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RESEARCH ARTICLE

Agricultural land use intensity and its determinants: a case study in Taibus Banner, Inner Mongolia, China

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Abstract Based on rural household survey data from Taibus Banner, in the Inner Mongolia Autonomous Region, China, this study separately categorizes agricultural land use intensity into labor intensity, capital intensity, the intensity of labor-saving inputs, and the intensity of yield-increasing inputs, and then analyzes their determinants at the household level. The findings reveal that within the study area: (1) labor intensity is higher and capital intensity is lower than in the major grain-producing and economically developed areas of eastern and central China; (2) the most widely planted crops are those with the lowest labor intensity (oats) and capital intensity (benne); (3) there are marked differences in agricultural land use intensity among households; a major factor affecting land use decision-making is the reduced need for labor intensity for those households with high opportunity costs, such as those with income earned from non-farming activities which alleviates financial constraints and allows for increased capital intensity. As a result, these households invest more in labor-saving inputs; (4) households with a larger number of workers will allocate adequate time to manage their land and thus they will not necessarily invest more in labor-saving inputs. Those households with more land to manage tend to adopt an extensive cultivation strategy. Total income has a positive impact on capital intensity and a negative impact on labor intensity. Households that derive a higher proportion of their total income through farming are more reliant upon agriculture, which necessitates significant labor and yield-increasing inputs. Finally, the authors contend that policy makers should clearly recognize the impacts of non-farming employment on agricultural land use intensity. In order to ensure long-term food security and sustainable agricultural development in China, income streams from both farming and non-farming employment should be balanced.

Keywords agricultural land use intensity, labor intensity, capital intensity, opportunity cost of farm workers, Taibus Banner

1 Introduction

Increasing agricultural yields is essential in overcoming the challenge of food security in China, which arises from a growth in the demand for food on the one hand and a reduction in agricultural land area on the other as economic development increases (Zhang et al., 2003; Li et al., 2006). In order to increase output, it is necessary to increase investment, i.e., increase land use intensity (Zhang et al., 2008b). In recent years, specialists in this area have increasingly advocated that more research be devoted to land use intensity, recognizing that agricultural intensification has become a top priority for China due to the limited reserves of arable land that exist within the country (Zhu et al., 2007; Long and Zou, 2010). In fact, an increase in grain yield per unit area that is attributable to changes in land use intensity has contributed greatly to the increase in total grain yield observed over the last three decades (Chen et al., 2011).

Agricultural land use represents the behavior of farmers on a microscopic scale, and under certain circumstances, farmers make decisions aimed at maximizing their total income. During the process of rapid urbanization in China, the price of labor has risen continually, and a large number of rural laborers have migrated to urban centers and are no longer employed in the farming industry. In both the economically developed regions of eastern China and the major grain-producing areas, many studies have provided evidences for the abandonment of agricultural land, or for

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its non-intensive use, due to increased engagement, and thus incomes, being derived from non-farming activities (An et al., 2009; Chen et al., 2009; Huang et al., 2009; Li and Zhao, 2009a, 2009b; Xin et al., 2009). Alternatively, results of studies conducted in the midwest region of China are inconsistent. These findings indicated that the workforce has become less involved in non-farming employment, relative to the more economically developed regions, and that farmers still rely upon farming and livestock rearing. Thus, agricultural land continues to be used intensively (Zhang et al., 2008a; Yan et al., 2010). Then again, in yet another set of studies, employment of the rural workforce in non-farming activities led to abandonment of the land and to a predominance of elderly people and women in the farming industry (Zhang et al., 2008a; Li and Zhao, 2009a, 2009b; Tian et al., 2011). In addition, land use intensity is diverse across areas that show varying levels of economic development. With economic improvement, capital intensity increases and labor intensity decreases, reflecting the trend in the process of regional development for capital inputs to gradually substitute for employment of labor (Zhang et al., 2008b; An et al., 2009; Chen et al., 2009).

The uncertainties and complexities of the impacts of non-farming employment on agricultural land use intensity are reflected in the extensive literature written on the subject. One interpretation supports the hypothesis that increased household income resulting from non-farming employment relaxes financial constraints and facilitates capital investment in agricultural land use, thereby increasing agricultural production (Paudel and Wang, 2002; Taylor et al., 2003; Ishemo et al., 2006; Oseni and Winters, 2009). The opposing viewpoint contends that labor is one of the key factors in agricultural production (Newell et al., 1997; Alwang and Siegel, 1999). According to this interpretation, work generated from non-farm activities reduces the availability of household labor for on-farm activities. A large number of rural laborers are engaged in non-farming employment and as a result, both the amount and the quality of the labor force that are engaged in agricultural land use are reduced (Rudel, 2006; Beyene, 2008; Brosig et al., 2009; Gray, 2009; Li and Zhao, 2009a, 2009b). Consequentially, farmers manage their land in an extensive manner (Strijker, 2005), as indicated by a decline in the cropping index (Xin et al., 2009; Yan et al., 2009) or the direct abandonment of agricultural land (Liu and Li, 2006; Morera and Gladwin, 2006; Gellrich and Zimmermann, 2007; Tian et al., 2011). Thus the effects on agricultural land use intensity by the employment of agricultural workers in non-farming industries remain a controversial issue in current literature. Even so, it is clear that such employment can affect both capital investment and labor inputs on the land. Recent empirical studies have found that farmers adopt labor-saving technologies, such as tractors and threshers, after they turn to non-farming employment (Strijker, 2005; Fernandez-Cornejo et al., 2007; Chen et al., 2009; Takahashi and Otsuka, 2009).

Spatial change is another important aspect of China's agricultural production. The direction of grain flow in China has changed – transformed from a "Grain Sent from the South to the North" to a "Grain Sent from the North to the South" operation. In addition, the center of gravity of grain production has moved to the north. During the past 20 years, the Inner Mongolia Autonomous Region has been ranked at the forefront of all the provinces in terms of both the increase in the total amount of cultivated land and the increase in the area sown to grain (Zhang et al., 2003; Liu and Li, 2006; Zhai and Liu, 2008; Liu et al., 2009, Yan et al., 2009). Currently, both per capita arable land area and per capita grain production in this region are higher than the national average. The grain output has shown a clear upward trend as a proportion of total national grain output resulting in the region becoming one of the country's major grain-producing provinces (Yin et al., 2009; Zhang et al., 2009). Therefore, agricultural land use is of great significance for national food security.

It has been recognized that the land use decisions made by individual farmers are inconsistent (Kilic et al., 2009). A specific type of agricultural practice can be seen as a set of optimal techniques operating within a particular historical, social, and economic environment (Strijker, 2005). The question therefore arises – is agricultural land use intensity in the Inner Mongolia Autonomous Region different from that in other areas and, if so, what determines this difference? By using the Taibus Banner County in this region as an example, the aim of this study has been to conduct an empirical enquiry into the agricultural land use intensity of farming households and into the various factors that determine it.

2 Materials and methods

2.1 Study area

Taibus Banner is situated in the center of the Inner Mongolia Autonomous Region, China, 350 km from Beijing. It is located between 114°51'E and 115°49'E, and 41°35'N and 42°10'N (Fig. 1), at altitudes ranging from 1,802 m to 1,325 m, and covers an area of 3,414.74 km^2. It is under the administration of Xilin Gol League[1)]. The population was about 200,500 in 2009, of with approximately 170,800 living in rural areas, accounting for 81.1% of the total. Taibus Banner is situated at the northern foot of Yinshan Mountain and the southern edge of the

1) Banner and league are two holdovers from earlier forms of administration in Mongolia. Banner is the same as counties except in the name, and league is effectively the same as prefectures.

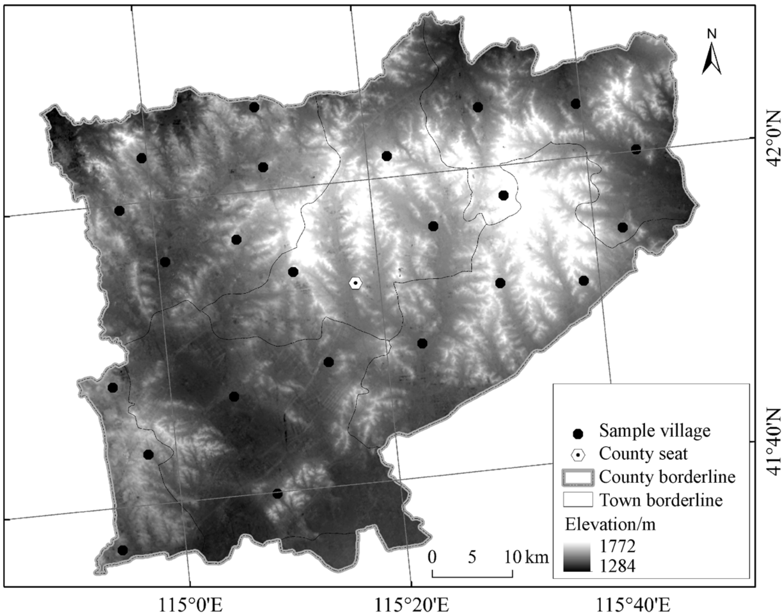

Fig. 1 Location of Taibus Banner and of the villages sampled in the survey

Hunshandake Sandy Land. The climate is temperate, semiarid continental. The annual rainfall is about 400 mm, 75% of which falls from July to September, with droughts occuring frequently. The average annual temperature is 1.6°C. There are some seasonal stream flows within the territory, but no permanent streams. The soil types include chestnut soil, chernozem, and meadow soil. Chestnut soils comprise the major agricultural soil type, covering 88.6% of the total agricultural land.

According to a land survey undertaken by the Bureau of Land and Resources in 2009, the total area of agricultural land is 83,552.04 ha, accounting for 24.0% of the total territory. In the rural districts, the area of agricultural land per capita is 0.57 ha, which is 3.37 times the national average. Dry land accounts for a very large proportion (87.7%) of the total agricultural land, with the output greatly affected by precipitation. Crops include oats, benne (sesame), wheat, potatoes, vegetables (celery, cabbage, and cauliflower), peas, soybeans, and kidney beans. Farmers plant crops once a year. According to the Inner Mongolia Statistical Yearbook, the yield of cereals was 1,643.72 kg/ha in 2009, compared to provincial and national cereal yields for the same year of 4,618 kg/ha and 5,447 kg/ha, respectively.

The market for crops within the study area is well developed. According to the Statistics Bureau of Taibus Banner, the commodity ratios for oats, benne, wheat, and potatoes were 18.67%, 47.54%, 0%, and 2.00%, respectively, in 2009. The commodity ratios for oats, wheat, and potatoes were lower than that for benne because the main objective for their production was to meet household consumption requirements.

The net income per farmer was 4,659 CNY in 2009, 9.59% less than the national average and 5.61% less than the provincial average. Taibus Banner was therefore a relatively poor area. The three main income sources for farm households came from crops, livestock husbandry, and non-farming employment, accounting for 24.33%, 18.64%, and 31.02% of total income, respectively (according to the household survey data of this study). In addition, 13.98% of income was from subsidies and 12.03% was from other income sources. According to the second-quarter survey of rural labor resources undertaken by the Bureau of Labor and Employment of Taibus Banner in 2009, the total number of rural migrant workers was 56,519, accounting for 52.3% of the total rural labor force, which is far higher than the national average level. (The results of the Second Agricultural Census showed that in 2006 rural workers in non-farming employment accounted for 29% of the total labor force in China.)

2.2 Household survey data

The data used for this study were obtained from farm household surveys taken from July to August 2009 and in May 2010. Twenty-three villages (Fig. 1) were selected in total, uniformly distributed throughout the county and representing different topographies, soil types, and economic conditions. We randomly interviewed approximately ten farm householders in each village, asking questions mainly related to the resources at their disposal and to the agricultural land use practices they used in 2009. The content of the questionnaire included topics such as: (i) the make-up of the family and residents of the household, such as the number of persons within the household, their occupations, and the age of the head of the household; (ii) the nature and extent of non-farming occupations and employment, such as the number of workers engaged in non-farming occupations, the types of jobs involved, and incomes and expenditures; (iii) livestock husbandry, such as numbers of livestock, sales of livestock, and income from livestock husbandry; (iv) agricultural land use, such as the amount of agricultural land, crop planting regimes, machinery, agricultural inputs, and yields.

To ensure the quality of the data, we checked and monitored the entire survey process, including the design of the questionnaire, the conduct of the surveys, and the selection of the samples. Initially, the questionnaire was revised repeatedly to ensure that the questions could be answered meaningfully and accurately and that the data could be collected effectively. Secondly, the survey team received careful training before the household surveys were conducted. Thirdly, in conducting the surveys, both stratified sampling and random sampling were used (towns and villages were selected by stratified sampling and households were selected by random sampling), to ensure that the sampling was fully representative of the study area. Finally, we obtained 242 completed questionnaires in total, of which only 6 (2.48%) were inadmissible, giving a total of 236 meaningful responses. Fifty-four of these came from non-farming households which had completely abandoned farming; the remaining 182 households, which remained involved in land management, were therefore the objects of the study. Within these 182 households, the total population and the number of workers were 552 and 417, respectively.

The total area of agricultural land managed by the 182 households was 371.74 ha. Oats, benne, wheat, and potatoes were the most common crops planted, with the area sown for each of these crops at 193.31 ha, 95.71 ha, 44.83 ha, and 15.33 ha, accounting for 52.00%, 25.75%, 12.06%, and 4.12% of the agricultural land area, respectively. Thus, the combined area sown for these four crops accounted for 93.94% of the total sown area. Therefore, we only collected data relating to these four crops for our analysis of household land use intensity.

2.3 Measurement and categorization of agricultural land use intensity

On the one hand, land use intensity reflects the extent to which other production factors, such as capital and labor, substitute for land itself (i.e., resource substitution). On this basis, the magnitude of such non-land inputs should provide a basic measurement of land use intensity (Li et al., 2008). Agricultural land use intensity thus refers to the magnitude of the inputs per unit area of land, with the exception of the land itself; such inputs are therefore mainly comprised of labor and materials (Barlowe, 1985). On the other hand, as previously discussed, earlier studies have shown that the labor and capital inputs of farming households differ; and that individual factors vary in their effects on these inputs. Therefore, to achieve a better understanding of agricultural land use intensity and to put forward effective measures for agricultural improvement, it is necessary to analyze the individual components that comprise land use intensity. Consequently, we divided agricultural land use intensity further, into labor intensity and capital intensity. Due to the difficulty in estimating the cost of labor, the amount of labor time input per unit area (day/ha) has been used to calculate agricultural land use labor intensity. During the household survey, we recorded the labor input during each stage of crop cultivation, including plowing, planting, fertilizing, weeding, irrigating, harvesting, threshing, etc. We then used these data to obtain a value for the total labor input. Agricultural land use capital intensity refers to the value of material inputs per unit area (CNY/ha), including seeds, fertilizer, manure, pesticides, plastics, machinery, irrigation, pumping, technical services, equipment depreciation, employee costs, and other expenses.

Small tractors comprised the principal inputs of machinery made by farmers within the study area. Ninety-seven households (53.30%) had their own tractors, and one tractor for every 1.88 households. Horses, mules, and donkeys were the principal draft animals. In total, there were 67 draft animals, 22 of which were horses and mules and 45 of which were donkeys. There was one draft animal for every 2.72 households. Because of the difficulty of calculating the value of draft animal input and because we were using single-year data, we ignored the depreciation of machinery and the input for draft animals in the calculation of capital intensity. Farmers do not employ workers when they cultivate their land and as a result, capital investment in agricultural land use mainly relates to expenditure on seeds, fertilizers, manure, pesticides, herbicides, mulching film, machinery, and irrigation.

On the basis of the principal purpose to which investment is directed, capital intensity can be divided further when aimed at raising yields or reducing labor. For example, seeds, manure, fertilizers, mulching film, irrigation, and pesticides are invested to increase the yield per unit area, whereas machinery and herbicides are applied with the aim of saving, or substituting for, the input of labor.

2.4 Method used for agricultural land use intensity determinants analysis

We assume that farming households follow rational economic rules, and that their land use strategy is aimed at a maximization of total revenue. Their behavior with respect to agricultural land use inputs can be expressed as the following function:

$$Y_i = IF(X_i > x_i), \quad (1)$$

where Y_i is the agricultural land use intensity function, i represents a particular element of input, and X_i and x_i represent, respectively, the marginal revenue and the marginal cost associated with that element. *IF* is a decision function; if $X_i > x_i$, farmers will continue increasing their input of that element.

Agricultural production operates in line with the Law of Diminishing Marginal Returns. In response to changes in external and internal factors, such as the characteristics of the farming households, their economic status, and the productive capacity of the land, X_i and x_i also alter. Therefore, the function can be expressed as:

$$X = F(K_i), \quad (2)$$

where X is the return on agricultural land use under various production conditions and K_i denotes the factors that influence the decision-making of farmers and their profits. Any agricultural land use inputs that are made directly depend on the profits that result from the combination of the marginal revenue and the marginal cost; in turn, these profits depend on the number of laborers, income received, availability of resources, and other factors. Therefore, specific agricultural land use inputs can be expressed as the following function:

$$Y_i = IF(X_i > x_i) = F(K_i). \quad (3)$$

In this paper, these factors have been analyzed by a stepwise regression statistical model, which adopts the following form:

$$Y = a + \sum b_i x_i + e, \quad (4)$$

where Y represents agricultural land use intensity. In the analysis presented here, the dependent variables are land use labor intensity (Y_1), land use capital intensity (Y_2), the intensity of labor-saving inputs (Y_3), and the intensity of yield-increasing inputs (Y_4). The term a is a constant, b is the coefficient for each of the influencing factors; and e is an error term.

In this study, by taking into account the limitations of the survey data and correlations between variables, the independent variables were selected to reflect the characteristics of the farming household, the resources available to it, its income level, and its income structure. The two variables 'age of head' (X_1) and 'family size' (X_2) were selected to represent the characteristics of the household. Three variables, including the total number of workers (X_3), the total area of agricultural land (X_4), and the opportunity cost (see below) of farm labor (X_5), were selected as representing the resources available. Three additional variables, namely the total income (X_6), the share of income obtained from farming (X_7) and the share of income obtained from livestock rearing (X_8), were selected as representation of the income level and structure of the farming household. The inter-correlations of all the independent variables have been tested. The results show that the only significant correlation is between the family size and the total number of workers. Where the correlation between independent variables is negligible, it will not appreciably bias the regression coefficients; therefore, all eight independent variables have been included in the regressions.

The parameter, the 'opportunity cost' of farm labor, is intended to assist in evaluating the impacts of the employment of farm workers in non-farming occupations on land use decision-making. All adult unpaid farm labor should be valued at its opportunity cost, and the non-farming wage rate for individuals who possess particular attributes (e.g., with respect to gender, age, schooling, or experience) provides a good approximation to the opportunity cost of their farm labor (Huffman, 1996; Bicak et al., 2004). Clearly, this approach is appropriate for measuring the labor costs of agricultural production in rural China, where the labor market and the land market are incomplete. Because the chances or possibility (P) of obtaining employment in the non-farming labor market vary according to the particular type of non-farming occupation under consideration, the wages for such occupations are weighted by a correction factor that takes into account their accessibility to a farm worker, such that

$$OC = P \times W, \quad (5)$$

where OC is the opportunity cost of farm labor, P is the correction factor described above, and W is the average wage for non-farming employment.

There are many factors that influence the possibility (P) of a worker becoming engaged in non-farming employment, but the end-result is fundamentally reflected in the ratio of non-farming working days (d_i) to the annual total of working days (D), estimated by using

$$P = \frac{d_i}{D}. \quad (6)$$

By taking leisure time into account, the total annual number of working days is defined as 300 days. For a worker engaged for 300 or more days per year in non-farming work, we define the possibility to be 1, i.e., $P = 1$.

By use of this estimation method, two key factors – the possibility of alternative work and the wage paid for undertaking it – are both comprehensively measured within the concept of opportunity cost. An individual for whom the opportunity cost for engagement in farming is higher than normal is a person who is more likely to turn to non-farming employment.

3 Results

3.1 Labor intensity

As shown in Table 1, the maximum value for agricultural land use labor intensity per household is 150.90 day/ha, the minimum is 57.45 day/ha, and the mean is 108.15 day/ha. The values are lower than those reported by Yan et al. (2010) for the Three Gorges Reservoir Area – also an economically poor area – in 2009 (345 day/ha for full-time farming households and 405 day/ha for part-time farming households. Alternatively, values are higher than average (66.29 day/ha) for Suixian County, which is located in a major grain-producing province of Henan (Chen, 2010).

Comparisons of the four crops studied show that labor intensity decreases in the order: potatoes> benne> wheat> oats. The labor intensity for potatoes is the highest at 134.25 day/ha. This is mainly because, within the study area, machinery cannot be used for potato cultivation for tasks such as harvesting and fertilizer application, which therefore can only be carried out manually. The lowest value, 99.00 day/ha, for oats reflects the fact that they are generally planted in larger plots of land, which facilitates the use of machinery and reduces labor input.

As reported in Table 2, the stepwise regression statistical model for agricultural land use labor intensity takes the form

$$Y_1 = 0.447 + 0.023x_3 - 0.002x_4 - 0.063x_5 - (8.584e-05)x_6 + 0.043x_7. \quad (7)$$

R^2 and Adjust R^2 are two statistics that provide some information about the goodness of fit of a model. R^2 is the proportion of variation within the dependent variable that can be explained by the independent variables in the regression model. An R^2 (or Adjust R^2) value of 1.0 indicates that the regression line is a perfect fit to the data. The values of F and Sig. test the significance of regression. If the F value is large and Sig. is less than the critical value, such as 0.05 or 0.01, it indicates that there is a strong linear relationship between the predictor variables and the indicator variables, and the regression is significant. As shown in Table 2, the overall test of the regression is significant, and the model can reflect the relationship between the labor intensity and independent variables to some degree (similarly for Table 4 to Table 6 below).

The values determined for the parameters show that the key determinants of agricultural land use labor intensity are: the total number of workers, the total area of agricultural land, the opportunity cost of farming labor, the total income, and finally, the proportion of income which is derived through farming. Both the total number of workers and the proportion of income derived from farming have positive effects on labor input, whereas the opportunity cost of farming labor, the total area of agricultural land, and the total income all have negative effects.

Households with more workers will allocate more working time to agricultural production, resulting in higher labor intensity. Undoubtedly, those households whose income is mainly derived from farming activities will be more involved in farming practices. Conversely, a household that has a higher opportunity cost for farming labor, indicating that its workers are more likely to leave the farm to engage in non-farming employment, becomes constrained by the availability of labor and will reduce the amount of its labor input into agricultural land use. The total area of agricultural land has a negative impact on labor intensity. This is mainly because, on the one hand, households that manage more agricultural land generally have a tractor, or invest in more labor-saving inputs (the following analysis verifies this), thereby reducing the constraints associated with the labor force. On the other hand, such households tend to manage their land less intensively, adopting an extensive cultivation strategy. The income of these households arises not only from arable farming activities, but also from livestock rearing and other, non-farming activities. The higher the household income the greater the proportion from non-farming sources. Conversely, it is suggested that households with a higher proportion of non-farming income earn more income in total, and their workers tend to engage in non-farming activities more frequently, with the result that agricultural land use labor intensity declines.

3.2 Capital intensity

The maximum value for the agricultural land use capital intensity of a household is 3,450.00 CNY/ha, the minimum is 780.00 CNY/ha, and the mean is 1,404.45 CNY/ha (Table 3). The maximum value is much lower than the values for capital investment in the country's major grain-producing areas, such as the Daxing District of Beijing (11,908.89 CNY/ha, in 2004), Quzhou County in Hebei Province (4,823.91 CNY/ha, in 2004), and Suixian County in Henan Province (3,570.94 CNY/ha, in 2007), as

Table 1 Descriptive statistics for agricultural land use labor intensity (day/ha)

	Labor intensity	Wheat	Oats	Benne	Potatoes
Mean	108.15	99.00	87.15	108.45	134.25
Maximum	150.90	136.80	131.10	152.25	160.80
Minimum	57.45	57.45	57.45	61.65	80.85

Table 2 Estimated parameters of the stepwise regression model for agricultural land use labor intensity

	Unstandardized coefficients		Standardized coefficients	t	Sig.
	B	Std. error	beta		
Constant	0.447	0.057		7.781	0.000
X_3	0.023	0.007	0.300	3.537	0.001
X_4	–0.002	0.000	–0.669	–11.479	0.000
X_5	–0.063	0.036	–0.129	–4.575	0.000
X_6	–8.584E-05	0.000	–0.236	–3.266	0.001
X_7	0.043	0.021	0.151	3.050	0.002

Overall testing: $R = 0.673$; $R^2 = 0.453$; Adjusted $R^2 = 0.444$; DW = 1.741; $F = 49.142$; Sig.= 0.000

Table 3 Descriptive statistics for agricultural land use capital intensity (CNY/ha)

	Capital intensity	Intensity of labor-saving inputs	Intensity of yield-increasing inputs	Oats	Benne	Wheat	Potatoes
Mean	1,404.45	607.95	796.50	1,137.45	723.45	1,039.35	3,417.15
Maximum	3,450.00	1,125.00	2,025.00	1,440.00	960.00	1,305.00	4,200.00
Minimum	780.00	120.00	420.00	945.00	495.00	975.00	2,850.00

reported by Zhang et al. (2008b) and Chen (2010). On average, the intensity of labor-saving inputs is 607.95 CNY/ha and the intensity of yield-increasing inputs is 796.50 CNY/ha, accounting for 43.29% and 56.71% of the total capital investment, respectively.

The capital intensity values for the four crops are significantly different, decreasing in the order: potatoes> oats> wheat> benne. The capital intensity for potatoes is the highest, mainly due to greater inputs for tubers and fertilizer; particularly as indicated by the recent price increase of tubers. The capital intensity for benne is the lowest, due to the lower cost of seed and decreased use of machinery for harvesting.

3.2.1 Capital intensity

As indicated in Table 4, the stepwise regression statistical model for agricultural land use capital intensity takes the form

$$Y_2 = 4.151 + 0.553x_2 - 0.436x_3 - 0.226x_4 + 0.043x_5 + (5.728e-05)x_6. \quad (8)$$

The estimated parameters show that the key determinants of agricultural land use capital intensity are family size, total number of workers, total area of agricultural land, opportunity cost of farming labor, and total household income. Family size, opportunity cost of farming labor, and total income all have positive effects on capital input, whereas the total number of workers and the total area of agricultural land each have a negative effect.

The workers of a farm household participate in farming or non-farming employment dependent upon the relative advantages of the two kinds of activities (Low, 1986). If workers are abundant, and therefore reasonably able to fulfill the demand for farming labor, households can invest less capital (especially in labor-saving inputs, as shown in the findings from the regression analysis of labor-saving intensity, shown below). If there is an increase in the actual worked area of cultivated land, the capital investment per unit area will be reduced, resulting in a decline in capital intensity. A higher opportunity cost indicates that the household has the prospect of non-agricultural employment, and that its members can earn a higher income from engaging in non-farming activities. The additional income permits the household to invest more money in agricultural land use; the impact of total income on capital intensity reflects this mechanism. In contrast, the proportion of income received through farming and received through livestock-rearing do not have significant impacts on capital intensity. This may be due to financial constraints that may be faced by households that receive a high proportion of their income from these sources. Alternatively, households that receive a lower proportion of their income through arable farming or through livestock rearing tend to engage in non-farming employment, and are very likely to increase their capital investment on land.

3.2.2 The intensity of labor-saving inputs

As reported in Table 5, the statistical model for the intensity of labor-saving inputs takes the form shown as

$$Y_3 = 20.319 - 2.084x_3 + 0.040x_5 - 0.036x_8. \quad (9)$$

The estimated parameters show that the factors that significantly influence the intensity of labor-saving inputs

Table 4 Estimated parameters of the stepwise regression model for agricultural land use capital intensity

	Unstandardized coefficients		Standardized coefficients	t	Sig.
	B	Std. error	beta		
Constant	4.151	0.205		20.230	0.000
X_2	0.553	0.127	0.308	4.342	0.000
X_3	−0.436	0.084	−0.552	−5.157	0.000
X_4	−0.226	0.063	−0.290	−3.559	0.000
X_5	0.043	0.004	0.609	10.305	0.000
X_6	5.728E-05	0.000	0.017	3.973	0.000

Overall testing: $R=0.925$; $R^2=0.855$; Adjusted $R^2=0.852$; DW = 1.553; $F=220.619$; Sig.= 0.000

in agricultural land use include the total number of workers, the opportunity cost of farming labor, and the proportion of income obtained through livestock rearing. The opportunity cost of farming labor has a positive effect on labor-saving inputs, whereas the total number of workers and the proportion of income obtained through livestock rearing each have negative effects.

A higher opportunity cost for the farm workers indicates that the family members have obvious prospects of non-farming employment. Constrained by a limited availability of labor, it is reasonable for such households to increase their investment in labor-saving inputs for land cultivation to enable them to devote more time to non-agricultural employment, thereby maximizing total income. Of course, households with more workers are able to allocate adequate time to manage their land; hence, investments in more labor-saving inputs are not necessary.

As is well known, the study area is a typical pastoral agricultural, mixed-farming region. Rural households often engage in both arable farming and livestock rearing. Because livestock rearing requires a continuous, at times intensive, labor input, these households do not usually choose to engage in non-farming employment. They can rather devote a high proportion of their working time to managing their land whilst at the same time, rearing their livestock. As a result, investing in additional labor-saving inputs is unnecessary. In addition, a higher proportion of income obtained from livestock rearing indicates that households have draft animals available for agricultural use, although draft animals are not included in labor-saving inputs. This is one of the factors that accounts for the negative impact of the proportion of livestock-related income on the intensity of labor-saving inputs.

3.2.3 The intensity of yield-increasing inputs

As reported in Table 6, the statistical model for the intensity of yield-increasing inputs takes the form of

$$Y_4 = 7.470 - 0.134x_1 + 1.838x_2 - 0.088x_4 + (2.825e-05)x_6 + 0.064x_7. \quad (10)$$

The estimated parameters show that the factors that significantly influence the intensity of yield-increasing inputs of agricultural land use include: the age of the head of the household, family size, total area of agricultural land, total income, and the proportion of total income that is obtained through farming. Family size, total income, and the proportion of income obtained through farming all display positive effects, whereas the age of the head of the household and the total area of agricultural land each show negative effects on yield-increasing inputs.

Households in which the head of the household is older generally apply conventional farming practices, and no longer invest more in inputs such as seeds, fertilizers, and pesticides. Larger households, and those that obtain a higher proportion of their income through farming, are more likely to rely on agriculture, and in order to obtain a better harvest, usually increase their yield-increasing inputs. Households earning higher incomes have the

Table 5 Estimated parameters of the stepwise regression model for the intensity of labor-saving inputs, and overall testing of the model

	Unstandardized coefficients		Standardized coefficients	t	Sig.
	B	Std. error	beta		
Constant	20.319	4.304		4.721	0.000
X_3	−2.084	0.967	−0.232	−2.155	0.032
X_5	0.040	0.007	0.395	5.760	0.000
X_8	−0.036	0.015	−0.138	−2.428	0.016

Overall testing: $R=0.662$; $R^2=0.438$; Adjusted $R^2=0.425$; DW = 1.989; $F=34.459$; Sig.= 0.000

Table 6 Estimated parameters of the stepwise regression model for the intensity of yield-increasing inputs, and overall testing of the model

	Unstandardized coefficients		Standardized coefficients	t	Sig.
	B	Std. error	beta		
Constant	7.470	2.687		2.780	0.006
X_1	–0.134	0.043	–0.097	–3.092	0.002
X_2	1.838	0.831	0.163	2.212	0.028
X_4	–0.088	0.021	–0.136	–4.227	0.000
X_6	2.825E-05	0.000	0.033	3.824	0.000
X_7	0.064	0.050	0.095	2.428	0.016

Overall testing: $R=0.911$; $R^2=0.830$; Adjusted $R^2=0.827$; DW = 1.989; $F=216.790$; Sig.= 0.000

capacity to increase their yield-increasing inputs to agricultural land use. As in the case of capital intensity discussed above, the cultivation of more land results in relatively less yield-increasing investment per unit area.

4 Conclusions and discussion

4.1 Conclusions

In this article, we have used Taibus Banner as an example of an ecologically-vulnerable area in northern China. We have explored empirical, agricultural land use intensity and the factors that influence it. Our results present the following new evidences.

1) On average, land use labor intensity in Taibus Banner was 108.15 day/ha, and capital intensity was 1404.45 CNY/ha. Compared to the major grain-producing and economically developed areas in eastern and central China, labor intensity was higher whereas capital intensity was lower. This indicates that local farmers still apply traditional land use practices.

2) The non-farming employment of rural workers has been the most prominent socio-economic phenomenon within the study area. We have used the opportunity cost of farm workers to measure its impact on land use intensity. The results suggest that the opportunity cost of farm workers is an important factor affecting agricultural land use intensity. First, as more workers engage in non-farming employment, labor intensity is reduced, whilst the income earned alleviates their financial constraints and enables farming households to increase capital intensity. Alternatively, it has been observed that both labor and capital intensity have decreased in the eastern and central regions of China, (Chen et al., 2009; Xin et al., 2009; Li and Zhao, 2009a, 2009b; An et al., 2009). Secondly, constrained by a shortage of workers, households in which the opportunity cost is higher tend to cultivate their land by using a ‘capital-substitute-for-labor’ strategy and invest more in labor-saving inputs. Of course, household workers do have opportunities for work that vary dependent upon their individual skills and attributes. Those households with more labor available will deploy more labor in agricultural production.

In addition, the total area of agricultural land has an impact on agricultural land use intensity. The greater the area of land to be managed, the less input per unit area. Households in which the income is mainly derived from farming devote more working time and investment into yield-increasing inputs.

3) By correlating the land use intensity of the four crops studied to the proportion of land area sown to them, it is seen that the crops with lower labor intensity (oats) and lower capital intensity (benne) are currently the two crops that are planted the most widely.

4.2 Discussion

1) A decrease in the available labor due to the employment of rural workers in non-farming activities has become an important factor constraining agricultural production. Policy makers need to clearly recognize the impacts of non-farming employment on agricultural land use intensity, while at the same time, recognize and take into account the current state of different types of farming households and workers. In order to ensure long-term food security and sustainable agricultural development in China, farming and non-farming income streams should be balanced. From the capital investment point of view, farming households, especially those that have fewer opportunities to engage in non-farming activities, are still financially constrained. Policies should therefore be put in place to provide better financial and technical support. Many farmers have already invested in labor-saving inputs in order to alleviate the negative impact of non-farming employment on agricultural production. Provision of effective support focused on labor-saving technologies has now become urgent.

2) Grain production in China has shifted from the south to the north and west, where ecological conditions are relatively vulnerable (Yan et al., 2009). Over the past few decades, population pressures and the extensive utilization

of resources have become recognized as the main reasons for ecological degradation in this region. Given that off-farm work may change the nature of on-farm operations, the potential for environmental consequences could easily increase (Phimister and Roberts, 2006). Some researchers have argued that a “win-win” situation (poverty alleviation and ecosystem conservation) can be achieved through the employment of rural workers in non-farming occupations and the concomitant reduction in the intensity of agricultural activities (Moran-Taylor and Taylor, 2010; Groom et al., 2010), especially in remote mountainous regions and ecologically vulnerable areas. A number of international observations, such as the transition to and regrowth of forest that has occurred in some areas of North America and Europe, provide some evidence for this argument (Caraveli, 2000; Rudel et al., 2005; Gellrich and Zimmermann, 2007). Therefore, studies that develop and use land use intensity analysis to indicate how the relationship between food security and ecological security might best be managed will be especially valuable.

3) There are correlations between the four land use intensities, in particular a negative correlation between labor intensity and the intensity of labor-saving inputs. In order to reduce labor inputs (thereby reducing the labor intensity), farming households increase their investment in labor-substituting or in labor-saving inputs, which leads to increases in capital intensity and in the intensity of labor-saving inputs. The point at which there is equilibrium between labor inputs and labor-saving inputs shows a direct relationship with the opportunity cost of farm labor (as shown in the regression model). Households with higher opportunity costs will allocate less time to farming activities and invest more in labor-saving materials and technologies.

4) This paper aims to apply an opportunity cost model to farm work and farm workers in order to examine the impact of non-farm work on land use intensity. The approach adopted is theoretically feasible and reasonable. However, neither the definition nor the estimation of the opportunity costs of farm workers is currently clear, and in this respect, further study is required. It also should be noted that this work is restricted to an analysis of the differences in agricultural land use intensity among households in Taibus Banner, based on household survey data for the year 2009. Land use intensity is influenced by many other factors, and farmers will adjust their land use strategies in response to changes in both the physical and socio-economic environment. For example, since 1998 the county has implemented the Grain for Green Project. Inevitably, this project will have had an impact on the labor allocation and land use decisions of farming households and will thereby have influenced the household survey data. Therefore, further studies now need to be carried out on the agricultural land use intensity of households over a longer time period and in additional regions.

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