Does adoption of zero tillage save or intensify production costs? Evidence from Kyrgyzstan

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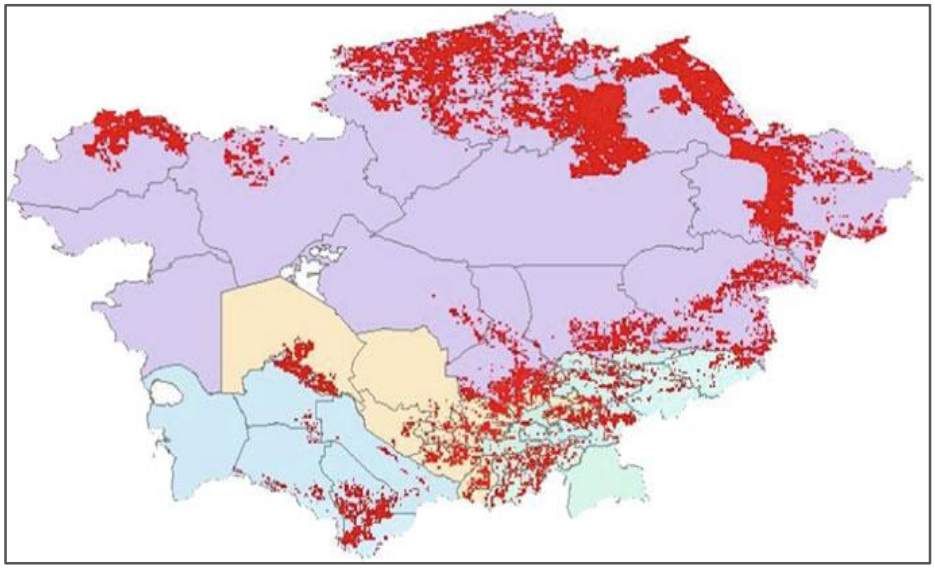
Land degradation in Central Asia



"Land degradation hotspots in Central Asia (in red)".
Source: Mirzabaev et al. (2016)

Expansive and intensive land use (1924-1990), lack of land management system (after 1991) deteriorated **land degradation** in Central Asia (Nurbekov et al. 2016)

Rural households have limited **physical, financial and human** resources (Wolfgramm et al. 2010)

Soil erosion is a much greater problem in the mountainous places of Kyrgyzstan (Pender and Mirzabaev 2008)

Introduction

Zero tillage as an option

Agronomic benefits

Economic benefits

Reduce **Nitrogen** and phosphorus runoff (Lankoski et al. 2006).

Reduces **soil erosion** from 100% to 57% (Schuller et al., 2007)

Accumulates **more carbon** in soil (Six et al., 2000; Chatterjee and Acharya, 2021)

Increases **soil organic carbon** by 38% (Modak et al., 2020)

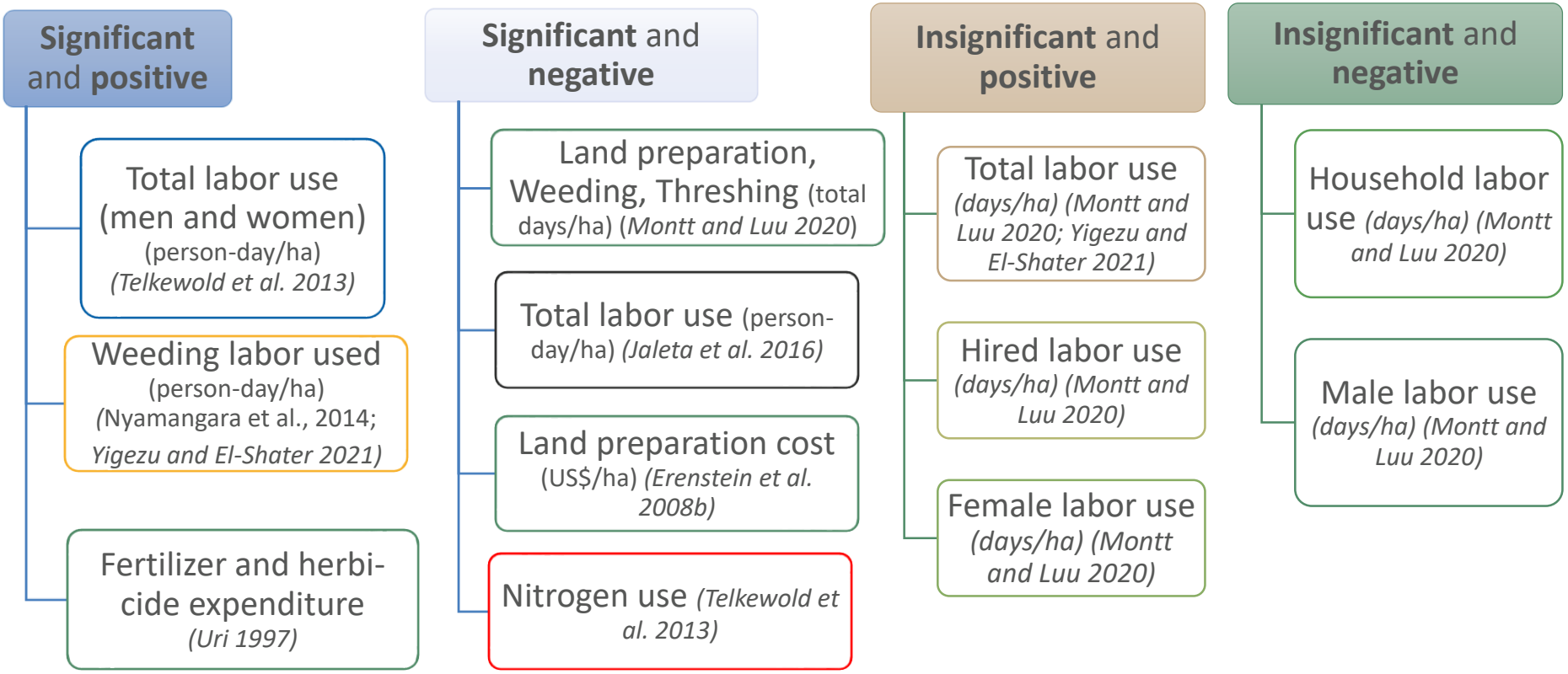
Reduces farmer's working time for **land preparation** (Montt and Luu, 2020)

Reduces **land preparation cost** (Erenstein et al. 2008b)

Maintains soil humidity and **decreases fuel, labor and machinery costs** (El-Shater et al. 2016, Ribera et al. 2004)

Improves **water savings** (Erenstein et al. 2008a).

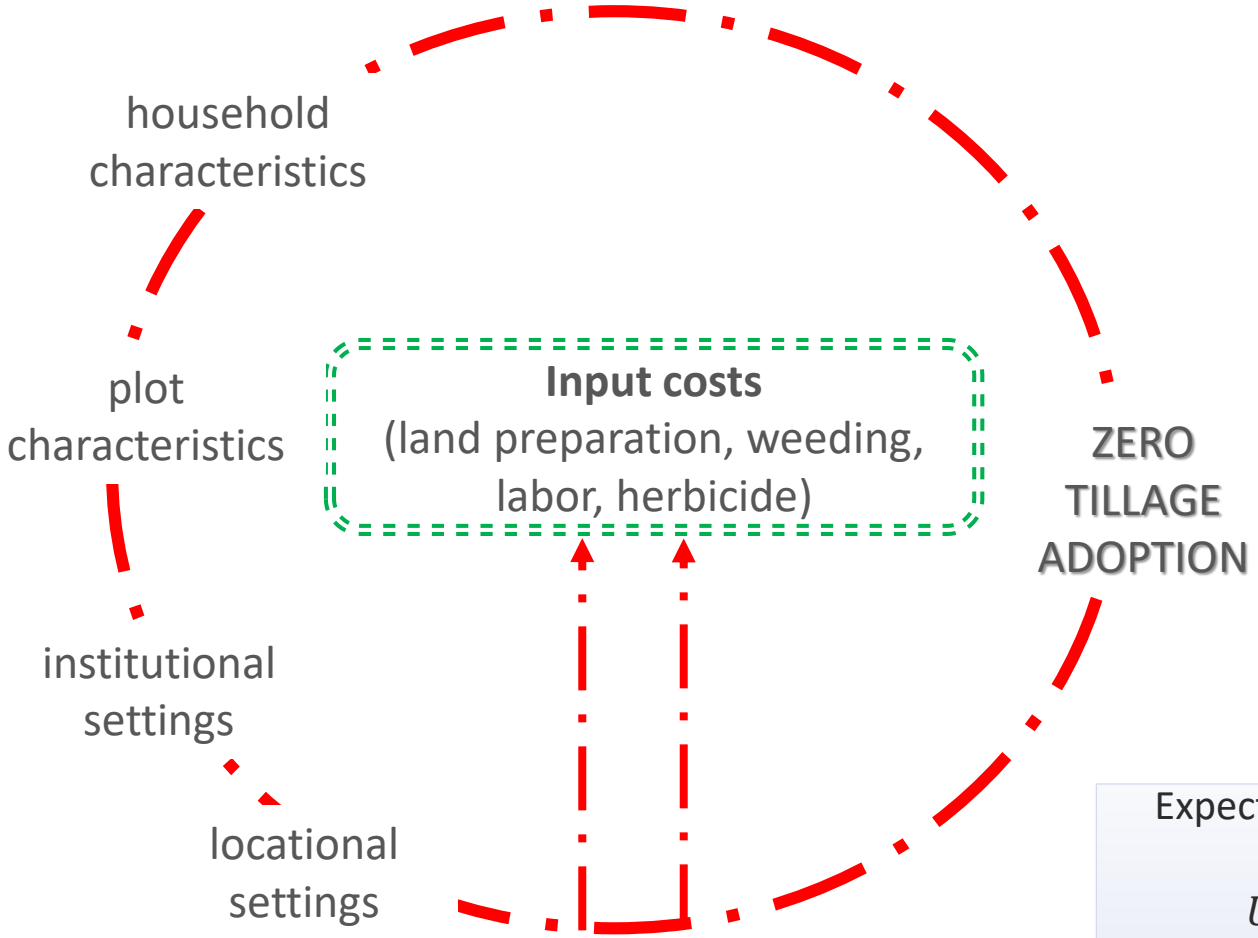
Empirics-based discussions: Zero (minimum) tillage adoption & input use



No agecon study on impact of ZT in Central Asia, e.g. based on “panel data” approach;

The **main goal** of the study is to answer a question “if ZT adoption saves or intensifies production costs in rural households”

Conceptual framework



Literature: Jaleta et al. (2016), Montt and Luu (2020).

Expected utility form adoption

$$U_a - U_{na} > 0$$

U_a - adoption

U_{na} - non-adoption

Data source

- Life in Kyrgyzstan (LiK) dataset, 2016 and 2019 waves, plot level data
- Rural households in 7 provinces and 2 cities

Number of plots	2016	2019
1	243	307
2	963	882
3	128	203
4	19	28
5	10	0
6	0	5
Total	**1363**	**1425**

Dropped from dataset:

- if HHs were surveyed only one year
- outliers (especially variables about “costs” of HH)
- plot size > 21 ha (strange difference comparing previous year)
- two cities (Bishkek and Osh)

Source: Life in Kyrgyzstan 2016 and 2019 HH survey data

Data source

Zero tillage adoption level

Field Code	"What types of tillage methods were used in this field?" *List up to TWO, starting with the most important method first, then the second most important (see codes below)* *98. Not applicable*	
	A304	A305
1 (1st field)	**2 or 7**	**4**
2 (2nd field)	**3**	**6**
..6		

Main Tillage (A304, A305)
1 = Hand tillage
2 = Zero tillage
3 = Ploughing with tractor
4 = Ploughing with horses
5 = Ridging (before planting)
6 = Mounding
7 = Did not till – broadcast seed
8 = Other tillage method

Zero tillage (ZT) plots = 1; non zero tillage (nZT) plots=0

Provinces	2016		2019	
	ZT plots	nZT plots	ZT plots	nZT plots
Issik-Kul	39	179	70	185
Jalal-Abad	11	279	45	241
Narin	15	84	12	56
Batkent	16	154	63	111
Osh	7	348	44	373
Talas	1	107	5	95
Chuy	4	119	51	74
Total	**93**	**1,270**	**290**	**1135**

Source: Life in Kyrgyzstan 2016 and 2019 HH survey data

Data source

Explanatory variables (selected)

stylized facts: 1-human capital (education) 2-financial capital (assets) 3-physical capital (farm size)	Pooled 2016 and 2019 (N=2788)		
	ZT (N=383)	nZT (N=2405)	mean differ
	Mean	Mean	
Age of HH (year)	56.342	55.941	0.401
Education level of HH (categorical, 1=illiterate…7=university)	4.350	4.262	0.088
Female HH (dummy, 1=female)	0.209	0.229	-0.02
Employment in agricultural sector (dummy, 1 = occupation as agriculture, fishing)	0.462	0.319	0.143***
Number of household members, (above 10 and under 65)	4.587	4.475	0.113
Ethnicity of the household (dummy, 1 = Kyrgyz)	0.815	0.771	0.044*
Remittance (during the last year did household receive money, dummy, yes=1)	0.180	0.188	-0.007
Number of assets (number)	10.402	10.610	-0.208
Tractor (number of owned tractors)	0.047	0.042	0.005
Amount of credit (US$)	579.826	227.735	352.091***
Distance to main road (km)	0.808	0.627	0.181***
Plot size (ha)	1.027	0.700	0.327***
Distance from dwelling to field (km)	1.565	1.280	0.285*

Source: Life in Kyrgyzstan 2016 and 2019 HH survey data

Data source

Outcome variables

	Pooled 2016 and 2019 (N=2788)		
	ZT plots (N=383)	nZT plots (N=2405)	mean differ
	Mean	Mean	
Total payment for hired labor on a plot (US$/ha) (How much did you pay for **hired labor** to work on this plot?)	7.994	8.514	-0.052
Machinery cost for land preparation and seeding on a plot (US$/ha) (How much did the HH spend on **machinery** for this crop during this season on this plot?)	25.674	37.242	-11.568***
Machinery cost for weeding (US$/ha) (How much did the HH spend on **machinery** for this crop during this season on this plot?)	10.830	8.294	2.536
Total herbicide cost on a plot (US$/ha) (How much did it cost to spray with **herbicides**?)	25.750	12.956	12.794***
Total machinery, labor and herbicide costs on a plot (US$/ha)	68.845	67.106	1.739

Source: Life in Kyrgyzstan 2016 and 2019 HH survey data

Estimation procedure

Endogeneity switching regression (ESR) model

- Logit model (1st stage)

$$Pr\ (zt_{itj}) = \frac{\exp(\alpha_i + \beta' x_{itj} + \delta' x_{it} + \gamma' \bar{x}_i + R_p + Y_t)}{1 + \exp(\alpha_i + \beta' x_{itj} + \delta' x_{it} + \gamma' \bar{x}_i + R_p + Y_t)}$$

where;

- $i's$ household; $j's$ plot; at t time
- $x_{itj} -$ observables at plot level
- $x_{it} -$ observables at household level
- $\bar{x}_i -$ mean of time $-$ varying variables
- $R_p -$ province dummy (Issyk $-$ Kol is reference province)
- $Y_t -$ time dummy (2016 is the reference year)

$$\lambda_{0itj} = \frac{\varphi(\delta Z_{itj})}{\Phi(\delta x_i)}$$

$$\lambda_{1itj} = \frac{-\varphi(\delta x_i)}{1 - \Phi(\delta x_i)}$$

- OLS model (2nd stage)

$$y_{1itj} = X_{itj1}\beta_1 + \bar{x}_{it1}\nu_1 + R_p + Y_t + \lambda_{1itj}\sigma_1 + Y_t * \lambda_{1itj}\tau_1 + \eta_{1itj}\ \text{, if}\ ZT = 1$$

$$y_{0itj} = X_{itj0}\beta_0 + \bar{x}_{it0}\nu_0 + R_p + Y_t + \lambda_{0itj}\sigma_0 + Y_t * \lambda_{0itj}\tau_0 + \eta_{0itj}\ \text{, if}\ ZT = 0$$

$ATT -$ average treatment effect

Distance to main road (km)

Sources: Khonje et al. (2018), Montt and Luu (2020)

Results

Determinants of zero tillage adoption decision (selected)

Logit model

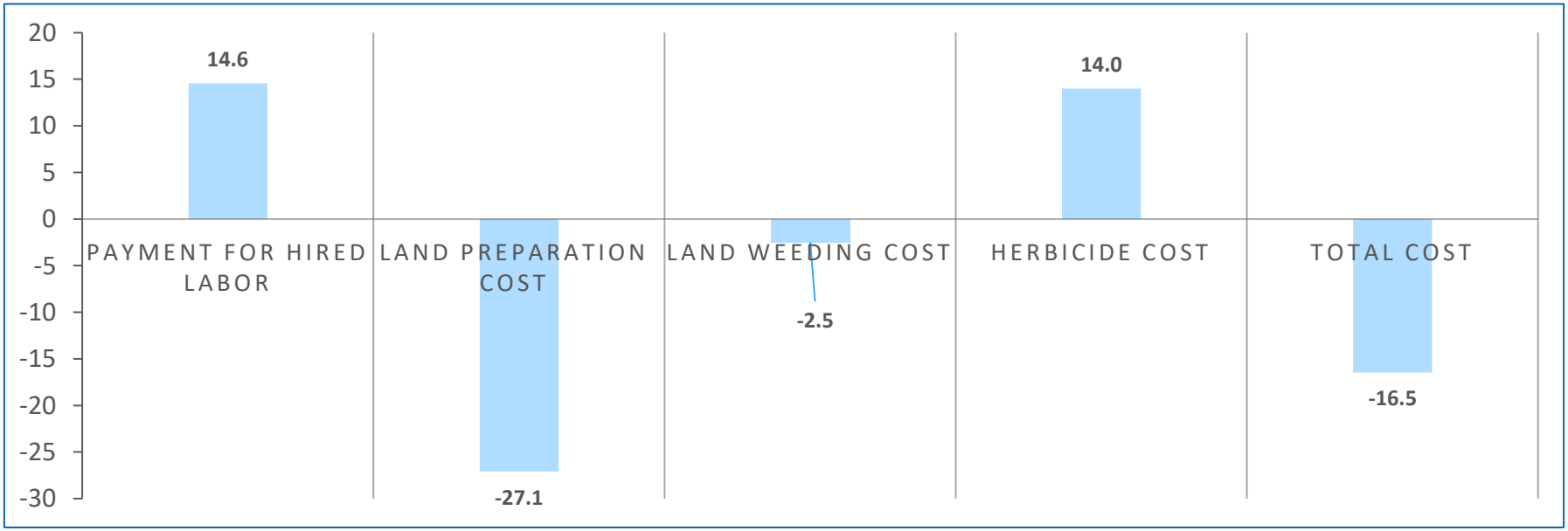
	Marginal effect	St.err
Employment in agricultural sector	0.052**	0.026
Number of owned assets	-0.010***	0.003
Distance to plot	0.006***	0.003
Number of plots of land owned by household	-0.019*	0.011
Using fertilizer on a plot (dummy, 1=used)	-0.047**	0.020
Jalal-Abad	-0.090****	0.021
Osh	-0.136***	0.024
Talas	-0.252***	0.047
Year	0.141***	0.015
Distance to main road	0.020***	0.006

*significant at 10% level, **significant at 5% level, ***significant at 1% level

- ZT adoption is positively related with:
  - ✓ employment in agriculture
  - ✓ distance to the field
  - ✓ distance to main road
- HHs from Jalal-Abad, Osh and Talas provinces are less likely to adopt ZT compared to HHs of Issyk-Kol provinces
- HHs using fertilizers on plots and with own assets are less likely to adopt ZT

Results

Outcome variable (USD $/ha) (ln)	ZT plots (actual)	nZT plots (counterfactual)	Average treatment effect
Payment for hired labor	1.240	1.556	-0.316***
Machinery cost for land preparation	0.380	0.244	0.136***
Machinery cost for land weeding	0.527	0.552	-0.025
Herbicide cost	0.898	0.767	0.131**
Total machinery, labor and herbicide costs	2.044	2.224	-0.180**



Note: Values calculated as 100*(exp(ATT)-1)) as in Asfaw et al. (2012)

Source: Calculation based on LiK 2016 and 2019 HH survey data

Conclusions

- A negative effect of “number of owned assets” on ZT adoption
  - Wealthy HHs use mechanized services (tractor) instead of applying ZT
- The probability of adoption increases with more number of plots and if plots are located further away from household dwellings
- ZT adoption decreases land preparation (27%) and weeding costs (3%) associated with machinery services, but increases hired labor costs (15%) and herbicide cost (14%)
  - ZT is an attractive option for reducing machinery costs and improving the employment of hired agri workers

Policy recommendations

- Policymakers should promote ZT adoption among rural households as a way to reduce machinery costs:
  - particularly among poor households and those with multiple plots and located at a distance from roads:
    - Promoting ZT adoption as a labor-saving or herbicide-reducing practice will create false expectations among smallholders

Thank you for your attention!

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Outcome determinants (selected)

	Labor payment (ln)		Land preparation cost (ln)		Land weeding cost (ln)		herbicide cost (ln)		Total cost (US$)	
	ZT plots	nZT plots	ZT plots	nZT plots	ZT plots	nZT plots	ZT plots	nZT plots	ZT plots	nZT plots
Education level of HH (categorical, 1=illiterate…7=university)	0.047	-0.061*	0.057	0.028	0.083*	-0.005	-0.019	0.018	0.015	-0.052
Employment in agricultural sector (dummy, 1 = Occupation as agriculture, fishing and private Households with employed persons)	1.079**	0.325*	0.395	0.066	0.092	0.221*	0.245	0.077	1.328**	0.255
Number of household members, (above 10 and under 65)	0.185	0.057	0.054	-0.006	-0.108	0.039	-0.329**	0.057*	-0.027	0.057
Ethnicity of the household (dummy, 1 = Kyrgyz)	0.604**	0.417***	-0.138	-0.216***	0.172	-0.066	-0.375	-0.148*	0.259	0.294***
Number of assets (number)	-0.053	0.041**	-0.025	-0.015	-0.022	0.032**	0.000	0.043***	-0.031	0.066***
Tractor owned (number of tractors that hh owned)	-0.325	0.223	-0.039	-0.160	-0.541	-0.070	1.168*	0.063	0.841	0.169
Plot size, (ha)	0.070**	0.023	0.065*	0.065***	0.030	0.078***	-0.047	-0.023	0.035	0.033
wheather shock (dummy, 1=yes)	0.730**	0.319**	-0.017	0.033	-0.095	-0.035	0.298	0.138	0.801*	0.362**
agricultural shock (dummy, 1=yes)	0.332	0.054	0.059	-0.168**	0.356	0.251***	-0.665*	-0.017	0.107	0.050
average distance form dwelling to field (km)	0.162***	0.145***	0.076**	0.084***	0.075*	0.067***	-0.012	0.022**	0.122***	0.155***
Using fertilizer (dummy, 1=used)	0.263	1.141***	0.377	0.409***	0.784**	0.413***	0.563	0.864***	1.007*	1.559***
Number of plots of land owned by household	-0.337*	0.174***	-0.028	-0.017	-0.101	0.136***	-0.123	-0.009	-0.406**	0.113
Total livestock units owned by households	-0.024	-0.020	-0.018	0.004	-0.062**	-0.010	0.071*	0.027**	-0.028	-0.006
Amount of credit (US$)	0.068	-0.004	0.020	0.018	0.022	-0.010	0.041	-0.040**	0.109	-0.021
Jalal-Abad	-2.110***	-0.354**	-0.274	-0.053	-0.467	-0.595***	-0.299	-1.268***	-2.030***	-0.998***
Narin	-1.393**	-0.141	-0.130	0.174	-0.5740*	-0.513***	-0.288	-0.991***	-1.229**	-0.573***
Batkent	-0.193	-0.820***	0.136	-0.027	0.154	-0.427***	0.364	-0.701***	0.335	-1.158***
Osh	-0.943	0.562***	0.515	-0.027	-0.068	-0.624***	1.066	-0.977***	-0.118	-0.077
Talas	-3.186*	0.395**	-0.196	0.754***	-1.113	0.012	-0.245	-0.802***	-2.891	-0.047
Chuy	-0.217	-0.310*	0.299	0.307***	-0.025	-0.260**	0.440	-0.866***	0.235	-0.745***
year_2	1.826*	-0.396***	0.115	-0.151**	0.822	0.149**	-0.187	0.358***	1.407	-0.062