IOWA STATE UNIVERSITY
Department of Economics

Economics Working Papers

2017

Working Paper Number 17037

Land Tenure and Adoption of Straw Retention: Evidence from Henan, China

Yingdan Mei
China University of Petroleum

Lie Gao
China University of Petroleum

Wendong Zhang
Iowa State University, wdzhang@iastate.edu

Yu Song
Henan Agricultural University

Shugqin Jin
Ministry of Agriculture

See next page for additional authors

Follow this and additional works at: https://lib.dr.iastate.edu/econ_workingpapers

Part of the Agricultural and Resource Economics Commons, Asian Studies Commons, Growth and Development Commons, and the Regional Economics Commons

Recommended Citation

Mei, Yingdan; Gao, Lie; Zhang, Wendong; Song, Yu; Jin, Shugqin; and Sam, Abdoul, "Land Tenure and Adoption of Straw Retention: Evidence from Henan, China" (2017). *Economics Working Papers*: Department of Economics, Iowa State University. 17037.
https://lib.dr.iastate.edu/econ_workingpapers/43

Iowa State University does not discriminate on the basis of race, color, age, ethnicity, religion, national origin, pregnancy, sexual orientation, gender identity, genetic information, sex, marital status, disability, or status as a U.S. veteran. Inquiries regarding non-discrimination policies may be directed to Office of Equal Opportunity, 3350 Beardshear Hall, 515 Morrill Road, Ames, Iowa 50011, Tel. 515 294-7612, Hotline: 515-294-1222, email eooffice@mail.iastate.edu.

This Working Paper is brought to you for free and open access by the Iowa State University Digital Repository. For more information, please visit lib.dr.iastate.edu.

Land Tenure and Adoption of Straw Retention: Evidence from Henan, China

Abstract
We examine how land tenure arrangements affect Chinese crop farmers' adoption of straw retention, a key conservation practice promoted by the Chinese government in part to curb rising air pollution. Using data from a 2016 farmer household survey covering 1,659 crop plots in Henan Province in central China, we analyze how straw retention choices are influenced by two different land tenure arrangements: own-contracted plots versus rented plots. Empirical results from several probit regressions reveal that, after controlling for crop choice, harvest season, spatial climate, and other plot-level and household-level covariates, a rented plot is associated with a 10.7 percent reduction in the probability of adopting straw retention after harvest throughout 2015. A Heckman selection model that corrects the sample selection bias further supports the negative correlation between less secure rented farmland and straw retention adoption. This suggests that more caution and attention is warranted to the long-term sustainability of farmland in urbanizing China as the Chinese government keeps pushing for further development of rural land rental market.

Keywords
land tenure security, straw retention, conservation practice, adoption, China

Disciplines
Agricultural and Resource Economics | Asian Studies | Growth and Development | Regional Economics

Authors
Yingdan Mei, Lie Gao, Wendong Zhang, Yu Song, Shugqin Jin, and Abdoul Sam

This article is available at Iowa State University Digital Repository: https://lib.dr.iastate.edu/econ_workingpapers/43

Title Page

Title: Land Tenure and Adoption of Straw Retention: Evidence from Henan, China

Author names and affiliations:

Yingdan Mei, PhD, Assistant Professor
School of Business Administration, China University of Petroleum Beijing
meiyingdan@vip.sina.com
B1003 New Main Building, 18 Fuxue Rd, Changping, Beijing, China 102249

Li Gao, PhD, Assistant Professor ***(Corresponding author)***
School of Business Administration, China University of Petroleum Beijing
gaoli0711@163.com
+8615901009160
B1003 New Main Building, 18 Fuxue Rd, Changping, Beijing, China 102249

Wendong Zhang, PhD, Assistant Professor
Department of Economics, Iowa State University
wdzhang@iastate.edu
478C Heady Hall, 518 Farmhouse Lane, Ames, Iowa USA 50011

Yu Song, PhD, Associate Professor
School of Economics and Management, Henan Agricultural University
Foxsong2003@126.com
No.15 East Longzi Lake Road, Zhengzhou, China 450002

Shuqin Jin, PhD
Research Center for Rural Economy, Ministry of Agriculture, Beijing 100810, China
jinshuqin@126.com

Abdoul Sam, PhD,Associate Professor
Department of Agricultural, Environmental and Development Economics,
The Ohio State University
Sam.7@osu.edu
338 Agricultural Administration Building, 2120 Fyffe Road Columbus, Ohio USA 43210

Land Tenure and Adoption of Straw Retention: Evidence from Henan, China

Abstract

We examine how land tenure arrangements affect Chinese crop farmers' adoption of straw retention, a key conservation practice promoted by the Chinese government in part to curb rising air pollution. Using data from a 2016 farmer household survey covering 1,659 crop plots in Henan Province in central China, we analyze how straw retention choices are influenced by two different land tenure arrangements: own-contracted plots versus rented plots. Empirical results from several probit regressions reveal that, after controlling for crop choice, harvest season, spatial climate, and other plot-level and household-level covariates, a rented plot is associated with a 10.7 percent reduction in the probability of adopting straw retention after harvest throughout 2015. A Heckman selection model that corrects the sample selection bias further supports the negative correlation between less secure rented farmland and straw retention adoption. This suggests that more caution and attention is warranted to the long-term sustainability of farmland in urbanizing China as the Chinese government keeps pushing for further development of rural land rental market.

Keywords: land tenure security; straw retention; conservation practice; adoption; China

1. Introduction

Land tenure security has been shown as crucial in promoting the adoption of various conservation practices, including conservation tillage (Lee and Stewart, 1983; Soule et al., 2000), contour farming (Soule et al., 2000), conservation crops (Fraser, 2004), and stone terraces or soil bunds (Gebremedhin and Swinton, 2003). Arguably, more secure land tenure, which often refers to complete, permanent, or durable ownership of farmland, leads to higher willingness to adopt conservation practices, especially those practices with long-term soil fertility benefits. This is likely because greater land tenure security increases the likelihood of farmers reaping the benefits of land investments, which are often long-term (Feder et al., 1988; Soule et al., 2000; Fraser, 2004; Kabubo-Mariara et al., 2010). Despite the perceived significance of land tenure, there is a lack of evidence of land tenure security in conservation practice adoption, especially in developing countries. This, in part, results from varying definitions of land tenure security and heterogeneity in the ownership and tenure systems across different countries (Kabubo-Mariara et al., 2010).

In China, land tenure security has particular relevance because, under the current Household Responsibility System, agricultural land is owned by the collectives at the village level, and each eligible farmer household is granted a land contract right to farm a village-allocated land parcel with up to 30 years of tenure (Hu, 1997). The distinct nature of rural tenure systems confronts Chinese farmers with greater land tenure insecurity, which could potentially hinder farmers' investments in production and conservation practices, especially those with a long time horizon.

For instance, researchers have found that frequent land reallocation by the village collectives to accommodate growing rural population often dampens the stability and security of land tenure, resulting in a very uncertain land tenure length with an effective length of much less than 30 years (Liu et al., 1998; Brandt et al., 2002; Tan et al., 2006).

In fact, since Jacoby et al. (2002), many researchers have examined the impacts of land tenure insecurity in Chinese farmers' production decisions, with a focus on input use such as organic fertilizer (e.g., Jacoby et al., 2002), land use efficiency (Zhang et al., 2011; Leight, 2016), and forest output efficiency (Salant and Yu, 2016). In contrast, evidence of the impacts of land tenure in conservation practice adoption in China is relatively scarce. Wang et al. (2010) investigated the determinants of adopting conservation tillage as well as residue retention; however, they did not consider land tenure as a driving factor. Liu and Huang (2013) were among the first to assess the role of land tenure security on a conservation practice; they have shown that the ownership of land is slightly positively associated with increased likelihood of using contour cultivation.[1]

However, to the best of our knowledge, no study has explicitly modeled the role of land tenure in the adoption of straw retention, an increasingly important conservation practice (Pittelkow et al., 2015) with substantial local and downwind air quality benefits as China aims to curb the PM 2.5 pollution. Straw retention (i.e., returning straw to the field) refers to a residue management strategy of covering the crop straws on the soil surface after harvest, which has

[1] In fact, Chinese farmers do not own the farmland. As will be discussed in details later, the "ownership" of a plot by a farmer household in China is actually represented as the land contract right.

been proven to improve long-term soil productivity (Lu, 2015; Wang et al., 2015), boost yield (Huang et al., 2013; Wang et al., 2015), and reduce PM 2.5 emissions through burning of these fields (Li et al., 2008; Tao et al., 2013). Since 2015, many provinces in China have offered 20–60 Chinese Yuan per *mu* subsidy to encourage straw retention adoption.[2] In addition, we analyze the land tenure insecurity in a new policy context in which China increasingly promotes rural land transfers among farmers through a land rental market, and there is a lack of understanding on whether and how farmers behave differently on rented land obtained through the rental market versus their own-contracted farmland allocated by the collectives.

This study aims to examine how land tenure arrangements affect Chinese farmers' adoption of straw retention, especially in the new era of rural land transfer market. We hypothesize that more secure land tenure leads to a higher probability of straw retention adoption by crop farmers in China. In particular, we define land tenure security based on the participation of the rural land transfer market: we distinguish fields "owned" and farmed by the original contractee who obtained the allocated land from the rural village collectives from fields "rented" from other farmers through participation of the rural land rental market. We argue that farmers on rented fields are facing less secure land tenure due to the short-term nature of leasing contracts, and thus have lower willingness to undertake a conservation practice.

We test the hypothesis by applying several discrete choice models to a rural household

[2] In an attempt to reduce open burning of crop residues, in May 2015 the Chinese government announced a straw retention subsidy pilot project in five provinces—Anhui, Shandong, Hunan, Sichuan and Zhejiang, which offered a cash payment to farmers who returned crop straws to the field after harvest. Since 2016, the project has been extended to the entire China. Mu is the area unit used in China; 1 mu=0.0667 hectares. Our study analyzed crop and crop residue choices by crop farmers in Henan province for the 2015 growing season, and as a result they did not receive the straw retention subsidy.

survey during 2016 summer in Henan Province, which was based on stratified random sampling and covered all 17 prefecture-level cities. Empirically, we run a base probit regression with a tenure dummy entered as an independent variable using the full sample. Additionally, we run two separate probit models for each of the land tenure categories. We also employ a Heckman two-stage model with a selection equation on the rental decision as the first stage because growers on rented farmland may self-select into non-conservation activities. This is either due to the fact that fields that are difficult or challenging to implement a conservation practice may be likely to be rented out, or because renters are likely large-scale producers who are keener to profit maximization and thus more cognizant of cost-saving activities. The driving distance from the village to the nearest city center is used as the exclusion restriction variable in a sense that the distance to urban core would largely affect a farmer household's decision to migrate for off-farm employment, and thus the decision to rent out fields, though it does not directly influence the adoption of straw retention.

Probit regression results show that, after controlling for crop choice, harvest season, spatial climate, and other plot-level and household-level covariates, a rented plot is associated with a 10.7 percent reduction in the probability of adopting straw retention after harvest throughout 2015; the determinants of adoption vary a lot under different tenure arrangements. In addition, the Heckman procedure correcting the sample selection bias reveals that plots closer to the city center are more likely to be rented out. The decision to rent farmland appears to be significantly associated with decreased adoption rate of straw retention, which is consistent with the probit

results. Overall, our results confirm the hypothesis and are comparable to many studies in other countries.

This study contributes to the literature of conservation practice adoption by quantitatively examining the link between land tenure security and straw retention adoption in China for the first time. More importantly, our research is of great policy relevance since it reveals the previously overlooked, potentially negative interconnection between two policies both promoted by the Chinese government—encouraging the adoption of straw retention and extending the rural land rental market—and offers insight into how the government can better promote and balance them.

The rest of this paper is organized as follows: section 2 provides a brief review of Chinese land system and the development of the land rental market; section 3 introduces the conceptual framework; section 4 describes the data used in this study and empirical implementation; section 5 discusses the empirical results; section 6 provides concluding remarks.

2. Land Tenure and Land Rental Market in China

China prohibits private land ownership. The current Household Responsibility System (HRS) was introduced in the early 1980s and allocates a parcel of contracted farmland to each eligible rural household on the basis of household size, which is referred to as the land contract (and use) right. Nevertheless, the allocated land is owned by village collectives represented by villager committee or township government (Hu, 1997). Farmers are free to make their own agricultural

117 production decisions, though they are not permitted to convert the land to non-agricultural use. In
118 the early stages of HRS, land contracts only lasted for a 1- or 2-year period, which led to
119 significant land tenure insecurity and discouraged farmers from making land improvements
120 (Krusekopf, 2002). Realizing this limitation, the Chinese government lengthened the land
121 contract terms to 15 years, further extending it to 30 years in 1993 (Zhang et al., 2011).

122 However, the increase in duration of land contracts did not necessarily improve the tenure
123 security for rural households: first, village collectives periodically reallocate the village land
124 through administrative means to reach egalitarian goals in response to household demographic
125 changes, even in the midst of land contract periods (Liu et al., 1998; Brandt et al., 2002; Tan et
126 al., 2006). In addition, the allocations by collectives are less efficient due to inability to adjust to
127 events of increasing rural migrants going off-farm and working outside the village, which tends
128 to lead to productive inefficiency (Benjamin and Brandt, 2002).

129 In response to the rising need of more secure land tenure, the central government has
130 codified a framework for the protection of land rights and development of a land rental market,
131 including the Land Management Law (1998), the Rural Land Contracting Law (2003), and the
132 Property Law (2007). Subsequently, the land rental market took off rapidly, with a participation
133 rate of about 10 percent in 2001 (Deininger and Jin, 2005), and stayed around that level for
134 almost a decade. However, in many areas, farmland continued to be illegally reallocated by local
135 officials (Zhang et al., 2011). With the steady increase in the number of rural workers migrating
136 to urban regions, more and more rural households no longer have the need to keep all contracted

land due to lack of laborers, which to a large extent stimulates the development of a rural rental market. Figure 1 shows the national growth of transferred rural land in China. As can be seen, the percentage of transferred land over the total contracted land to rural household has tripled from less than 10 percent in 2008 to about one third in 2015.

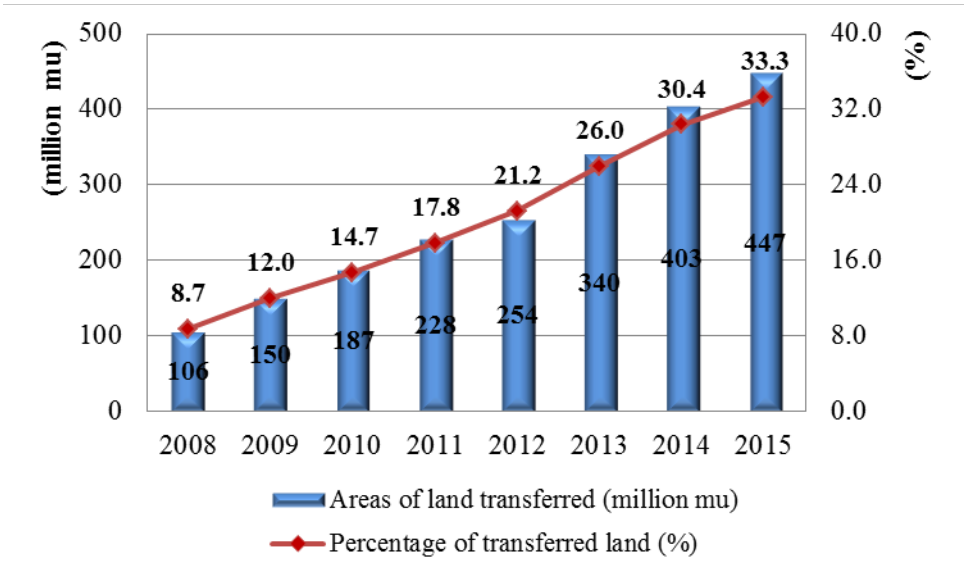

Figure 1. The Scale of Land Transfers in China, 2008–2015.
(Source: Author's Calculation; Ye, 2015; Ministry of Agriculture, 2014, 2015, 2016)

More recently, the Chinese government has formally announced the intent to protect and split rural land rights into three parts: ownership, contract, and use. Ensuring permanent collective land ownership, the government allows rural households to lease out the land use right while maintaining on the original land contract with the village government, which is largely to stimulate the land transfer through the rental market.[3] However, the decomposition of rural land rights may raise a further question. The transferred land use right, which depends on how the

[3] See the 2014 No. 1 Policy Document available at http://www.moa.gov.cn/zwllm/zwdt/201401/t20140120_3742582.htm (in Chinese).

leasing contract is made between rural households, may not be as secure as the land contract right.

While the rural land transfer allows more flexible allocation of farmland across farmers, potentially moving from inefficient producers to more efficient producers, it remains uncertain how the tenants, who obtained the farmland via the rural land transfer market for a finite amount of time, would treat these land parcels differently compared to those owned and operated by its original contractees. Enlightened by previous literature on limited investments on rented land (Soule et al., 2000; Fraser, 2004; Kabubo-Mariara et al., 2010), it is reasonable to assume that tenants of rented land would have less incentive to make long-term investments, such as adopting conservation practices (i.e., straw retention) on these parcels, an issue that will be investigated in this study.

3. Conceptual Framework

Following previous works by McConnell (1983) and Soule et al. (2000), we develop a three-stage model to analyze the adoption behavior of straw retention under different land tenure arrangements.

In the first stage, after the crop is harvested for the current growing season, the farmer household decides on the treatment of crop residues (straws), which involves a treatment cost denoted by C_j. In this context, we designate $j = s$ for adopting straw retention and $j = n$ for

169 no adoption (i.e., all other treatments such as burning and discarding).[4] Straw retention requires
170 residues covering the surface and being mixed with the soil, which can be accomplished by
171 machinery or manpower. However, whether C_s is higher than C_n depends on the specific straw
172 treatment as well as the crop type. Generally, when compared to burning and discarding straws in
173 the fields, $C_s > C_n$. Straw treatment in the first stage will also affect farming for the next season.
174 Let π_j be the second-season net returns under first-stage straw treatment, j. Straw retention
175 may increase the probability of insect damage and thus hurt short-term crop yields and profits, as
176 a result we assume $\pi_s < \pi_n$. For the final stage, the farmer household is concerned with the
177 terminal value of its farmland, denoted by V_j. Straw retention can help reduce soil erosion,
178 improve fertility and productivity over time, and thus better retain the long-term value of the
179 land. Therefore, $V_s > V_n$.

180 Assume that farmer household selects a straw treatment option j to maximize the present
181 value PV_j of three terms discussed above, as shown by the following equation:

182 $$\max_{(j)} PV_j = \pi_j - C_j + \lambda V_j/(1+r)^T \quad (1)$$

183 where r represents the discount rate and T the number of periods; following Soule et al.
184 (2000), λ is included as a tenure-security indicator weighting the third term that measures the
185 farmer household's belief about its ability to use or sell the land in the future. Therefore, the
186 more secure the land tenure, the higher λ and greater importance of the long-term land value in

[4] Besides straw retention, other straw treatment options include burning, discarding in the fields, collecting and storage, use as fuel, etc.

household's decision-making process.

Based on equation (1), it is optimal for a rational farmer household to adopt straw retention when

$$\pi_s - C_s + \lambda V_s/(1+r)^T > \pi_n - C_n + \lambda V_n/(1+r)^T \quad (2)$$

or

$$\lambda \Delta V/R > \Delta \Pi \quad (3)$$

where $\Delta \Pi = (\pi_n - C_n) - (\pi_s - C_s)$, $\Delta V = V_s - C_n$ and $R = (1+r)^T$. Since $V_s > V_n$ and R is positive, if we generally assume $C_s > C_n$ and $\pi_s < \pi_n$, condition (3) actually suggests the adoption of straw retention hinges on whether the potential short-term profit loss (i.e., the right-hand side) can be offset by the perceived gains in long-term land value (i.e., the left-hand side). That is, with higher λ or more secure land tenure, the farmer household is more likely to undertake long-term improvement activities such as straw retention, as stated in our hypothesis.

Empirical estimate of the value of λ is lacking. In countries where private land ownership is well-established, it is plausible to assume that $\lambda = 1$ for a land owner. While in the context of China, the corresponding "owner" of farmland may be the contractee who bears both the land contract and use rights. The value of $\lambda_{contractee}$ is possibly lower than, but close to 1, since land contractees are also confronted with tenure insecurity such as land reallocation. For renters, λ should be much lower since they only possess the land use right and are mainly concerned with the short-term profits. However, λ_{renter} could be higher than zero if renters can

206 continually use the land, which depends on the duration of the lease. In this case, as will be noted
207 later, more than 90 percent of the existing leases in the study region are verbal and informal on a
208 one-year basis. Thus, we hypothesize that $\lambda_{renter} < \lambda_{contractee}$ or the probability of adopting
209 straw retention is higher for contractees than for renters, which will be tested in our empirical
210 model.

211 ***3.1. Discrete choice model***

212 To test the above hypothesis, we employ a binary discrete choice model derived from the latent
213 variable approach. Let y denote a farmer household's decision to adopt straw retention or not,
214 which is generated from a latent variable y^* equal to $\lambda \Delta V/R - \Delta \Pi$ from equation (3). The
215 difference between short-term profits and long-term land values for the farmer household is
216 unobserved, but one can observe the household's decision of adoption. If y^* is positive, straw
217 retention is adopted and $y = 1$ is observed; otherwise, $y = 0$ is observed if y^* is negative.

218 For each household i, the latent variable y_i^* is assumed to be a linear function of the
219 vector of observable household, plot, and regional characteristics ($\mathbf{X}_i$) as follows:

220 $$y_i^* = \boldsymbol{\beta}\mathbf{X}_i + \varepsilon_i \quad (4)$$

221 where $\boldsymbol{\beta}$ is the coefficient vector and ε_i a random error term. The linkage between y_i^* and y_i
222 is as follows:

223 $$y_i = \begin{cases} 1, & if\ y_i^* > 0 \\ 0, & if\ y_i^* < 0 \end{cases} \quad (5)$$

224 then the probability that the household i adopts straw retention ($y_i = 1$) is given by

$$Pr[y_i = 1] = Pr[y_i^* > 0] \quad (6)$$

$$= Pr[\boldsymbol{\beta}\mathbf{X}_i + \varepsilon_i > 0]$$

$$= 1 - Pr[\varepsilon_i \leq -\boldsymbol{\beta}\mathbf{X}_i]$$

$$= F(\boldsymbol{\beta}\mathbf{X}_i)$$

where $F(\cdot)$ is the cumulative distribution function of the error term ε_i. We assume that ε_i follows the standard normal distribution and equation (6) is estimated by probit regression.

3.2. Heckman Selection Model

Growers on rented plots may self-select into non-conservation activities, our plot-level estimation may subject to a sample selection problem that prevents us from obtaining unbiased estimates. First, the original farmer contractee may be more likely to rent out fields that are difficult or challenging to implement a conservation practice, possibly due to their shapes or other unobserved characteristics. Secondly, renters are probably large-scale producers who are keener to maximize profits on all grounds (including rented plots) and thus are more cognizant of all possible cost savings and prone to select the profit-maximizing practice. Given that air quality impacts from straw burning is currently external to a producer's decision process, the renters are more likely to adopt the least costly option as opposed to more costly straw retention. To test the existence of sample selection bias, we consider the Heckman two-stage method for correction.

The straw retention adoption equation, for each household i and cultivated plot k, is assumed to take a linear form written as:

$$Pr[adopt_{ik} = 1] = \beta rent_{ik} + \gamma X_{ik} + u_{ik} \quad (7)$$

where $adopt_{ik}$ represents the adoption dummy, which equals unity if the household i adopts straw retention on plot k; $rent_{ik}$ is a land tenure dummy, which equals one if the plot is rented from others, this is designed to capture the land tenure insecurity denoted earlier as λ_{renter}; X_{ik} is the vector of other plot-level and household-level control variables; u_{ik} is the error term. We assume that sample selection is present on $rent_{ik}$, hence regular probit regression would generate biased $\hat{\beta}$. Following the Heckman selection model, the selection equation is estimated as follows:

$$Pr[rent_{ik} = 1] = \alpha X_{ik}^{*} + \delta Z_{ik} + \varepsilon_{ik} \quad (8)$$

where X_{ik}^{*} contains a subset of control variables in X_{ik} that also have an effect on the decision to rent fields; Z_{ik} includes the exclusive restriction variables, which only affect land transfer but not directly the adoption of straw retention; ε_{ik} is the corresponding error term. In particular, we use the driving distance from the village to the nearest prefecture-level city center in Henan as the exclusion restriction variable. The shorter the distance is, the more convenient for rural laborers to migrate for off-farm employment in urban areas and thus a higher possibility that the fields are rented out. We posit that the distance to city center can largely affect farmer household's decision for land transfer, while it does not directly influence the adoption of straw retention.

The Heckman correction builds on the assumption that the error terms in both the adoption

and selection equations are jointly normal with correlation ρ (i.e., $\rho = corr(u_{ik}, \varepsilon_{ik})$). A rejection of the null hypothesis $\rho = 0$ would indicate the presence of sample selection issues. To correct for that, a new variable called the Inverse Mills Ratio (IMR) IMR_{ik} will be calculated from equation (8) and added into the adoption equation (the tenure dummy $rent_{ik}$ is not included), which yields:

$$Pr[adopt_{ik} = 1] = \tilde{\gamma} X_{ik} + IMR_{ik} + \nu_{ik} \quad (9)$$

where $\tilde{\gamma}$ denotes the coefficients corrected for selection bias.

In this adoption equation, we include three variables that only affect straw retention but not necessarily participation of rural land rental market for exclusion restriction purposes: a winter season dummy and average July temperature and precipitation at the county level. Unfavorable climatic conditions could reduce suitable field days available for straw retention and crop planting, especially after the summer growing season. Moreover, as the way we form plot-level samples may cause each surveyed household to have more than one plot observation, conventional regression techniques may generate biased parameter estimates for standard errors due to the presence of correlation among observations. To correct for the potential bias, we compute household-clustered standard errors in both the probit regressions and Heckman model that are robust to within-household error correlation.

4. Data Description

The data used in this study is drawn from a household survey conducted by Henan Agricultural University in 2016 summer in Henan Province, a major grain production province in central China (figure 2 provides a map of the studied region). Henan is also a big crop straw producer, accompanied by severe air pollution resulted from straw burning in the open fields (Fu et al., 2017).

The survey covered all 17 prefecture-level cities in the province, and for each prefecture-level city, a specific number of villages are randomly selected to form a sampling fraction proportional to the total rural population in Henan. For each selected village, between three and six farmer households are randomly picked to answer the questionnaire. The number of surveyed households is 710 in total, which covered 47 counties or county-level cities, and 175 villages, leading to a final of 670 valid questionnaires. The household-level data covers detailed information about agricultural production and operation throughout the year of 2015, as well as household and personal characteristics. We also supplement the survey data with climatic information obtained from the National Meteorological Information Center (NMIC), which reports historical averages over the 20-year period from 1981 to 2000 of climate variables at the county level in Henan Province. A key policy context to bear in mind is that in our study area for the 2015 crop year, there is no subsidy available for farmers specifically targeted to incentivize straw retention.

Figure 2. Map of Studied Region—Henan Province in China.

(Color should be used for this figure in print)

In our study area, many farmers grow at least two crops every year, typically corn during the autumn season (from June to October) and winter wheat during the winter season (from October to June). As a result, each year a farmer could face two straw retention choices. To better identify the impact of tenure, we treat the crop straw retention choices for these crops separately and our unit of observation is at plot-level for each season, with each representing a particular crop for a particular growing season.

Importantly, all plots are classified by a binary land tenure variable: own-contracted versus rented. Own-contracted plots refer to those cultivated by the original farmer households who got

313 the allocated land directly from the village collectives and hold both the land contract and use
314 rights. Rented plots are those rented out by original contractees and cultivated by farmers who
315 only hold the land use rights. After eliminating all plots that are not cultivated in 2015, and thus
316 do not involve any treatment of straw, we finally have 1,659 plot-level observations from 670
317 farmer households for analysis.[5]

318 For each specified plot, the farmer is asked how he or she dealt with the straws after harvest
319 and asked to choose among the following options: straw retention (tilled in), straw retention
320 (crushed straws broadcasted in field as cover), burnt, used for fuel, used for feed, and discarded.
321 We assume that straw retention is adopted for a particular plot if the straw is chosen to be tilled
322 in or broadcasted as cover, no matter whether there are other selected options as well and
323 regardless of the specific share of straws being returned to the field (retention).[6] Of all
324 observations, 9.3 percent of plots are rented and 90.7 percent are own-contracted, but the areas of
325 rented plots account for 20.3 percent of total cultivated land areas in our sample. In addition,
326 70.8 percent of plots adopted straw retention; 44.1 percent are wheat plots, 38.4 percent are corn
327 plots, and 17.5 percent are other crops including rice, soybean, peanut, cotton and so on. Table 1
328 and Table 2 report the descriptions and summary statistics of selected variables, respectively.
329

[5] Due to widely used informal contracts between farmer households in most cases, it is not clear how the decision is made on a rented plot in this context. The decision-making process has been shown crucial in affecting adoption of conservation practices (Soule et al., 2000; Kurkalova et al., 2006). For instance, in the U.S., there are two types of land renter: share-renters' decisions may be affected by land owners because both the owners and renters share the revenues and costs of production; cash-renters, however, may behave more independently since they only pay a fixed rent to the landlords while the owners do not participate in any activities. Failure to consider the differences in decision-making process may obscure the effect of land tenure on adoption.

[6] The survey does not collect information about the shares of straws for different straw treatments.

330

331 **Table 1. Descriptions of Selected Variables**

Variable	Description
Straw retention	Straw retention is adopted in the plot (1=yes, 0=no)
Rented plot	The plot is a rented plot (1=yes, 0=no)
Age	Age of the household head
Farming experience	Number of farming years of the household head
Risk preference	Risk preference of the household head (1=risk seeking, 0=risk averseness)
Education	Highest years of education of all household members
Number of laborers	Number of laborers that engaged in farming activities in 2015
Income	Household annual income in 2015
Organization	The household has participated in rural economic organization (1=yes, 0=no)
Insurance	The household has purchased agricultural insurance (1=yes, 0=no)
Plot size	Plot area (mu=0.0667 hectares)
Distance to city	Driving distance from the village to the nearest prefecture level city center in Henan (km)
July temperature	Average daily temperature of July days from 1981 to 2000 of the county that the household locates (℃)
July precipitation	Average annual daily precipitation of July days from 1981 to 2000 (mm)
Winter season	The plot is cultivated in the winter season (1=winter season, 0=autumn season)
Wheat	The plot is planted wheat (1=yes, 0=no)
Corn	The plot is planted corn (1=yes, 0=no)
Other crop	The plot is planted other crops (1=yes, 0=no)

332

333

334

335 **Table 2. Summary Statistics of Selected Variables**

Variable	All plots		Own contracted plots		Rented plots		T-test of
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	mean diff
Straw retention	0.708	0.45	0.712	0.45	0.665	0.47	-0.048
Rented plot	0.093	0.29	-	-	-	-	-
Age	44.28	11.76	44.08	11.93	46.28	9.71	**2.20****
Farming experience	28.28	13.59	28.32	13.55	27.92	14.04	-0.40
Risk preference	0.679	0.47	0.676	0.47	0.710	0.46	0.034
Education	12.40	3.58	12.32	3.59	13.20	3.47	**0.88*****
Number of laborers	2.611	1.26	2.620	1.27	2.516	1.21	-0.104
Income	4.200	3.16	4.079	2.96	5.367	4.47	**1.288*****
Organization	0.041	0.20	0.041	0.20	0.039	0.19	-0.003
Insurance	0.129	0.34	0.116	0.32	0.258	0.44	**0.142*****
Plot size	4.135	4.25	3.802	2.61	7.363	10.80	**3.561*****
Distance to city	52.30	38.63	52.50	38.72	50.37	37.73	2.13
July temperature	26.98	0.36	26.97	0.36	27.05	0.34	**0.08*****
July precipitation	337.6	70.4	336.5	67.7	348.2	92.0	**-11.74****
Winter season	0.461	0.50	0.463	0.50	0.439	0.50	-0.024
Wheat	0.441	0.50	0.443	0.50	0.413	0.49	-0.031
Corn	0.384	0.49	0.387	0.49	0.355	0.48	-0.032
Other crop	0.175	0.38	0.170	0.38	0.232	0.42	**0.063***
Observations	1659		1504		155		

Note: ***, **, and * represent significance at 1%, 5%, and 10% level, respectively.

336

337 Farm operator attributes appear to be important in adopting soil conservation practices (Feder et
338 al., 1988; Knowler and Bradshaw, 2007; Baumgart-Gets et al., 2012). In this study we focus on
339 three farmer characteristics: the age of the household head who is also the main operator, years
340 of farming, and risk preference. More experienced operators are apt to be adopters because of
341 better knowledge. Risk preference has been shown important in conservation practice adoption
342 (Fox et al., 1991; Baumgart-Gets et al., 2012). It could also be relevant in this context since straw

retention serves as a long-term land investment that possibly sacrifices short-term profits, which involves uncertainty. The household head's attitude towards risk is measured through responses to a binary question "whether you will utilize a newly developed fertilizer that may increase yields but has not been used yet." We hypothesize that a risk-seeking operator would adopt straw retention with a higher probability. We also include highest years of education of all household members, number of laborers, family income, participation in agricultural economic organization, and purchase of agricultural insurance, and we hypothesize that a richer, well-connected farmer household with insurance coverage or extra help on machinery and labor is more likely to adopt straw retention. In particular, wealthier and insured farmers would be less vulnerable to uncertain short-term profit lost. Finally, participation in an agricultural economic organization that offers market and technology information and shares farming experience among famer participants would increase the probability of adopting straw retention.

For plot-level variables, we consider plot size, crop choice, growing season, and tenure type. With a larger plot, farmers can spread their production costs, especially machinery, over the whole cropped areas (Soule et al., 2000). We also incorporate crop dummies to account for the divergent degree of difficulty dealing with the residues, which varies by crop type. For instance, corn residues are harder and much greater in length, and it thus takes more effort to grind corn straws into small pieces before covering the soil surface. A season dummy is also included because, while there is ample time after the winter crop harvest, in the autumn season (June to October) farmers are time-pressed with often less than one month between harvesting and

sowing. Our survey responses reveal that, of all the 29.2 percent of plots not adopting straw retention, about 35 percent of the respondents report that lack of time is the reason for not adopting. Thus, we expect that the winter season is associated with higher likelihood to adopt straw retention. We do not consider other topographic features such as the plot slope because Henan Province is located in a plains area, and thus there is no significant within-province variation.

5. Empirical Results

5.1. Probit regression results

In our empirical analysis, we first report the results of several simple probit regressions in which we test whether the probability of adopting straw retention is higher in own-contracted plots than rented plots. That is, we test the null hypothesis that $\beta = 0$, where $\beta = \lambda_{renter} - \lambda_{contractee}$ is the coefficient on the tenure dummy and represents the difference of tenure-security indicator between own-contracted and rented plots. The resulting estimated coefficients and marginal effects are presented in table 3.

Table 3. Results of the Binary Probit Regressions (Dependent: Adoption=1)

Variable	(1) Full sample		(2) Own contracted		(3) Rented	
	Coef.	Marg. eff.	Coef.	Marg. eff.	Coef.	Marg. eff.
Rented plot	**-0.3107****	**-0.1070**				
Age	-0.0078	-0.0025	**-0.0138***	**-0.0044**	0.0297	0.0100
Farming experience	0.0009	0.0003	0.005	0.0016	-0.0154	-0.0052
Risk preference	0.1325	0.0431	0.092	0.0295	0.3963	0.1394
Education	**0.0629*****	**0.0201**	**0.0562*****	**0.0178**	**0.1200****	**0.0406**
Number of laborers	**0.2497*****	**0.0800**	**0.2429*****	**0.0771**	**0.4562*****	**0.1543**
Income	0.0201	0.0064	0.0213	0.0067	-0.0058	-0.0019
Organization	**0.7020****	**0.1723**	**0.7589****	**0.1793**	0.8369	0.2098
Insurance	**0.4692*****	**0.1315**	**0.5273*****	**0.1426**	0.3689	0.1177
Plot size	**0.0354****	**0.0113**	**0.0465****	**0.0148**	0.0118	0.0040
July temperature	**-0.2998***	**-0.0960**	**-0.4406****	**-0.1398**	0.7746	0.2619
July precipitation	**0.0048*****	**0.0015**	**0.0050*****	**0.0016**	**0.0049****	**0.0017**
Winter season	**0.4880****	**0.1535**	**0.6129****	**0.1899**	0.077	0.0260
Intercept	5.5183		**9.3081****		**-25.678****	
Crop dummies	Yes		Yes		Yes	
Observations	1659		1504		155	
% correctly predicted	80.11%		79.32%		73.60%	

Note: ***, **, and * represent significance at 1%, 5%, and 10% level, respectively. Standard errors are clustered at the household level.

Column (1) in table 3 displays the results using the full sample. As can be seen, the coefficient on "rented plot" dummy is negative and significant at the one percent level. In other words, a rented plot is associated with 10.7 percent lower probability of adopting straw retention than an own-contracted plot, ceteris paribus. The result confirms our hypothesis and is consistent with previous studies regarding the tenure effect (Soule et al., 2000; Fraser, 2004;

Kabubo-Mariara, Linderhof, and Kruseman, 2010). The household-level characteristics appear to be more important in the adoption decision: higher educational attainment, greater number of laborers, participation in agricultural economic organization, and purchase of agricultural insurance are significantly and positively related to increased likelihood of adoption. Two climate variables are significant, suggesting that straw retention occurs more frequently where the climate is warmer and wetter (more rain). The positive sign on plot size reflects that larger farmland in fact lowers the average cost of adoption; and, the positive and significant winter dummy verifies the existence of seasonal effect on residue management.

We also examine whether the estimated coefficients systematically differ by tenure type. We conduct separate probit regressions for each of the two tenure categories, own-contracted and rented plots, with all other independent variables the same as those in the full-sample regression. A likelihood ratio test rejects the null hypothesis that the coefficients are identical across tenure types, implying that the impact of all other characteristics on adoption of straw retention relies on the specific tenure status of the plot.[7] The resulting coefficients and marginal effects by tenure type are reported in columns (2) and (3) in table 3. It shows that despite similarity on other variables, the age of household head, organization participation, purchase of insurance, plot size, and seasonal effect only matter for own-contracted plots, while they have no effects on adoption for rented plots. The sharp disparity reflects a significantly different decision mechanism for a renter in adopting straw retention.

[7] In conducting the likelihood ratio test, we do not specify clustered standard errors at any level in the regressions.

406 ***5.2. Heckman selection model results***

407 We examine whether growers on rented plots would self-select into non-conservation practice,
408 which is tested by the Heckman two-stage model. Columns (1) and (2) in table 4 shows the
409 estimated results for selection and adoption equation, respectively.

410

411 **Table 4. Results of Heckman Selection Model**

Variable	(1) Selection Equation		(2) Adoption Equation	
	Coef.	Marg. eff.	Coef.	Marg. eff.
Age	**0.0240*** **	**0.0036**	-0.0010	-0.0001
Farming experience	**-0.0150** **	**-0.0022**	0.0016	0.0001
Risk preference	0.0244	0.0036	0.1779	0.0151
Education	**0.0315***	**0.0047**	0.0331	0.0028
Number of laborers	-0.0805	-0.0119	**0.2709*** **	**0.0230**
Income	**0.0390** **	**0.0058**	-0.0085	-0.0007
Organization	0.0279	0.0041	0.2692	0.0229
Insurance	**0.5140*** **	**0.0763**	-0.2665	-0.0227
Plot size	**0.0698*** **	**0.0104**	**-0.0215***	**-0.0018**
July temperature			0.3069	0.0261
July precipitation			**0.0027***	**0.0002**
Winter season			-0.0733	-0.0062
Distance to city	**-0.0042** **	**-0.0006**		
ρ	**-0.9607****			
Crop dummies	No		Yes	
Observations	1659			

Note: ***, **, and * represent significance at 1%, 5%, and 10% level, respectively. Standard errors are clustered at the household level.

412

413 As shown in column (1), contrary to results in the adoption regression, characteristics of the
414 household head, including age and farming experience, appear to play an important role in

making land rental decisions. Higher family educational level, higher family income, and purchase of insurance are positively related to the probability of renting more farmland. In addition, the positive and significant coefficient of plot size confirms our conjecture that renters, usually as large-scale producers, are more likely to rent in greater land areas from more than one farmer household. We find that the coefficient for the exclusion restriction variable, distance to nearest city, is negative and significant, implying that farmers closer to cities tend to rent out farmland parcels.

The estimated correlation coefficient ρ is statistically different from zero at the five percent level with a value of -0.96, consistent with what we have found in the probit regression —a rented plot is linked with decreased likelihood of adopting straw retention. Since the estimate of land tenure dummy cannot be obtained from our Heckman model, we calculate a surrogate of marginal effect of tenure arrangement by differencing the average predicted probabilities of adoption between own contracted and rented plots. The difference is about one percentage point, which implies that, after correcting for sample selection bias, the adoption rate of straw retention is one percentage point lower on rented farmland.

Column (2) in table 4 reports the estimates of the adoption equation, in which we treat climate variables, the season dummy, and the crop dummies as the exclusive restrictions. All these terms are closely related to on-farm straw treatment but less relevant to land rental behaviors. We observed that the selection-bias-corrected coefficients change significantly compared with the probit results in table 3; number of laborers, July precipitation, and plot size

435 are the only variables that are significant. In particular, the coefficient on plot size carries an
436 opposite sign, meaning the cost of straw retention may actually increase with land areas. The
437 findings highlight the importance of accounting for sample selection problem.
438
439 ***5.3. Discussion***
440 Our empirical results provide evidence that there is negative correlation between land tenure
441 insecurity, as proxied by rented plots, and farmer's decisions to adopt straw retention in China.
442 Our survey shows that, of all 79 surveyed households (out of a total of 690) that rent land from
443 others, 75 households (or about 95 percent) are based on oral land leases without legal validity;
444 only four households (or about five percent) have signed formal and written contracts; 65
445 households' leases (or about 82 percent) are on a one-year-tenure basis. The figures reflect the
446 tenure of a rented plot, or the transferred land use right, may be far less secure than land contract
447 right in Henan province.
448 Our findings provide valuable policy implications. The disparity of adoption rates of straw
449 retention between own-contracted and rented plots have significant policy implications on the
450 long-term sustainability of farmland in China, especially as China aggressively promotes the
451 rural land rental market. In particular, the Chinese government is encouraging participation of
452 market-based rural land transfer as an alternative of committee-intervening land reallocation to
453 improve agricultural production efficiency. However, our results imply that more careful
454 deliberation or monitoring is warranted on the potential impacts on less-sustainable farming

455 practices on the rising acres of rented grounds. Our results also suggest that the air quality and
456 other environmental benefits from encouraged straw retention could be impacted without efforts
457 to boost adoption on rented land. Due to less secure land tenure, farmers on rented plots have
458 lower incentives to adopt conservation practices, causing environmental problems such as more
459 PM2.5 emissions from straw burning and more severe soil degradation.

460 Improving the land tenure security may be one effective measure to encourage adopting
461 straw retention, especially on rented plots. The government should regulate the rental market by
462 enforcing the use of a more stable and formal written contract, which incorporates specific
463 requirements on farm operation and residue management. On the other hand, it may also be
464 helpful to extend the current range of land contract rights transfer from within-village to
465 cross-village or within-township, in order to allow farmer households to own more contracted
466 land and stimulate long-run land improvements.

467 **6. Concluding Remarks**

468 Based on data from a 2016 farmer household survey in Henan Province in central China, we
469 apply several probit regressions and a Heckman two-stage model to test the potential link
470 between land tenure security and the probability of adopting crop straw retention. Empirical
471 results show that farmer households are more likely to adopt straw retention after harvest on
472 own-contracted than rented plots, which is consistent with previous literature that shows insecure
473 land tenure often hinders adoption of conservation practices. This study provides some of the

first evidence in assessing the negative impact of land tenure insecurity on the adoption of a long-term land improvement practice, straw retention. We argue that policies should be implemented to enhance the land renters' tenure security of their land use rights in order to boost adoption of this critical conservation practice, which is beneficial for local and downwind air quality and the long-term land fertility.

Further research should explore how the specific share of straws being returned to the field is influenced by tenure class, which is not tested in this study. Moreover, the effects of different aspects of tenure security need further investigation. For instance, the duration of tenure, another important dimension of tenure security either for own-contracted or rented land, may also play a role in affecting the adoption rate. In addition, with a panel dataset, one can examine whether the adoption rate of straw retention varies over time under different policy scenarios, such as varying strictness on the burning of straws. It is possible that the higher adoption rate is mainly due to prohibition of straw burning.

References

Baumgart-Getz, A., L.S. Prokopy, and K. Floress. 2012. “Why Farmers Adopt Best Management Practice in the United States: A Meta-analysis of the Adoption Literature.” *Journal of Environmental Management* 96(1): 17–25.

Benjamin, D. and L. Brandt. 2002. “Property Rights, Labour Markets, and Efficiency in a Transition Economy: the Case of Rural China.” *Canadian Journal of Economics* 35(4): 689–716.

Brandt, L., J. Huang, G. Li, and S. Rozelle. 2002. “Land Rights in Rural China: Facts, Fictions and Issues.” *The China Journal* 47: 67–97.

China, People’s Republic of, Ministry of Agriculture. 2014. *26% Contracted Land Has Been Transferred, Ministry of Agriculture Required No Forced Commands* [*Quan Guo 26% Cheng Bao Di Yi Liu Zhuan, Nong Ye Bu Yao Qiu Bu Neng Gao Qiang Po Ming Ling*]. Available at http://news.xinhuanet.com/fortune/2014-02/23/c_119460477.htm. (in Chinese)

China, People’s Republic of, Ministry of Agriculture. 2015. *The Transferred Land Has Accounted for More Than 30% of the Total Contracted Land [Quan Guo Geng Di Liu Zhuan Mian Ji Zhan Zong Cheng Bao Geng Di Bi Zhong Chao Guo San Cheng]*. Available at http://news.xinhuanet.com/fortune/2015-08/27/c_1116397151.htm. (in Chinese)

China, People’s Republic of, Ministry of Agriculture. 2016. *Ministry of Agriculture: The Transferred Land Areas Have Been 447 Million Mu by the End of Last Year [Nong Ye Bu: Jie Zhi Qu Nian Di, Quan Guo Jia Ting Cheng Bao Geng Di Liu Zhuan Mian Ji 4.47 Yi Mu]*. Available at http://www.chinanews.com/cj/2016/08-10/7967918.shtml. (in Chinese)

514 Deininger, K. and S. Jin. 2005. “The Potential of Land Rental Markets in the Process of
515 Economic Development: Evidence from China.” *Journal of Development Economics*
516 78(1): 241-270.

517 Feder, G., T. Onchan, Y. Chalamwong, and C. Hongladarom. 1988. *Land Policies and Farm*
518 *Productivity in Thailand*. Baltimore and London: Johns Hopkins University Press for the
519 World Bank.

520 Fox, G., A. Weersink, G. Sarwar, S. Duff, and B. Deen. 1991. “Comparative Economics of
521 Alternative Agricultural Production Systems: A Review.” *Northeastern Journal of*
522 *Agricultural and Resource Economics* 20(1): 124–142.

523 Fraser, E.D.G. 2004. “Land Tenure and Agricultural Management Soil Conservation on Rented
524 and Owned Fields in Southwest British Columbia.” *Agriculture and Human Values* 21(1):
525 73–79.

526 Fu, L., S. Wang, Z. Wu, S. Liu, S. Yang, and R. Zhang. 2017. “Estimation of Air Pollutant
527 Emissions from Straw Residues Open Burning in Henan Province [He Nan Sheng Jie
528 Gan Lu Tian Fen Shao Da Qi Wu Ran Wu Pai Fang Liang De Gu Suan Yu Fen Xi].”
529 *Journal of Agro-Environment Science*, 36(4): 808–816. (in Chinese)

530 Gebremedhin, B. and S.M. Swinton. 2003. “Investment in Soil Conservation in Northern
531 Ethiopia: The Role of Land Tenure Security and Public Programs.” *Agricultural*
532 *Economics* 29(1): 69–84.

533 Hu, W. 1997. “Household Land Reform in China: Its Impact on Farming Land Use and
534 Agro-environment.” *Land Use Policy* 14(3): 175–186.

535 Huang, S., Y. Zeng, J. Wu, Q. Shi, and X. Pan. 2013. “Effect of Crop Residue Retention on Rice
536 Yield in China: A Meta-analysis.” *Field Crops Research* 154: 188–194.

Jacoby, H.G., G. Li, and S. Rozelle. 2002. “Hazards of Expropriation: Tenure Insecurity and Investment in Rural China.” *The American Economic Review* 92(5): 1420–1447.

Kabubo-Mariara, J., V. Linderhof, and G. Kruseman. 2010. “Does Land Tenure Security Matter for Investment in Soil and Water Conservation? Evidence from Kenya.” *African Journal of Agricultural and Resource Economics* 4(2): 123–139.

Knowler, D. and B. Bradshaw. 2007. “Farmers’ Adoption of Conservation Agriculture: A Review and Synthesis of Recent Research.” *Food policy* 32(1): 25–48.

Krusekopf, C.C. 2002. “Diversity in Land-tenure Arrangements under the Household Responsibility System in China.” *China Economic Review* 13(2): 297–312.

Kurkalova, L., C. Kling, and J. Zhao. 2006. “Green Subsidies in Agriculture: Estimating the Adoption Costs of Conservation Tillage from Observed Behavior.” *Canadian Journal of Agricultural Economics* 54(2): 247–267.

Lee, L.K. and W.H. Stewart. 1983. “Landownership and the Adoption of Minimum Tillage.” *American Journal of Agricultural Economics* 65(2): 256–264.

Leight, J. 2016. “Reallocating Wealth? Insecure Property Rights and Agricultural Investment in Rural China.” *China Economic Review* 40: 207–227.

Li, L., Y. Wang, Q. Zhang, J. Li, X. Yang, and J. Jin. 2008. “Wheat Straw Burning and Its Associated Impacts on Beijing Air Quality.” *Science in China Series D: Earth Sciences* 51(3): 403–414.

Liu, S., M. Carter, and Y. Yao. 1998. “Dimension and Diversity of Property Right in Rural China: Dilemmas on the Road to Further Reform.” *World Development* 26(10): 1789–1806.

Liu, H. and Q. Huang. 2013. “Adoption and Continued Use of Contour Cultivation in the Highlands of Southwest China.” *Ecological Economics* 91: 28–37.

Lu, F. 2015. “How Can Straw Incorporation Management Impact on Soil Carbon Storage? A Meta-analysis.” *Mitigation and Adaptation Strategies for Global Change* 20(8): 1545–1568.

McConnell, K.E. 1983. “An Economic Model of Soil Conservation.” *American Journal of Agricultural Economics* 65(1): 83–89.

Pittelkow, C.M, X. Liang, B.A. Linquist, K.J. van Groenigen, J. Lee, M.E. Lundy, N. van Gestel, J. Six, R.T. Venterea, and C. van Kessel. 2015. “Productivity Limits and Potentials of the Principles of Conservation Agriculture.” *Nature* 517(7534): 365–368.

Salant, S.W. and X. Yu. 2016. “Forest Loss, Monetary Compensation, and Delayed Re-planting: The Effects of Unpredictable Land Tenure in China.” *Journal of Environmental Economics and Management* 78: 49–66.

Soule, M.J., A. Tegene, and K.D. Wiebe. 2000. “Land tenure and the adoption of conservation practices.” *American Journal of Agricultural Economics* 82(4): 993–1005.

Tan, S., N. Heerink, and F. Qu. 2006. “Land Fragmentation and Its Driving Forces in China.” *Land Use Policy* 23(3): 272–285.

Tao, J., L. Zhang, G. Engling, R. Zhang, Y. Yang, J. Cao., C. Zhu, Q. Wang, and L. Luo. 2013. “Chemical Composition of PM2.5 in an Urban Environment in Chengdu, China: Importance of Springtime Dust Storms and Biomass Burning.” *Atmospheric Research* 122: 270–283.

Wang, J., J. Huang, L. Zhang, S. Rozelle, and H.F. Farnsworth. 2010. “Why is China's Blue Revolution So Blue? The Determinants of Conservation Tillage in China.” *Journal of Soil and Water Conservation* 65(2): 113–129.

582 Wang, J., X. Wang, M. Xu, G. Feng, W. Zhang, and C. Lu. 2015. “Crop Yield and Soil Organic
583 Matter after Long-term Straw Return to Soil in China.” *Nutrient Cycling in*
584 *Agroecosystems* 102(3): 371–381.

585 Ye, J. 2015. “Land Transfer and the Pursuit of Agricultural Modernization in China.” *Journal of*
586 *Agrarian Change* 15(3): 314–337.

587 Zhang, Y., X. Wang, T. Glauben, and B. Brümmer. 2011. “The Impact of Land Reallocation on
588 Technical Efficiency: Evidence from China.” *Agricultural Economics* 42(4): 495–507.