



## THE IMPACT OF INTENSIVE UTILIZATION OF CULTIVATED LAND ON GRAIN YIELDS: A CASE STUDY OF SHANDONG PROVINCE IN CHINA

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### ABSTRACT

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Using time series data of agriculture in Shandong Province during the period from 2000 to 2015, this paper sets up an assessment system of intensive utilization of cultivated land, which has 4 criteria(input intensity, utilization intensity, output effectiveness and sustainability) consisting of 9 indices, comprehensively estimates the level of intensive use of agricultural land with entropy method, and empirically analyzes the impact of intensive utilization of cultivated land on grain yields through the use of a multivariable linear regression model. The results are shown as follows: (1) The level of intensive utilization of cultivated land in Shandong Province has been fluctuating upwards but not significantly progressing. (2) Grain yield per hectare is positively correlated with output effectiveness and utilization intensity, and the contribution of output effectiveness to grain yield per hectare is more than the other. (3) grain yield per hectare is negatively correlated with input intensity and sustainability. Therefore, in the long-term, cultivated land management strategy should be planned to improve the input intensity, to emphasis on the sustainability of farm land and to promote the consciousness of cultivated land protection in order to increase the productivity of grain yields.

**Contribution/Originality:** This study contributes in the existing literature by supplementing existing research related to Shandong Province cultivated land, few of which have been conducted on the relationship of grain yield and intensive utilization of arable land. Hence, the current research constitutes an original contribution in this field.

### 1. INTRODUCTION

The supply of grain has always been paid special attention to in the world, especially in China. By now, the Chinese government has comprehensively implemented the “two-child” policy for more than two years, but the age structure of population of China is during the transformation period of solving the aged tendency of population. So the demand of grain still continues to rise with the increase in the population of China. On the other hand, with the continuous development of urbanization and industrialization and the constant improvement of people’s living standard, the consumption of grain always indicates the tendency of rigid growth, while reduction of cultivated land resources, shortage of water supply, et al. are increasingly hampering the grain production (Lin *et al.*, 2008). Therefore, in this circumstance, the inevitable choices for the protection of the grain yield are to increase the cultivated land input and to improve the level of intensive utilization of cultivated land (Chen *et al.*, 2007).

The input intensity and the output effectiveness of cultivated land would obviously affect the agricultural economic growth and farmers' income, and farmers will make a production budget for the next year according to their total revenue for the previous year. Shandong Province is a big agriculture province in China, whose total value of agricultural output increased to ¥464.13 billion from ¥130.04 billion during the period from 2000 to 2016. In addition, the grain yield in 2016 reached 4700.7 million tons, in which the cereal crops yield reached 4505.2 million tons, beans crops yield reached 38.4 million tons, and tuberous crops yield reached 157.2 million tons. Under the stable climate condition, the rise of the grain yield caused by the increase in cultivated land input and the improvement of the quality of cultivated land can alleviate effectively the pressure on the grain production caused by seriously falling acreage of cultivated land. In the circumstance where the tendency of falling acreage of cultivated land cannot be reversed, it is necessary to study the relationship between grain yield and the level of intensive utilization of cultivated land to secure the grain productivity.

Nowadays, the research relating to Shandong Province cultivated land mainly focuses on spatial-temporal differences (Yuan-he and Zi-jun, 2017) assessments of intensive utilization and so on. Few studies have been conducted on the relationship of grain yield and intensive utilization of cultivated land. So, using time series data of agriculture in Shandong Province during the period from 2000 to 2015, this paper constructs an assessment system of intensive utilization of cultivated land, comprehensively estimates the level of intensive use of agricultural land, and empirically analyzes the impact of intensive utilization of cultivated land on grain yields (wheat, corn and so on) to further explain the contribution of the intensive utilization of cultivated land to grain productivity and to give some suggestions for the intensive utilization of cultivated land and the sustainable development of main grain production in Shandong Province.

## 2. THE EVALUATION OF INTENSIVE UTILIZATION OF ARABLE LAND

### 2.1. Theoretical Framework

Although there are many factors on the level of intensive utilization of cultivated land, according to the current intension and the extension of utilization of farmland (Long *et al.*, 2018) following scientific, comprehensive, leading and feasible principles, this paper sets up the assessment system of the level of intensive utilization of cultivated land, which includes 4 criteria and 9 indices, on the basis of the combination of some reference to domestic and overseas research results and the realities of agricultural development in Shandong Province. Entropy method is used to determine the weight of each factors and to avoid the influence of uncertain subjectivity. Extreme difference method would be used to do a non-dimensional treatment to data for standardization, which includes cultivated land data and social economy data, and these fundamental data originate from "Statistical yearbook of China" and "Statistical yearbook of Shandong Province".

### 2.2. Standardization for Data

To make sure that each index could be comparable and to eliminate the impacts of different indices which have different measurement units and nature, extreme difference method is used to standardize data:

$$x'_{ij} = \frac{x_{ij} - x_{jmin}}{x_{imax} - x_{jmin}}$$

Where  $x'_{ij}$  is the term after standardization;  $x_{ij}$  is the initial term of the  $j^{\text{th}}$  index in the  $i^{\text{th}}$  project;  $x_{jmax}$  is the maximum of the  $j^{\text{th}}$  index among all  $m$  projects;  $x_{jmin}$  is the minimum of the  $j^{\text{th}}$  index among all  $m$  projects.

2.3. Entropy Method for Weights

The principle of entropy method is introduced as follows: In the information theory, supposed  $m$  projects have  $n$  indices and each index is  $x_i$ , so entropy of information is  $H(X) = -\sum_{i=1}^n p(x_i) \ln p(x_i)$ , which indicates the order degree of this system. In general, the entropy of information becomes greater when the order degree is higher. On the contrary, the entropy of information gets smaller with the order degree becoming lower. Hence, the entropy of information could calculate the weight of each index based on the difference of each one and provide the basis for the assessment of the intensive utilization of cultivated land (all of  $x_{ij}$  are terms after standardization).

(1) calculate  $p_{ij}$ , which is the weight of the  $i^{\text{th}}$  project under the  $j^{\text{th}}$  index.

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^m x_{ij}}$$

Where  $x_{ij}$  is the term of the  $i^{\text{th}}$  project under the  $j^{\text{th}}$  index.

(2) calculate the entropy  $e_j$  of the  $j^{\text{th}}$  index.

$$e_j = -\frac{1}{\ln m} \sum_{i=1}^m p_{ij} \ln p_{ij}$$

Given  $j$  is fixed, when all  $x_{ij}$  are equal to each other,  $p_{ij} = \frac{x_{ij}}{\sum_{i=1}^m x_{ij}} = \frac{1}{m}$ , at this time,  $e_j$  reaches its maximum, which

indicates  $e_j = 1$  and  $0 \leq e_j \leq 1$ .

(3) calculate the otherness coefficient  $g_j$ .

$$g_j = \frac{1 - e_j}{n - \sum_{j=1}^n e_j}$$

Where  $0 \leq g_j \leq 1$ ,  $\sum_{j=1}^n g_j = 1$ .

For the  $j^{\text{th}}$  index,  $e_j$  becomes greater while the otherness of  $x_{ij}$  gets smaller. If all  $x_{ij}$  are equal,  $e_j = e_{\max} = 1$ ,  $X_i$  will have no impact on the comparison between different projects; however, if the difference of each  $x_{ij}$  is more obvious,  $e_j$  is smaller, which shows greater effect on the comparison between these projects.

(4) definite weights of each index.

$$a_j = \frac{g_j}{\sum_{j=1}^n g_j} \quad (0 \leq a_j \leq 1)$$

After calculating, the weighs of each index and criteria are as follows:

Table-1 the evaluation system of intensive utilization of cultivated land and its weights

Criteria layer (weight)	Index layer (weight)	Units
Input intensity (0.3651)	Labor input per hectare (0.1107)	person/hm <sup>2</sup>
	Chemical fertilizer input per hectare (0.1738)	t/hm <sup>2</sup>
	Mechanical input per hectare (0.0806)	kw/hm <sup>2</sup>
Utilization intensity (0.2677)	Multiple-crop index (0.1982)	%
	Irrigation index (0.0695)	%
Output effectiveness (0.1753)	Value of output per hectare (0.0844)	10 million Yuan/hm <sup>2</sup>
	Yield of output per person (0.0909)	Yuan/person
Sustainability (0.1919)	Cultivated land per person (0.1018)	hm <sup>2</sup> /person
	Non-agricultural index (0.0901)	%

2.4. Evaluation of Cultivated Land Intensive Utilization

$$v_i = \sum_{j=1}^n a_j x'_{ij}, \quad (i=1,2,3,\dots,16 \quad j=1,2,3,\dots,9)$$

Where  $v_i$  is the composite index of intensive utilization of cultivated land in the  $i^{\text{th}}$  year;  $a_j$  is the weight of the  $j^{\text{th}}$  index;  $x'_{ij}$  is the standardized term of the  $j^{\text{th}}$  index in the  $i^{\text{th}}$  year.

2.5. Evaluation Result

Table-2 the evaluation result of intensive utilization of cultivated land

Year	Input intensity	Utilization intensity	Output effectiveness	Sustainability	Comprehensive utilization
2000	0.1394	0.2149	0.0306	0.0002	0.3850
2001	0.1616	0.2118	0.0286	0.0062	0.4082
2002	0.0986	0.1036	0.0003	0.0335	0.2359
2003	0.1084	0.1108	0.0262	0.0462	0.2916
2004	0.1414	0.1135	0.0563	0.0530	0.3641
2005	0.1838	0.1243	0.0688	0.0588	0.4358
2006	0.2412	0.1365	0.0803	0.0605	0.5185
2007	0.2632	0.1393	0.0994	0.0750	0.5768
2008	0.0999	0.0223	0.1040	0.1045	0.3307
2009	0.1034	0.0266	0.1101	0.1026	0.3426
2010	0.1191	0.0344	0.1114	0.1224	0.3873
2011	0.1215	0.0408	0.1281	0.1285	0.4189
2012	0.1079	0.0254	0.1344	0.1371	0.4048
2013	0.0953	0.0088	0.1465	0.1442	0.3947
2014	0.0877	0.0272	0.1572	0.1551	0.4272
2015	0.0806	0.0352	0.1743	0.1919	0.4820

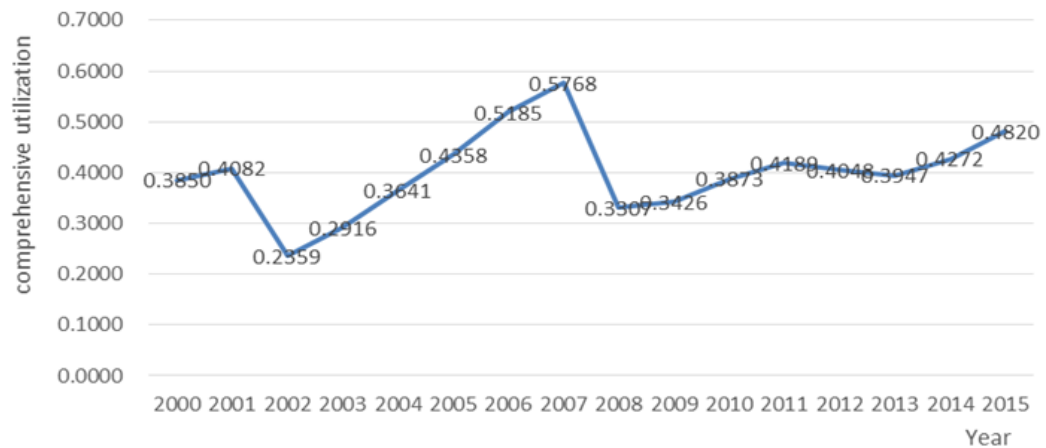


Figure-1. Intensive utilization of arable land in Shandong from 2000 to 2015 year

Combined the table-2 and figure-1, the level of intensive utilization of arable land in Shandong Province is fluctuating upwards as a whole. From 2001 to 2002, the grain yield sharply decreased because of the adjustment to arable land and severe natural disasters, of which both also limited the output effectiveness of cultivated land and caused the comprehensive utilization of arable land to fall to 0.2359 from 0.4082.

During the period from 2002 to 2007 year, the comprehensive utilization significantly increased year by year. The reasons mainly were agricultural taxes reduction, subsidies and allowances by governments and so on, which greatly enhanced farmers' enthusiasm for agricultural production. Input intensity which increased to 0.2632 from 0.0986 and utilization intensity that rose to 0.1393 from 0.1036 indicated that the population of agricultural production grew increasingly; in addition, the rapid development of township enterprises, especially in eastern Shandong peninsula (ESP), contributed to research and development of agricultural resources, which allowed the comprehensive utilization to rise steadily to 0.5768 from 0.2359.

From 2007 to 2008 year, a series of severe natural disasters such as rainstorms, drought and even blizzard struck to Shandong Province and caused damage to agricultural resources and a large number of agricultural facilities were destroyed. Input intensity fell down from 0.2632 to 0.0999; utilization intensity also decreased from 0.1036 to 0.0223; the growth rate of output effectiveness also slowed down.

From 2008 to 2015 year, the substantial transfer of surplus rural workforce into big cities, more and more farmers going out to work and the decline of traditional agricultural labor caused the growth of input intensity and utilization intensity to slow down and even to decrease. However, with more and more clearer land contract relationships, improvement of agricultural infrastructure and the introduction of new agricultural social pension insurance, the number of large farmers got more and more and agricultural production specialization was enhanced increasingly, which made output effectiveness and sustainability rise steadily and finally allowed the comprehensive utilization to get increased than before.

### 3. METHODOLOGY OF EMPIRICAL ANALYSIS

#### 3.1. Empirical Model Specification

This paper selects grain yield per hectare (According to the explanation about statistical indicators by National Bureau of Statistics, besides cereal, wheat, corn, millet, sorghum and other coarse cereals, grains also include tubers and beans) as explained variables, marked as  $Y$ . Then 4 criteria of the evaluation system of intensive utilization of cultivated land, input intensity, utilization intensity, output effectiveness and sustainability are explanatory variables, marked as  $x_1, x_2, x_3, x_4$ .

In order to rule out the heteroscedasticity problem, these variables corresponding to the data are adjusted by adopting their natural logarithm. After that, the multivariable linear regression can be set up as follows:

$$\ln y = \alpha + \beta_1 \ln x_1 + \beta_2 \ln x_2 + \beta_3 \ln x_3 + \beta_4 \ln x_4 + \varepsilon$$

Where:

$\ln$  = natural logarithm.

$\alpha$  = constant term

$\beta_i$  = regression coefficient of the  $i^{\text{th}}$  variables

$x_1$  = index of input intensity

$x_2$  = index of utilization intensity

$x_3$  = index of output effectiveness

$x_4$  = index of sustainability

$\varepsilon$  = random error

3.2. ADF Unit Root Test

To make sure that estimators satisfy the econometric assumptions which include unbiasedness, validity and consistency, stationarity test about each variable should be introduced before the multivariable linear regression.

This paper would test whether  $\ln y, \ln x_1, \ln x_2, \ln x_3, \ln x_4$  are stationary with the method of ADF unit root test, and the results are as follows:

Table-3. The result of ADF unit root test

Variable	t-statistic	1% level	5% level	10% level	prob.*	conclusion
$\ln y$	-0.8987	-4.8001	-3.7912	-3.3423	0.9263	non-stationary
$D(\ln y)$	-7.5144	-4.0579	-3.1199	-2.7011	0.0000	stationary
$\ln x_1$	-1.6456	-3.9591	-3.0810	-2.6813	0.4366	non-stationary
$D(\ln x_1)$	-3.6508	-2.7406	-1.9684	-1.6044	0.0014	stationary
$\ln x_2$	-3.2568	-4.8001	-3.7912	-3.3423	0.1139	non-stationary
$D(\ln x_2)$	-3.6121	-4.0579	-3.1199	-2.7011	0.0216	stationary
$\ln x_3$	-3.4580	-4.9923	-3.8753	-3.3883	0.0909	stationary
$\ln x_4$	-14.2919	-3.9591	-3.0810	-2.6813	0.0000	stationary

According to the result of stationarity test,  $\ln y (p = 0.9263), \ln x_1 (p = 0.4366), \ln x_2 (p = 0.1139)$  are non-stationary time series,  $\ln x_3 (p = 0.0909), \ln x_4 (p = 0.0000)$  are stationary time series. In addition, ADF unit root test would be used to test the first order difference of  $\ln y, \ln x_1, \ln x_2$ . The result shows that  $D(\ln y) (p = 0.0000), D(\ln x_1) (p = 0.0014), D(\ln x_2) (p = 0.0216)$  are stationary time series, which indicates  $\ln y, \ln x_1, \ln x_2$  are integrated of order 1, marked as I(1).

3.3. Cointegration Test

To satisfy the condition of cointegration test, the integration order of explained variable cannot be greater than that of every explanatory variable if the number of variable is more than two, meaning the number of explanatory variable is more than one. According to the result of ADF unit root test,  $\ln y, \ln x_1, \ln x_2$  are I(1), so cointegration test can be used. This paper use Engle-Granger method to conduct cointegration test for  $\ln y, \ln x_1, \ln x_2$ .

Firstly, conduct OLS regression for  $\ln y, \ln x_1, \ln x_2$ , then do ADF unit root test for the residual error. The result are as follows:

Table-4. The result of cointegration test

Variable	t-statistic	1% level	5% level	10% level	prob.*	Conclusion
resid	-4.8716	-2.7283	-1.9663	-1.6050	0.0001	stationary

According to the test result, p of residual is very small,  $p=0.0001 < 0.01$ , indicating residual is stationary time series and there is cointegration relationship among  $\ln y$ ,  $\ln x_1$ , and  $\ln x_2$ .

### 3.4. Result of Empirical Analysis

Because  $\ln x_3$ ,  $\ln x_4$  are stationary time series, which could be directly conducted by OLS regression, and the economic variables that are in cointegration relationship also have stable relationship in the long run (ZINAI LI, "Econometrics the 3<sup>rd</sup> edition"). Therefore, conduct OLS regression for  $\ln y$ ,  $\ln x_1$ ,  $\ln x_2$ ,  $\ln x_3$ ,  $\ln x_4$  to estimate the parameters  $\beta_i$ , and the result is as follows:

$$\ln y = 5.65 - 0.4\ln x_1 + 0.68\ln x_2 + 1.97\ln x_3 - 0.03\ln x_4$$

(4.94)   (-0.52)   (1.83)   (14.47)   (0.2)

$$R^2=0.965070 \quad \bar{R}^2=0.952368 \quad F\text{-statistic}=75.97859 \quad D.W.=2.079657$$

According to the result of OLS regression, grain yield per hectare (GYH) will decrease by 0.4 unit while input intensity of arable land increases by 1 unit; the GYH will increase by 0.68 unit with utilization increasing by 1 unit; and GYH is going to significantly increase by 1.97 unit with the output effectiveness increasing 1 unit, while sustainability increases 1 unit, GYH could decrease by 0.03 unit.

## 4. CONCLUSIONS

As a whole, the output effectiveness caused by intensive utilization of cultivated land brings the most obvious impact ( $\beta_3=1.97$ ) on grain productivity because the agricultural industrialization of Shandong Province is emerging these years; the agricultural large-scale production has been increasingly substituting for traditional production of intensive smallholder cultivation, especially in eastern Shandong peninsula. However, the agricultural large-scale production in Shandong is still on the infancy stage, and there are many shortcomings in many aspects such as insufficiency of agricultural production facilities, low use of mechanization and many more. The gains of utilization intensity of arable land ( $\beta_2 = 0.68$ ) are lower than expectation, which indicate that irrigation, protection and maintenance of cultivated land and other aspects still need to be improved and polished.

According to the result of regression, grain yield per hectare is negatively related with input intensity ( $\beta_1 = -0.4$ ) and sustainability ( $\beta_4 = -0.03$ ) of cultivated land. Combining with the reality of Shandong Province, one of the reasons is that the structure of agricultural input is unreasonable, too many resources such as human labor, water, cultivated land are wasted, resulting in lower and lower efficiency of agricultural input. Another reason is related with accelerated urbanization and industrialization, which cause a large number of arable

land to be transferred into industrial land and commercial land and further result in lower sustainability of arable land.

## 5. RECOMMENDATIONS

Based on above aspects, although the level of intensive utilization of arable land and grain yield per hectare are increasingly rising, many problems and shortcomings are exposed to individuals and society during the agricultural production. For these reasons, government and farmers are supposed to make progress in the development of agriculture from following aspects:

(1). The intensive utilization of cultivated land has volatility in a whole, the methods of improving intensive utilization should correspond with local practicalities.

In high-intensive utilization of arable land areas, local governments and farmers should emphasize on sustainability of cultivated land and its ecological benefits; in middle level of intensive utilization districts, local governments should enhance the development and improvement of agricultural infrastructure and encourage smallholder farmers to learn agricultural knowledge to promote that agricultural economy could be developed scientifically and reasonably; the districts, relating to low-intensive utilization of arable land, have usually fallen behind in economic development, and natural conditions of cultivated land are inferior to other districts. In these areas, governments are supposed to see the social and economic development as a priority and then increase productive and fundamental investments in agricultural development and subsidize farmers by supplying insurance and buying grains at a higher price. Through these methods, backward areas could improve agricultural development.

(2). Increase input intensity of arable land for guaranteeing the growth of grain productivity.

According to the result of regression, grain yield per hectare is negatively related with input intensity, which indicates that the insufficiency of agricultural input, the backward agricultural technology and low level of agricultural human resources, especially in western Shandong Province. For example, firstly, the extension system of agricultural technique in Shandong Province is more backward than other provinces in China. Secondly the utilization of agricultural research output is still at a low level; a lot of farmers still engage in the traditional smallholder agricultural activities because the level of farmers' competence is low, the channel of obtaining new techniques is narrow. Thirdly there are still a lot of farmers who cannot use formulas to apply fertilizers and not understand scientific breeding. On the contrary, they blindly use chemical fertilizers and pesticides and overuse food additives to breed livestock. Last but not least, with the accelerated urbanization and industrialization, many young adults and educated farmers go out to pursue better jobs, and most of people who are engaged in agricultural cultivation are elderly men and uneducated farmers. Based on these facts, governments should increase investments in agricultural infrastructure such as water pump, agricultural electricity, roads, et al. and open lectures regularly to spread agricultural knowledge in countryside. In addition, governments should encourage people to set up rural enterprises to promote large-scale and specialized production, which could not only increase farmers' income, but also apply advanced agricultural technology and improve the grain yield.

(3). Emphasis on sustainability of arable land, enhance protection of cultivated land for improving grain yield.

The facts that grain yield is negatively related with sustainability of arable land are mainly caused by urbanization and industrialization, which make a large number of cultivated land to be transferred into industrial land or commercial land. On the other hand, the quality of farmland gets decreasing, soil fertility reduces, and salinization phenomenon is serious because of unreasonable structure of cultivation and insufficient maintenance of arable land in many areas taking agriculture as the leading industry. Hence, farmers should adjust their methods of cultivation, reduce the use of chemical fertilizers and pesticides for the protection of soil fertility. Meanwhile, local governments should enhance farmers' consciousness of protecting arable land, make mass supervision play an important role and crack down the practices of illegally using cultivated land.



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