Climate Change Adaptation Strategies for In-field Conservation Practices by Irrigated Farm

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Abstract. Irrigated farmer is less adaptable to conservation practice. Total precipitation has positive significant impact on adoption of terrace conservation practices both in Bivariate and Univariate Probit model. Farmer who buys insurance is found to be less likely to adopt the terrace conservation practice. The temperature from May to July is still favourable for corn growth which causes not significant impact on temperature to conservation practice adaptation.

1. Introduction

Climate change in combination with depletion of water resources will present agriculture production problem. It is said that climate change can increase erosion rates in which will decrease agriculture productivity by 10% to 20% [1]. Nowadays we may notice that there is a changing in temperature and rainfall precipitation across some region. The temperature is rising in some region result to higher evapotranspiration rate and lower water effectiveness rate for each crop and soil condition. Rainfall precipitation is getting lower in some region. Higher evapotranspiration rate and lower precipitation rate will force farmer with irrigated land to draw more water from groundwater supply to irrigate the crops and to keep the sufficient soil moisture level. However, groundwater resources have depleted over time due to increasing water consumption for industry, agricultural irrigation, public supply and other uses. The climate changing and groundwater depletion raise grave concern especially because irrigated systems agriculture will use more groundwater for irrigation that result in more severe groundwater depletion problem. Not sufficient precipitation will cause soil has less water and not sufficient moisture level. However, irrigated land has more capability than non-irrigated land in decreasing the adverse impact of low precipitation.

The conservation practice can be one of the solutions to adapt with the climate changing. Conservation practices have two primary benefits such as conservation of water, soil and soil organic matter and also a reduction of costly input [2]. One of the soil and water conservation practices is terrace. Applying terrace to subsequent crops will reduce erosion and keep soil moisture level stable. Terraces conservation practice can be combined with other practices such as buffer. Other conservation practices such as no-tillage and precision farming. However, the big question is whether the farmer willing to adapt the conservation practices or not.

There are many factors that will affect farmer decision on adoption of conservation practices. One of the primary factors is the benefit in the short term and long term profitability of the farm enterprise [3]. The economic characteristic of new technology will have an influence on technology adoption enrollment and the rate of adoption [4]. The new technology adopted will change the farming
profitability as the variance of profitability will increase \[3\]. Farmer will unlikely to adopt new technology as most farmers are risk averse person.

The social and economic characteristic of farm will affect farmer decision in adopting conservation practices. The livestock producers are less likely to invest in conservation practices than crop growers \[5\]. There is also evidence that older farmer and non-corporate farm are less likely to invest in conservation practices. The effect of social characteristic of farm operator has been mixed in some literature. Some research found that age has no significant impact on conservation practices \[6, 7\]. However, other concluded that it was negatively significant impact on conservation practices \[5, 8\].

Water conservation policy such as cost share program and incentive payment has little effectiveness and limitation in reducing irrigation water use. Higher crop prices will give an incentive to the farmer to use more water. Therefore, it will reduce the enrollment and effectiveness of water conservation practice adaptation. The cost share program is more efficient in an area with relatively thick saturated depths than thin saturated depths. However, rising energy prices and deeper surface of well cone will increase pumping cost and farmer will have more incentive to use water conservation practices. Increasing in energy prices would decrease water extraction by individual farmer \[9\].

The purpose of this paper is to determine the effect of farm attributes, farmer social characteristic, and weather to an adoption of conservation practices by irrigated farming in Western Kansas. This research also analyzes the enrollment of conservation practices for irrigated agriculture.

2. Model and Methods

The Univariate Probit model will be used to analyze the impact of farm attributes, farmer social characteristic, and weather to an adoption of conservation practices for irrigated farmer. We cannot use Bivariate Probit model for irrigated model because too small sample and no iteration convergence during the estimation of irrigated farmer.

In general the adoption decision model can be represented as: \(y_i = 1\) if practice is adopted, 0 otherwise. For single technology case, the factors that impact the adoption of technology can be analyzed using Univariate Probit. In this case the probability of adopting the technology conditional on the explanatory variable can be represented as:

\[
P(y = 1|x_1, x_2, \ldots, x_k) = F(XB)
\]

Where \(x_1, x_2, \ldots, x_k\) are explanatory variables and \(F(.)\) is the cumulative distribution function. We are using standard normal distribution for Univariate Probit model. The empirical models of Univariate Probit model on terrace conservation practices adoption and buffer conservation practices adoption for irrigated farmer are given below:

\[
F[Prob(terraces)] = F[P(Y = 1|x)]
= F[\beta_0 + \beta_1 Acres + \beta_2 CashSale + \beta_3 Insure + \beta_4 TotalPrecipitation + \beta_5 PrecipitationApril + \beta_6 PrecipitationMay + B_2 PrecipitationJune + B_3 PrecipitationJuly + B_4 MaxTempApril + B_5 MaxTempMay + B_{10} MaxTempMay + B_{11} MaxTempJune + B_{12} MaxTempJuly + B_{13} Livestock + B_{13} Married + B_{14} Age + B_{15} Tenure]
\]

\[
F[Prob(Buffer)] = F[P(Y = 1|x)]
= F[\beta_0 + \beta_1 Acres + \beta_2 TotalPrecipitation + \beta_3 PrecipitationApril + \beta_4 PrecipitationMay + B_5 PrecipitationJune + B_6 PrecipitationJuly + B_7 MaxTempApril + B_8 MaxTempMay + B_9 MaxTempJune + B_{10} MaxTempJuly + B_{11} Livestock + B_{12} Married + B_{13} Age + B_{14} Tenure]
\]

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The explanatory variable consists of capacity category and farm characteristic category. The categorization of explanatory variable was made using categorization made [10]. Capacity is the ability to maintain some function after it experience some type of change [11]. The capacity category consists of explanatory variable that related with farmer capacity to adopt the conservation practices. Farm characteristic category consists of explanatory variable that show an unique characteristic which may differ one farm to another and affect farm ability to adopt the conservation practices [11].

3. Result and Discussion

Different model specification was estimated for terrace conservation practice and buffer conservation practice. The dependent variables of those models are the adoption of terrace conservation practices and the adoption of buffer conservation practices. We are not using cash sale and insurance in buffer conservation practices model as the variable was omitted by STATA.13.

| Conservation Practice | Correctly predicted | Positive Predictive Value | Negative Predictive Value | Log likelihood |
|-----------------------|---------------------|---------------------------|---------------------------|----------------|
| Terrace               | 82.02%              | 63.16%                    | 84.28%                    | -72.388        |
| Buffer                | 97.75%              | 75.00%                    | 98.28%                    | -10.024        |

The correctly predicted is measuring the frequency of the model to correctly predicted the adoption and non-adoption decision. Terrace conservation practice model able to correctly predicted 82.02% of the adoption decision comprising 63.16 correctly predicted positive adoption decision and 84.28% correctly predicted non-adoption decision. Buffer conservation practice has better performance as the model correctly predicted 97.75% adoption decision. The buffer conservation practice model performs better than terrace conservation practice model based on “percentage correctly predicted”.

Most variable are found not significant in likelihood of terrace conservation practices adoption for irrigated farmer. As it is expected, insurance has negative significant impact on the likelihood of terrace conservation practices adoption. The negative impact of insurance is larger on irrigated farmer compare to non-irrigated farmer. Irrigated farmer has less incentive to adopt terrace conservation practices if they have insurance because the insurance company will pay the risk premium if unfavorable condition happened during the growth season. Irrigated farmer with insurance also concluded less likely to adopt terrace conservation practice compared to non-irrigated farmer with insurance. It is because even though favorable weather condition happens during the growth season, the irrigated farmer still could supply the water to corn crops using water from groundwater. However, non-irrigated farmer does not have any source of water rather than only the precipitation or rainfall. Irrigated farmer with insurance will less likely to adopt terrace conservation practice by 25.9%.

There is an expected positive significant impact of total rainfall likelihood of terrace conservation practice adoption. The positive impact of total rainfall is because irrigated farmer wants to avoid the agricultural runoff caused by erosion of rain. The terrace conservation practice can maintain the soil nutrient needed for corn growth. However, from data summary we know that there are only small proportions of irrigated farmers who adopt terrace conservation practices. This means that only few areas in Western Kansas who have high precipitation. The total precipitation for irrigated farmer is varying from minimum 261.19 inches to maximum 1101.01 inches. The likelihood of terrace conservation practice adoption will increase by 0.096% if total precipitation increase by 1 inch. There is unexpected positive significant impact of precipitation in April to likelihood of terraces adoption conservation practices. The positive impact of precipitation in April is because irrigated farmers want to avoid agricultural runoff caused by precipitation during seeding time. The likelihood of terrace conservation practice adoption will increase by 0.35% if precipitation in April increases by 1 inch. Temperature does not have a significant impact on the likelihood of terrace adoption conservation
practices. It is because the temperature from May to July is still favorable for corn growth so that the farmer does not need additional action to keep the soil temperature.

Table 2. Model estimation and marginal effect of terrace conservation practice model

| Variable      | Estimated Model | Marginal effect |
|---------------|-----------------|-----------------|
|               | Coef.           | SE              | Coef.           | SE              |
| acres_irrigated| 4.58E-05        | 5.45E-05        | 1.03E-05        | 1.22E-05        |
| cash_sale     | 0.026423        | 0.332501        | 0.005931        | 0.074652        |
| insure        | -1.15367*       | 0.60637         | -0.25895**      | 0.132959        |
| precip        | 0.004082*       | 0.002412        | 0.000916*       | 0.000527        |
| precipm4      | 0.015915*       | 0.008248        | 0.003572**      | 0.001803        |
| precipm5      | 0.0016          | 0.007387        | 0.000359        | 0.001659        |
| precipm6      | -0.00351        | 0.006623        | -0.00079        | 0.001482        |
| precipm7      | -0.00591        | 0.00683         | -0.00133        | 0.001524        |
| tmax24        | -0.04638        | 0.131858        | -0.01041        | 0.02953         |
| tmax25        | 0.007788        | 0.174727        | 0.001748        | 0.039221        |
| tmax26        | 0.081473        | 0.183072        | 0.018287        | 0.041007        |
| tmax27        | 0.099601        | 0.153862        | 0.022356        | 0.034419        |
| livestock     | -0.14952        | 0.255533        | -0.03356        | 0.057267        |
| Married       | -0.45924        | 0.346749        | -0.10308        | 0.076967        |
| Age           | 0.005363        | 0.011156        | 0.001204        | 0.002498        |
| Tenure        | -0.0164         | 0.010919        | -0.00368        | 0.002406        |
| _cons         | -8.84263        | 7.474203        | 1.03E-05        | 1.22E-05        |

Wald Chi2(16) 37.18

The acres area has negative significant impact on the likelihood of buffer conservation practices adoption. The buffer conservation practice is not efficient to a vast farm area. Irrigated farmer will less likely to adopt buffer conservation practices as the size of their land acreage getting larger. The likelihood of buffer conservation practice adoption will decrease by 0.019% if acreage area increases by 1 acre. There is unexpected positive significant impact of precipitation in April to likelihood of terraces adoption conservation practices. Irrigated farmers want to avoid agricultural runoff caused by precipitation during seeding time. However, from data summary we know that only small percentage of irrigated farmers who apply buffer conservation practice.

This fact implies that only farmer who has small and medium acreage with a particular topography will apply buffer conservation practice. Only small and medium farm will get the most benefit from buffer conservation practice. The likelihood of buffer conservation practice adoption will increase by 0.298% if precipitation in April increased by 1 inch. There is a positive significant impact of temperature in April to likelihood of buffer conservation practice adoption. Temperature in April is varying from minimum 27.7 Fahrenheit to 35.7 Fahrenheit. Irrigated farmer can gain several benefit from applying buffer conservation practices such as reduce water runoff energy and stabilize soil. The likelihood of farmer to adopt buffer conservation practice will increase by 4.18% if the maximum temperature in April increased by 1 Fahrenheit.
Table 3. Model estimation and marginal effect of buffer conservation practice model

| Variable     | Model estimation |         | Marginal effect |         |
|--------------|------------------|---------|-----------------|---------|
|              | Coef.            | SE      | Coef.           | SE      |
| acres_irrigated | -0.00609*       | 0.003766 | -0.00019*       | 0.000108 |
| precip       | 0.003901         | 0.008697 | 0.000123        | 0.000272 |
| precipm4     | 0.094153**       | 0.04367  | 0.002978**      | 0.001203 |
| precipm5     | -0.00402         | 0.026066 | -0.00013        | 0.000822 |
| precipm6     | -0.00856         | 0.018251 | -0.00027        | 0.000561 |
| precipm7     | 0.041101         | 0.032701 | 0.0013          | 0.00098  |
| tmax24       | 1.321961*        | 0.684578 | 0.04181**       | 0.019534 |
| tmax25       | -0.36029         | 0.689709 | -0.0114         | 0.021641 |
| tmax26       | -1.04736         | 0.991429 | -0.03313        | 0.030183 |
| tmax27       | 1.244653         | 1.14998  | 0.039365        | 0.035259 |
| livestock    | 0.903826         | 1.119312 | 0.028586        | 0.035109 |
| Married      | 0.337743         | 1.201493 | 0.010682        | 0.037983 |
| Age          | 0.015068         | 0.038401 | 0.000477        | 0.001208 |
| Tenure       | -0.02635         | 0.038526 | -0.00083        | 0.001203 |
| _cons        | -53.8217         | 39.08532 | -0.00019        | 0.000108 |

Wald Chi2(14) 32.43

4. Conclusion
Irrigated farmer is less adaptable to conservation practices. Total precipitation has positive significant impact on adoption of terrace conservation practices both in Bivariate and Univariate Probit model. Farmer who buys insurance is found to be less likely to adopt the terrace conservation practice. The temperature from May to July is still favorable for corn growth which causes not significant impact on temperature to conservation practice adaptation.

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