

参考文献

[1] 孟凡生,李美莹.我国能源消费影响因素评价研究—基于突变级数法和改进熵值法的分析[J].系统工程,2012,30(8):10-15. (Meng F S, Li M Y. Research on evaluation influencing factors of energy consumption in China—Based on catastrophe theory and improved entropy[J]. Systems Engineering, 2012,30(8): 10-15.)

[2] 王琦.产业集群与区域经济空间耦合机理研究[D].长春:东北师范大学,2008. (Wang Q. Research on coupling mechanism of industrial cluster and economic space of region [D]. Changchun: Northeast Normal University, 2008.)

[3] 罗子嫒,何宜庆,毛华.华东地区金融集聚与经济发展耦合关系研究[J].企业经济,2013(8):135-138. (Luo Z Y, He Y Q, Mao H. The coupling relationship between financial agglomeration and economic development in East China[J]. Enterprise Economy, 2013(8):135-138.)

[4] 吕洁华,毛玮,崔臻祥.基于能值分析的林业生态经济系统可持续发展指标体系研究[J].中国林业经济,2009(2):1-8. (Lyu J H, Mao W, Cui Z X. Research of indexes system of sustainable development of forestry eco-economic system based on energy analysis[J]. China Forestry Economy, 2009(2):1-8.)

[5] 荆立新.东北国有林区林业生态经济发展模式研究[D].哈尔滨:东北林业大学,2009. (Jing L X. Research into the development model of forestry economics in Northeast State-owned forestry region[D]. Harbin: Northeast Forestry University,2009.)

[6] 谢煜.林业生态与产业共生协调度评价模型[D].南京:南京林业大学,2009. (Xie Y. Harmonious symbiosis evaluation model and its application for forestry ecology and forestry industry system [D]. Nanjing: Nanjing Forestry University,2009.)

[7] 钟金传.中国大豆产业国际竞争力研究[D].北京:中国农业大学,2005. (Zhong J Z. Study on international competitiveness of soybean industry of China [D]. Beijing: China Agricultural University, 2005.)

[8] 张淑荣,李广,刘稳.我国大豆产业的国际竞争力实证研究与影响因素分析[J].国际贸易问题,2007(5):10-15. (Zhang S R, Li G, Liu W. Experimental study and factors analysis on the international competition power of Chinese soybean industry[J]. Journal of International Trade, 2007(5):10-15.)

[9] 程遥.借鉴大豆主产国经验促进我国大豆产业健康发展[J].大豆科学,2012,31(6):1013-1016. (Cheng Y. Learn from the major soybean producing countries experience to promote the healthy development of China's soybean industry[J]. Soybean Science, 2012,31(6):1013-1016.)

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[35] Mascarenhas M, Busch L. Seeds of change: Intellectual property rights, genetically modified soybeans and seed saving in the United States [J]. Sociologia Ruralis, 2006, 46(2): 122-138.

[36] Thomas M, Demeulenaere E, Dawson J C, et al. On-farm dynamic management of genetic diversity: the impact of seed diffusions and seed saving practices on a population-variety of bread wheat [J]. Evolutionary Applications, 2012, 5(8): 779-795.

[37] Hugo Perales R, Brush S B, Qualset C O. Dynamic management of maize landraces in central Mexico [J]. Economic Botany, 2003, 57(1): 21-34.

[38] Han T F. Guide for Soybean Technology Extension [M]. Beijing: China Agriculture Press, 2011. (in Chinese)

[39] Huang J K, Xu Z G, Hu R F, et al. China's seed industry: A chievement, problems and development strategies [J]. Agricultural Economics and Management, 2010,(3): 5-10. (in Chinese with English abstract)

[40] Keller M, Karutz C, Schmid J E, et al. Quantitative trait loci for lodging resistance in a segregating wheat x spelt population [J]. Theoretical and Applied Genetics, 1999, 98(6-7): 1171-1182.

[41] Zhang L X, Kyei-Boahen S, Zhang J, et al. Modifications of op-

timum adaptation zones for soybean maturity groups in the USA [J]. Crop Management, 2007. doi: 10.1094/CM-2007-0927-01-RS.

[42] Wrather J A, Koenning S R. Effects of diseases on soybean yields in the United States 1996 to 2007 [J]. Plant Health Progress, 2009, doi: 10.1094/PHP-2009-0401-01-RS.

[43] Wrather J A, Anderson T R, Arsyad D M, et al. Soybean disease loss estimates for the top 10 soybean producing countries in 1994 [J]. Plant Disease, 1997, 81(1): 107-110.

[44] Hu J C, Xue D L, Wang S J. Obstacles of soybean continuous cropping II: mechanism of soybean yield decline and control strategies for toxin of *Penicillium purouregenum* in soils [J]. Chinese Journal of Applied Ecology, 1998, 9(4): 429-434.

[45] Liu X B, Herbert S J. Fifteen years of research examining cultivation of continuous soybean in Northeast China: A review [J]. Field Crops Research, 2002, 79(1): 1-7.

[46] Bellon M R, Hodson D, Hellin J. Assessing the vulnerability of traditional maize seed systems in Mexico to climate change [J]. Proceedings of the National Academy of Sciences of the United States of America, 2011, 108(33): 13432-13437.