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# Factors affecting herder adoption of winter lambing practices in the desert steppe region of Inner Mongolia, China

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**Abstract.** Although winter lambing practices (WL) have been shown to be a 'win-win' strategy for reducing the degradation of grasslands and improving herder livelihood in the pastoral regions of China, the adoption rate is still low. A survey was conducted to explore herders' opinions of WL and other factors which influenced the adoption in the desert steppe region of Inner Mongolia, China. Herders who have spring lambing practices generally hold unfavourable opinions about WL. Most have only heard about WL but did not understand the detailed information of implementation or how it increases income. Herder ethnical background, distance to market and neighbours' choices significantly affected the adoption rate. Han herders were more likely to adopt WL than Mongolian herders. Proximity to market led herders to be more market-focused and to adopt WL. Herders were more inclined to make the same choices as their neighbours. The results showed that herders were prepared to change and were carefully assessing the gains and losses of adopting WL. Results had implications for improving the adoption rate for WL and other livestock management practices in China.

**Additional keywords:** adoption, China, lambing time, land degradation, neighbourhood effect.

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## Introduction

The area of Chinese grasslands is ~400 million hectares, which covers 41.7% of the national land area (Ren *et al*. 2008) and 90% of useable grasslands have been degraded (Li 1999; Liu *et al*. 2002; Li *et al*. 2008; Yang 2010). Overgrazing has been shown to be the major factor in degradation of grasslands by government and scientists (Yuman 1993; Sheehy *et al*. 2004; Harris 2010; Li *et al*. 2016). Many studies have shown that lower stocking rates are necessary to rehabilitate the degraded grasslands (Dyer *et al*. 1986; Kaiser 1998; Kemp and Michalk 2007; Steffens *et al*. 2008; Zheng *et al*. 2011; Cao *et al*. 2013). Because of this the Chinese government has proposed the 'balancing animals and grass' policy with the main aim of reducing livestock numbers along with increasing household income. The proposal is for winter lambing instead of spring lambing as this will enable herders to sell livestock earlier (PGXM 2008).

Historically spring and winter lambing has been conducted in pastoral regions of northern China. According to data from past surveys, lambing in spring (SL, February/March, with some households lambing until April) is the traditional lambing time practiced by herders with local Sunite sheep mostly bred for SL. Herder households who have adopted SL seldom used shelter or feed forage to livestock and were more likely to graze them on pastures in winter. This resulted in high weight loss of the pregnant ewes, which negatively influenced the lambing rate, birth weight, lamb survival, livestock productivity and lowered household income (Reynolds 2001; Cong *et al*. 2014; Yang *et al*. 2014). These households usually sold livestock in autumn months (September–November), which led to increased grazing pressure on early spring and autumn pastures, and summer grazing lands (Chao *et al*. 2002; Yang *et al*. 2002; Li *et al*. 2005). In contrast, winter lambing (WL) was often accompanied by the use of warm sheds, feeding of forage, stall-feeding and the use of new sheep breeds, for example, Ujumqin sheep and the Du-Meng sheep (a cross between a Dorper sheep and a Mongolian sheep). Households adopting were required to change lambing time to December–January, with the lambs reared in the warm shed and fed forage, hay and other supplements. Under this management ewes gained weight because of the shelter and feeding regime, which resulted in higher lamb birthweight and survival. In addition, these lambs also gained more weight through stall-feeding and can be sold earlier (July) than herders practicing SL. These households were also able to increase their income as they received subsidies from the government according to the WL incentive policy, which was adopted in 2009. This WL policy promoted herders to reduce the number of livestock in the long

 

term, which allowed the grassland to get more time to rest leading to increased plant growth in the next year. The details for the comparisons between SL and WL were given in Table 1.

There is growing evidence for the benefits of adopting WL. Some researchers have shown that lambs gain more weight through WL even where households encountered drought in summer or heavy snow in winter (Li 2016; XLAIC 2017), and herders can also increase their incomes by selling lambs earlier (Reynolds 2001).Yang *et al*. (2014) showed that net income per ewe increased more than 10% where WL was used. Cong *et al*. (2014) established that ewe weight loss was significantly lower, and the pregnancy rate and lambing rate were 98% and 97%, respectively, significantly higher than SL. The weight of newborn winter lambs and survival rate were also significantly higher than SL. In addition households received 109 more yuan per lamb than SL. Nie (1997) showed that WL reduced the incidence of disease in lambs and improved their disease resistance.

Despite the benefits of WL, adoption rate remains low, especially in the eastern regions of Inner Mongolia (Hulunbuir Steppe) and has not been widely adopted by herders (Brown *et al*. 2009; Li and Zhang 2009; Wang 2010). For example, our survey found that a minority of herders adopted WL in the Xilinhot region, which is a typical steppe region. Several studies have been conducted trying to understand the factors which influence herder adoption of WL. Some external factors, such as climatic factors (e.g. heavy snow, being cold in winter and early spring), short feed supplies, poor infrastructure and little access to formal credit were considered as negatively affecting herder adoption (Jia 2005; Gegentu *et al*. 2006; Wang and Liu 2006; Wang 2009). However, there has been little discussion on the internal factors associated with herder decision behaviour with regard to WL at the household level.

Herders have been directly responsible for managing grasslands in pastoral regions of China since the Household Contract Responsibility System (HCRS) was introduced in the 1980s. Herder decisions have a direct or indirect impact on both livestock production and grasslands. Climatic variability and market fluctuations have increased herder risk and uncertainties about lambing practices. Thus, it is important to understand the factors associated with herder decisions regarding the adoption of WL. The objective of this study is to explore the factors affecting herders' decision-making behaviour with respect to the adoption of WL and to obtain data for policy suggestions and institutional development to encourage adoption of WL.

## Materials and methods

### *Study area*

Sunite Right Banner was selected as the study area, located in the central part (111°08′–114°16′E, 41°55′–43°39′N) of Inner Mongolia, China (Fig. 1). The county has a total area of 26 700 km$^2$ and 90% of the area is covered by natural steppe rangelands. The area lies within the temperate climatic zone and is semi-arid in nature, has an annual temperature of 5.5°C and an annual mean rainfall of 194.6 mm, rainfall mainly in summer (June–August) favouring forage growth (Hou *et al*. 2012). The topography is characterised by undulating hills with large areas of flat land in the region.

The study area is characteristic of the desert steppe, and also includes a small part of typical and desert. The dominant native forage species includes grass (*Stipa krylovii* and *Agropyron cristatum*), forbs (*Artemisia frigida* and *Allium polyrhizum*) and less abundant but important legumes (*Melissitus ruthnica* and *Caragana microphylla*) (Li *et al*. 2006). Livestock production includes sheep, goats and horses which mainly graze native vegetation and are the primary income of herder households, which contribute to 73% of gross agricultural production of the county (Hou *et al*. 2012). Under the HCRS, households own livestock and hold rangeland use rights through contracts. The grassland ecosystem in the region deteriorated rapidly at the end of last century as the result of drought with 100% of useable grasslands being degraded to different extents (Chen and Luo 2007), which adversely affected local livelihoods. The net annual income in 2015 was 8405 yuan per person, lower than

**Table 1. The comparisons between the characteristics of SL and WL**

| Index | SL | WL |
|---|---|---|
| Time | February/March | December/January |
| Sheep breed | Local breed | New breeds |
| Warm shed | No | Yes |
| Forage | Less | More |
| Ewe condition | Weight loss and worse health condition | Weight gain and better health condition |
| Lamb condition | Lower birthweight and survival; Less weight | Higher birthweight and survival |
| Selling weight | Uncertain, and totally decided by the grassland condition | More weight brought by stall-feeding and improved breeds |
| Selling prices | Uncertain and totally decided by market | Get subsidies from governments, and governments regulate the prices in some places |
| Selling time | September to November | July |
| Stocking rate | Increase in the long run | Decline in the long run |
| Grassland | Increased grazing pressure for a long time | Reducing grazing pressure; more time to rest leading to increased plant growth |
| Cost | Lower cost brought by buying less forage | Higher |
| Net livestock income per sheep unit | Lower | Higher |
| Total household income | Lower | Higher |

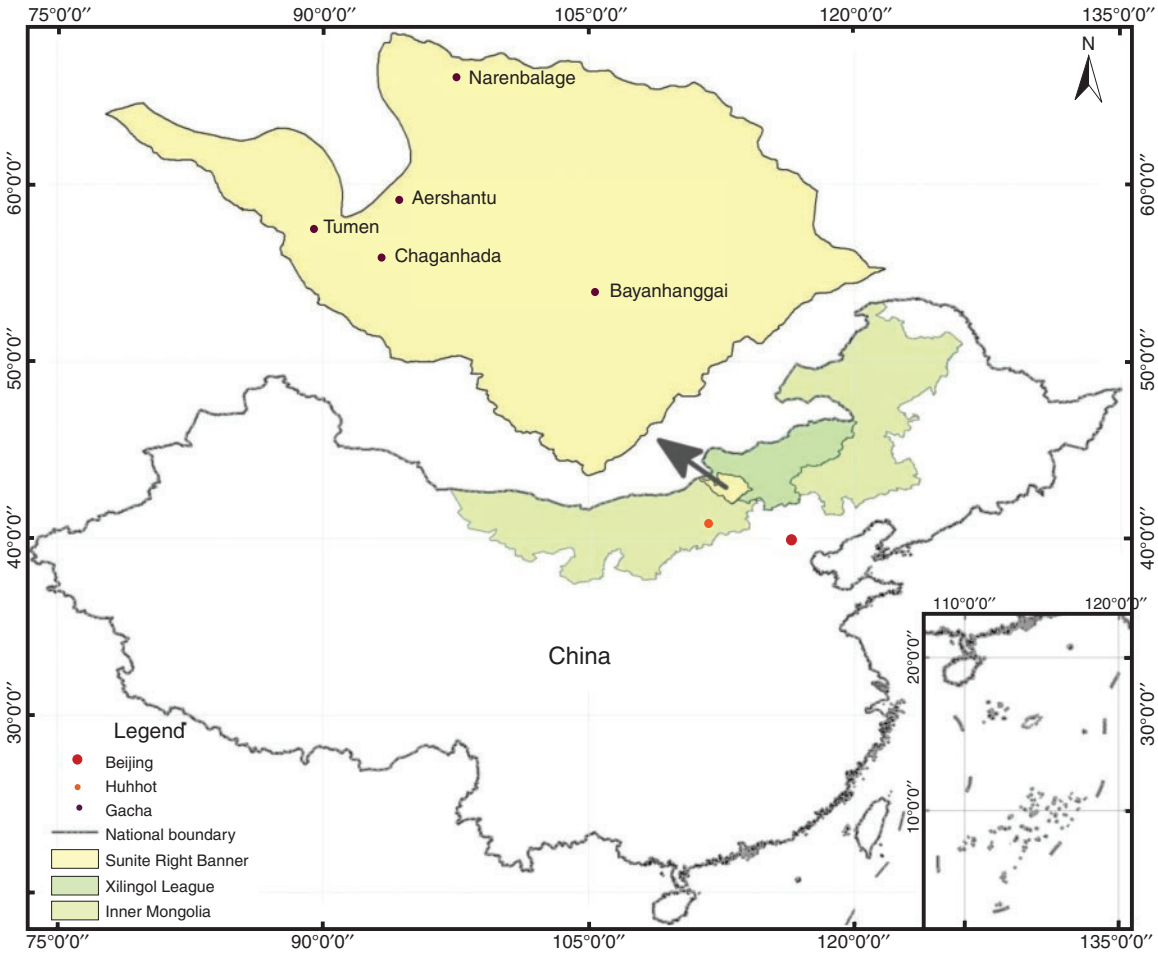


**Fig. 1.** Location of surveyed villages in Sunite Right Banner of Inner Mongolia, China.

the regional average (10 776 yuan in Inner Mongolia) and national levels (11 442 yuan in China).

### *Household survey*

In July–August 2012, a survey was conducted in villages from the county using a semi-structured questionnaire. Pastoral agriculture is the primary income of households in each village. A random-stratified sampling technique was used to select households. Finally, 5–15 households were randomly selected from 5 Gachas (village) within the study area (Fig. 1), which belong to 3 Sumus (township) in proportion to the total household numbers. The household heads or their representatives (if the household head was not available, and often a key decision maker of livestock production practices) were interviewed. A person who understood the whole situation within the village (including the geographic and economic aspects) was hired as a translator. The translator was trained to be familiar with the questionnaire before the surveys were conducted in each village. At the start of each interview, a researcher introduced and explained the survey. Another researcher monitored the interview process to ensure that the questions were asked in an appropriate way and all questions were asked. All herders gave verbal consent for the interview to take place with a total of 60 herders being interviewed. Three questionnaires were omitted from the study due to data quality issues. The survey yielded 57 valid questionnaires.

A pre-test questionnaire was used to identify the important issues regarding lambing practices. The survey was divided into four parts to gather the following information:

(i) The formal questionnaire provided the socio-economic information about herders and their households, including age, ethnicity (Mongolia or Han), education level, family size, household labour and market access.
(ii) The questions were related to livestock production, including grassland area, shed condition, herd size, and household input and output.
(iii) Questions related to their present choices of lambing time and other factors that influence their choices, including credit access, neighbours' decisions and government support.
(iv) This section was used to explore herder opinions of grassland degradation, its protection and WL and assess their willingness to adopt WL.

### *Variable definition*

Explanatory variables included in the regression model are defined in Table 2. The estimated variance inflation factor (VIF) for independent variables is small, with a mean VIF of 1.38.

**Table 2. Definition of variables in the WL adoption model**

| Variables | Definition |
|---|---|
| *Herder characteristics* | |
| Gender | Dummy variable; 1 if the herder is male; 0 otherwise |
| Age | Age of the herder in years |
| Education | 0 = No formal education; 1 = primary school; 2 = junior high school; 3 = senior high school and above |
| Ethnicity | Dummy variable; 1 if the herder is with Mongolian background; 0 otherwise |
| Household labour | Number of active family members |
| *Household assets/resources* | |
| Farm size | Areas of rangeland owned by the household |
| Herd size | Livestock number in winter |
| Shed area | Shed areas in households (brick shed) |
| *Social factors* | |
| Distance to market | Distance to local nearest input/output market (km) |
| Neighbours' choices | Dummy variable; 1 if the neighbours lambed in winter; 0 otherwise |
| Access to credit | 1 if there is loan; 0 otherwise |

A VIF close to 0 means there is little multicollinearity, whereas a value greater than 10 is generally seen as indicative of severe multicollinearity.

Hypotheses about the relationship of the explanatory variables to the adoption of WL were based on theoretical underpinnings and also based on previous results. Previous research exhibited an ambiguous result of the effect of gender on adoption. Some indicated that female herders were more likely to adopt technologies (Neupane *et al*. 2002; Zhang *et al*. 2012). In contrast, some researchers showed that female herders were discriminated against when wanting to use external technologies or new ideas (Oluka *et al*. 2004). It was difficult to assign gender values to the data.sex.

Previous research had shown no correlation with herder age as it was ambiguous. For example, some researchers (Adesina *et al*. 2000; Nkamleu and Adesina 2000; He *et al*. 2007; Núñez and McCann 2008; Zhang *et al*. 2012) indicated that younger famers would have a higher likelihood of adopting new technologies, whereas some found that age was positively related with adoption (Amsalu and De Graaff 2007; Grabowski *et al*. 2016), meaning that the older herders were more inclined to adopt new technologies.

Higher education level was linked to individual judgment and attitude to new practices and ideas. Education was expected to have a positive relationship with adopting WL based on previous researchers (Pender and Kerr 1998; Nkamleu and Adesina 2000; Tey *et al*. 2014).

Ethnicity influenced herder decisions through its effect on belief, traditions and knowledge (Elkind 1993), and some researchers have revealed that ethnic background significantly influenced herder decision of technology adoption (Núñez and McCann 2008; Barrow *et al*. 2010; Tey *et al*. 2014). We hypothesised that herder ethnicity had a significant impact on herder's adoption behaviour.

Household labour would encourage the adoption of agriculture technologies (Grabowski *et al*. 2016) and households with more labour had a higher chance of adopting new technologies (D'Emden *et al*. 2008; Grabowski *et al*. 2016). Due to the demand of more labour of WL, it was expected that household labour would have a positive relationship with herder adoption of WL.

The household assets/resources include three indicators: grassland area, herd size and shed size. Some researchers have found a positive relationship between farm size and technology adoption (Asafu-Adjaye 2008; Zhang *et al*. 2012), whereas it was negative in the results of Pender and Kerr (1998). Therefore, the hypothesised sign of grassland area was indeterminate.

Households with more livestock were less likely to adopt new technologies (Grabowski *et al*. 2016). Our survey found that households with large herd size were likely to continue SL as they had already spent a large amount on capital expenditure and labour and were not prepared to borrow more funds to adopt WL as it would increase their costs and the risk of livestock production. Thus we hypothesised that herd size had a negative impact on the adoption of WL.

Warm shed was considered as a positive factor in encouraging herders to adopt WL (Cong *et al*. 2014; Yang *et al*. 2014). Many sheds in the study region were usually made of soils or rocks, and technically speaking, they could only be called shelter as herder mainly used them against cold night and for the new born lambs instead of stall-feeding. Shelter size was generally too small compared to the number of livestock. Hence, it is difficult to assume the sign of shed size.

In the social factors, distance to market was hypothesised to have a negative relationship with the adoption of lambing in winter. Distance hindered herder contact with market (Zhang *et al*. 2012), and those who were located farther away from market were less like to adopt new technologies (Anley *et al*. 2007).

The neighbours' choices positively and significantly influenced technology adoption (Sidibé 2005). Herders were more likely to learn from their neighbours, especially when neighbours received more profits from new technology or other new practices (De Janvry *et al*. 2005; Sambodo 2007; Willy and Kuhn 2016). It was assumed that neighbours' choices had a positive and significant relationship with the adoption of WL.

Access to credit showed mixed results in previous research. In some research (Bekele and Drake 2003; Jara-Rojas *et al*. 2012) the effect of credit access on adoption of a new practice was not significant, whereas it was significant in other research (Caviglia-Harris 2003; Abebe *et al*. 2013), where access to credit had a positive impact on the herder adoption of sustainable agricultural practices.

### *Empirical analysis*

In this study, herder respondents were asked whether they chose WL or not. The aim is to investigate which factors influenced the herder's decision process. As in most empirical studies, the observed yes/no decision to use some technology had been viewed as the outcome of a binary choice model. Hence, a binary regression model was used to determine the decisive factors influencing herder adoption of WL. The model can be given as:

$$P_i(y_i = 1) = \frac{e^{xi\beta}}{1 + e^{xi\beta}}$$

where $P_i$ represents the probability that WL will be adopted by the $i$th herder. $y_i$ is the dependent variable, and its value is 1 if the $i$th herder adopted WL, or 0 if no adoption occurred. $x_i$ is a matrix of explanatory variables, which is related with the adoption of WL by the $i$th herder, and β denotes the vector of parameters to be estimated.

The marginal effect of each explanatory variable was also estimated, which is defined as the effect of a unit change in $x_i$ on the probability that a herder adopts WL when all other factors are held constant. It can be expressed as:

$$\left.\frac{\Delta p_i}{\Delta x_i}\right|_{\text{all other} \times \text{constant}} = \frac{\partial p_i}{\partial x_i}$$

## Results

### *Statistical description of the variables for WL adopters and non-adopters*

Table 3 provided the descriptive statistics of the variables for adopters ($n = 18$) and non-adopters ($n = 39$) of WL. Herders with different ethnic backgrounds had significantly different choices for lambing time ($\chi^2 = 5.93$, $P$-value = 0.15). Only 50% of interviewed WL adopters are Mongolian compared with 84.6% of non-adopters. The distance to local nearest market also had significant differences between WL adopters and non-adopters ($P < 0.05$). For the WL adopters, their houses were located closer to the local markets (Mean distance was 35.7 km) than the non-adopters (Mean distance was 61 km). Herder neighbours' choices were also significantly different for the WL adopters and non-adopters ($P < 0.05$). The neighbours of WL adopters had higher probability to choose WL (77.8%) compared with 28.2% of non-adopters.

Although there were no significant differences, older male herders, households with more labour, less pasture, less livestock, and more access to credit were more likely to choose WL.

**Table 3. Descriptive statistics of explanatory variables for adopters and non-adopters of WL**

| Variables | Adopters | | Non-adopters | |
|---|---|---|---|---|
| | Mean | s.d. | Mean | s.d. |
| Household number | $n = 18$ | – | $n = 39$ | – |
| *Herder characteristics* | | | | |
| Gender (%) | 88.3 | 0.383 | 71.8 | 0.456 |
| Age | 46.5 | 2.150 | 48 | 1.684 |
| Education | 1.7 | 0.752 | 1.5 | 0.556 |
| Ethnicity (%) | 50.0 | 0.514 | 84.6 | 0.366 |
| Household labour | 2.4 | 0.143 | 2.3 | 0.157 |
| *Household assets/resources* | | | | |
| Farm size | 653.7 | 109.674 | 785.8 | 67.333 |
| Herd size | 259.9 | 22.927 | 310.9 | 23.282 |
| Shed area | 94.4 | 48.655 | 118.65 | 82.873 |
| *Social factors* | | | | |
| Distance to market | 35.7 | 4.643 | 61.0 | 5.566 |
| Neighbours' decisions (%) | 77.8 | 0.428 | 28.2 | 0.456 |
| Access to credit (%) | 55.6 | 0.511 | 51.3 | 0.506 |

### *Logit regression results regarding herder adoption of WL*

A binary logit regression was performed with herders' actual lambing choice as a variable dependent variable, which value is 1 if the herder adopted WL, or 0 if no adoption occurred. The estimated coefficients of the parameters and the marginal effects in the model are summarised in Table 4.

The herders' ethnic background had a significant and negative relationship with the adoption of WL ($P < 0.1$). The Mongolian herders tended to keep SL, whereas the Han herders were more in favour of WL. Distance to market also had a negative impact on herders' adoption of WL at the 5% significant level but had a low marginal effect. The households closer to markets favoured the adoption of WL, whereas those households located farther away from the market were more inclined to keep the SL. The neighbours' choices were significantly and positively related to the herder choices regarding the adoption of WL ($P < 0.05$). When neighbours chose to adopt the WL, the neighbouring herders would exhibit a greater inclination to choose to adopt WL. When neighbours used SL, their neighbours would also be inclined to keep using SL.

### *Herders' opinions of adopting and non-adopting WL*

Interviewers obtained herders' opinions of adopting WL. The most frequent reason that herders adopted WL was to get more economic income. One herder explained his motivation of adopting WL in detail:

> '*By lambing in winter*, *I can sell the livestock earlier and earn more money*; *Even if I choose to lamb in spring months*, *there is still no fresh grass or hay for livestock* (*called qing huang bu jie in Chinese language*). *If a natural disaster comes*, *we will lose much more and have little livestock left.*'

**Table 4. Binary logit estimates of WL adoption**
*$P < 0.1$; **$P < 0.05$

| Variables | Coefficient estimates | | Marginal effects | |
|---|---|---|---|---|
| | Coeff. | s.e. | Coeff. | s.e. |
| *Herder characteristics* | | | | |
| Gender | 1.3375 | 1.0698 | 0.1551 | 0.1041 |
| Age | 0.0320 | 0.0533 | 0.0046 | 0.0076 |
| Education | 0.8007 | 0.7671 | 0.1151 | 0.1060 |
| Ethnicity | –2.0789* | 1.1790 | –0.3850 | 0.2441 |
| Household labour | 0.7953 | 0.5214 | 0.1144 | 0.0697 |
| *Household assets/resources* | | | | |
| Grassland area | 0.0009 | 0.0014 | 0.0001 | 0.0002 |
| Herd size | –0.0013 | 0.0043 | –0.0002 | 0.0006 |
| Shed area | –0.0068 | 0.0079 | –0.0010 | 0.0011 |
| *Social factors* | | | | |
| Distance to market | –0.0402** | 0.0179 | –0.0058** | 0.0023 |
| Neighbours' decisions | 1.9796** | 0.9409 | 0.3091** | 0.1523 |
| Access to credit | 0.8768 | 1.0002 | 0.1247 | 0.1418 |
| Constant | –4.3766 | 3.7294 | – | – |
| LR $Chi^2$ (11) | 28.3400 | – | – | – |
| Prob > $Chi^2$ | 0.0029 | – | – | – |
| Log-likelihood | –21.3798 | – | – | – |
| Pseudo $R^2$ | 0.3986 | – | – | – |

Several herders also pointed out that when they lambed in winter months, those livestock could be sold earlier, so the ewes had more time to rest and improve their physical conditions quickly, and selling livestock earlier also reduced the grazing pressures on grasslands. Notably, among the interviewed WL adopters, seven mentioned that more labour was needed for WL; five herders said that there was still a lack of access to technology.

We also asked SL herders why they did not adopt the WL system. The reasons and their frequencies were presented in Table 5. The lack of labour, poor availability of fodder and being not economically efficient were the top reasons that herders refuse to adopt WL. Several herders also said that lack of technology and warm sheds obstructed their use of WL. Two herders also mentioned that grassland condition was another factor. If their grassland areas were large enough for their livestock, or the grasslands grew well because of good rainfall, they would continue to lamb in spring months instead of winter. Notably, six herders who lambed in spring also told the advantages of WL, such as benefiting more from selling livestock earlier, and being good for grasslands and ewes.

## Discussion

The results showed that 31% of the interviewed herders chose WL. According to our survey data, the net livestock income per sheep unit of WL adopters (mean income 397.2 yuan) was higher than non-adopters (mean income was 392.9 yuan) though not at the significant level. These WL adopters also stated its advantages and admitted that they were benefiting from adopting WL. Some researchers have proven the efficacy of WL in increasing household income and grassland protection (Reynolds 2001; Yang *et al*. 2011; Cong *et al*. 2014; Yang *et al*. 2014). Herders who chose SL pointed out the disadvantages of WL and the problems faced if they adopted WL. Some researchers have agreed that herders would not adopt some technologies unless they understand the necessity of protecting natural resources and think that these technologies could solve problems of ecosystems the herders perceive themselves (Sidibé 2005; Tenge *et al*. 2007; Subedi *et al*. 2009). Most herders in the study area admitted that their grassland was degraded, and expressed their interests in grassland protection and believed it was a concern for every herder. However, most of them had negative attitudes towards WL. Herders doubted that they could alleviate the problem of grassland degradation, and thought that they would increase their economic and labour costs. Our survey data did show that mean forage cost per sheep unit of WL herders was 134 yuan whereas for SL herders it was 110 yuan but not at a significant level. Herders with such negative attitudes were more likely to refuse WL (Sulemana and James 2014; Marques *et al*. 2015; Hammes *et al*. 2016). Some researchers have shown that herder attitude played an important role in helping or hindering individual adoption of new technologies (Subedi *et al*. 2009; Kerschner and Ehlers 2016).

Herders not only need to know WL, but also have to understand how to implement WL correctly and when to apply the necessary procedures if they are to adopt WL (Wildemeersch *et al*. 2015). Several herders who used SL stated the benefits of WL, but they were not willing to adopt WL. Their knowledge about WL was poor as they were not familiar with the detailed information, such as which winter months were suitable for lambing, how much forage to buy, when and how much to feed livestock, and the requirements for warm sheds (the area and the quality). Our survey showed that SL herders and some WL herders state that technology was a constraint of their adoption. Few herders have access to any extension service or technology training (Wu *et al*. 2011; Hua and Squires 2015). This suggests that more extension service and activities should be provided to educate SL herders of the benefits of WL, infrastructure requirements and the management strategies herders would require to adopt WL. A close connection needs to occur between extension agents and herders to allow the herders to understand the changes that they will need to adopt for WL to be a success. Field days and on-farm demonstrations of WL are essential for WL to be adopted more fully. Extension agents need to have a good understanding of adult education principles and how these can be used to in their extension methodology to ensure adoption of WL. The extension deliverers need to have a sound knowledge of WL and a detailed knowledge of sheep nutrition to allow them to advise herders on forage choice and the quantities to feed to their animals. Local and regional governments should be approached about funding infrastructure for WL to protect rangelands. More forage storages/barns should be also built by governments around the Sumus or

**Table 5. The reasons given by herders why they did not adopt WL**

| Reasons for non-adopting WL | Number of herders | Quotes |
|---|---|---|
| Labour constraints | 14 of 39 | WL costs more labour; it takes more time to take care of new-born lambs, and the households do not have enough labour |
| More fodder | 9 of 39 | I need to buy more fodders for little lambs, and they cost more money |
| Economic considerations | 9 of 39 | Forage and fodder are too expensive, and sometimes I earn less than lambing in spring. It is not economically efficient |
| Lack of technology | 3 of 39 | I have no access to WL technology, and do not know how to feed the new-born lambs, e.g. which fodders I need, when and how much to feed them |
| Lack of warm shed | 3 of 39 | Lambing in winter months requires the availability of warm sheds. I do not have enough large warm sheds and the present sheds do not qualify |
| Grassland condition | 2 of 39 | It depends on the grasslands condition. If there is rain and the grass grows well, I would not choose WL |
| Vague response | 3 of 39 | I am not certain about the reasons |

Gachas to ensure that herders have access to high quality forage at a reasonable price instead of poor quality fodder at high prices, especially in urgent situations (e.g. in early spring or when encountering long-term snow), this would reduce the forage cost substantially. Herders should be encouraged to make early decisions on selling livestock with companies, which will reduce the economic cost, but also herder labourers would be able to seek jobs in non-agricultural industries, which would increase household incomes.

After the initial training has been conducted it may be possible to establish phone and Internet services which could be utilised, to enable herders access to new livestock management practices.

Five socioeconomic attributes, including gender, age, education, household labour and ethnicity were used in the logit model. Gender and age showed insignificant impacts on the adoption. Education had a positive relationship with herder adoption as expected but not at a significant level. Household labour had a positive but not significant impact, but with an almost significantly marginal effect ($P$-value = 0.101). It implied that for a unit of increase of household labour, there would be 0.11 times increase of the probability of adoption. It suggests that the cooperation among households be encouraged, which could reduce the labour cost and ensure that households had access to labour when needed. It will resolve the labour problem to some extent.

Ethnicity had a negative and significant relationship with the adoption of WL ($P < 0.1$). Herder households of Han background were more likely to adopt the WL whereas the Mongolian households were more inclined to keep the SL. This is consistent with the findings of some researchers (Godoy *et al*. 1998; Floyd *et al*. 2003; Tey *et al*. 2014), which indicated that herder ethnic background played a significant role in the adoption of agriculture technologies. Similarly with the findings of Sulemana and James (2014), the result showed Han herders acted more orientated towards product, markets and profits. This is probably because their ancestors emigrated from source-scarce agriculture lands, whereas Mongolian herders behaved more like conservationists, because they have lived in grassland regions for generations and had higher awareness of grassland protection (Yin 2013; Hou *et al*. 2014).

Distance to market was significantly negatively related with the adoption ($P < 0.05$), indicating that herders closer to the market were more likely to adopt WL. Selling livestock earlier and buying more forage were needed when herders adopted WL, which are sold through market channels although livestock markets have been not developed well in Chinese pastoral regions (Wu *et al*. 2011). Many itinerant traders (called 'er dao fan zi' in herders' eyes) came to herders' doors, and bought livestock from them and sold forage to them. These itinerant traders play an important role in connecting herders with markets, including the dissemination of market information, especially for herders who lived farther away from markets. At present, most adult herders have smart phones, which allow them easy access to the internet. Therefore, it suggests that market information on sale prices from the livestock markets could be published online to enable herders to obtain independent market prices as Australian livestock producers have with the NMRS, where prices for animals from different markets and states are published. Categories include location, livestock type, weight, fatness and age (www.mla.com.au/prices-markets/market-reports-prices/,accessed29November2017).

Livestock were mainly sold in September or even October, when many itinerant buyers came to herders' doors. Herders could compare the prices offered and sold their livestock to those who offered the highest price. Lambs born in winter usually needed to be sold in June or July when itinerant buyers are in short supply. Herders who were closer to markets could easily go to town and collect the market information. Hence they did not rely as much on itinerant buyers, and could choose to bring their livestock to market themselves when they thought that the prices were appropriate. In contrast, the herders farther away from the market, had poorer access to market information, especially in June or July when livestock prices were still volatile as most livestock were not ready for the market and there were fewer itinerant buyers. This leads to almost no competition among traders. Itinerant traders often became the dominant decision makers of livestock market prices to a large extent (Kemp *et al*. 2011; Zhang *et al*. 2012). The prices itinerant traders offered were usually low (Reynolds 1986). However, herders had little choices but to accept these prices, which negatively influenced their incomes.

Second, forage markets had a similar trend. Herders closer to market could go to market and buy forage and fodder by themselves or buy them from itinerant traders if the prices were appropriate. Herders located farther away from markets had few choices and could only buy forage at higher prices offered by itinerant traders. These factors resulted in lower incomes and higher costs to the herders, especially those farther away from markets. Wu and Pretty (2004) found that poorer access to market information had hindered herders' adoption of new management practices. Our results suggest that infrastructure (roads and telecommunications) be improved to assist this market information. Herders will then have easier access to market information, be more market-orientated and increase their likelihood of adopting new WL.

Herder neighbours' decisions had a positive and significant relationship with herders' choices of lambing time ($P < 0.05$). It implied that herders would adjust their lambing practices when the profit from WL was significantly greater than when using their present method. This result is similar to the findings of many researchers (Conley and Udry 2010; Wydick *et al*. 2011; Wollni and Andersson 2014; Adjognon and Liverpool-Tasie 2015), which showed the significantly positive relationship between neighbourhood effects and the adoption of agricultural technologies. Therefore, it is critically important from a policy perspective as it provides a new way of thinking for how to implement new technologies effectively. Only a limited number of demonstration stations/households were established in the study area by the support of government or scientific projects. Herders would be at risk of rejecting this new technology if the projects were terminated. It suggests that a long-term extension service be provided for demonstration stations, especially to herder households to ensure that these demonstrations have the opportunity to showcase the superiority of WL over SL in terms of profits, grassland protection and inspires other herders to adopt WL.

A significant relationship was not found between access to credit and the adoption of WL. This is consistent with the finding of Jara-Rojas *et al*. (2012). In contrast, a researcher found that access to credit had a positive and significant relationship with herder adoption of agricultural technologies (Caviglia-Harris 2003). In our study, this may be because many herders were not willing to admit their informal loans from other individuals even if asked about them. This directly led to incomplete information about access to credit. Further research will be needed to explore the effect of informal credit on herder adoption.

As for household assets/resources variables, grassland area was positively but not significantly associated with herder adoption of WL. It was similar to the result of Zhang *et al*. (2012), which indicated that a larger area of grassland was related with a higher probability of the adoption of WL. Shed area had a negative but not significant relationship with the adoption of WL. This result was contrary to the view that shed area positively affected the adoption of WL (Yin 2013). This may be attributed to the fact that the present sheds of herder households in the survey area were too small to have a meaningful impact on the adoption of WL. Herd size also had a negative but not significant impact on the adoption of WL and implied that herders with small herd size were more likely to adopt WL. Small herd size means that there are only small numbers of livestock to sell and lowers the herder income (Zhao and Ba 2009; Chen 2010), which was the one herders pursued. They hoped that they could benefit more from adopting WL.

Winter lambing is not suitable for all herders in the pastoral regions of China. Previous research has shown that no herders and less than 1% of herders adopted WL in meadow steppe and typical steppe regions, respectively (Yin 2013). Herder adoption of any livestock management practice was affected by their skills, assets, livelihoods strategies and local ecological conditions (Grabowski *et al*. 2016). For instance, herders from meadow steppe regions said that longer and colder winters with more snow made WL not suitable (Yin 2013). Some empirical studies had showed that changing lambing, such as to April in Siziwang (Li *et al*. 2015) and to July in Taibusi (Zheng *et al*. 2011), together with stall-feeding would improve grassland condition and increase herder net income (Michalk *et al*. 2011). Therefore, providing a basket of choices is much more likely to improve grassland condition and herder income for the long term, rather than only one or two solutions (Grabowski *et al*. 2016).

## Conclusion

The study investigated herders' opinions of WL and the factors which influenced their adoption. Herders who still used SL generally hold unfavourable opinions about WL. Most herders did not understand the details of implementation. Herders with Han background were more likely to adopt WL than the ones with Mongolian background. Herders who were located closer to market had a higher probability of adoption. Herders' decisions about adoption of WL were positively affected by their neighbours and are more inclined to make the same choices with their neighbours.

The results imply that herders were not stuck in present and traditional SL or unwilling to change. There were many uncertainties and they were evaluating the gains and losses of adopting this new technology. We recommend that more extension services be provided through more channels, such as extension agents, training, on-farm demonstrations, televisions, phones and Internet, which will ensure herders get more access to the detailed information of the new livestock management practices and get timely technical guidance when needed. It was clear that the adoption of WL can be promoted further if there are appropriate marketing channels. Hence the second policy recommendation relates to the infrastructure, including road and telecommunication, which should be more developed, to enable herders, who live farther away from markets to obtain more timely access to market information and be more market-oriented. The results also imply that there was neighbourhood effect in herders' decisions about adopting WL. Hence demonstration farms located nearby should be developed as they are more effective for herder adoption of WL. A neighbourhood effect also exists in herder decision behaviour with respect to other farm management practices and could be addressed in future research. WL is not applicable for all pastoral regions of China. It is necessary to provide a basket of choices to improve grassland condition and herder income for a long-term.

## Conflicts of interest

The authors declare no conflicts of interest.

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