The Economic Impact of Climate Variability on Agricultural Output and Income: Evidence from Armenia

Development Economics

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INTRODUCTION

MOTIVATION

Climate Change

Destabilizes Weather

- Increase in global temperatures
- Unpredictable rainfall
- More extreme events
- More droughts

Agricultural Production

- Production capacity suffers
- Problematic for future
- FAO estimates production must increase by 60% to 100% to meet future demand

Inequality

- Disproportional consequences to poor vs rich
- Increases poverty & inequality
- Small farmers suffer more as they depend on subsistence agriculture

MOTIVATION

Armenia

1. Landlocked developing country
2. Faces extreme climate events often, especially recently
3. Heavily dependent on agriculture (15% of GDP)
4. Rural Marz suffer more than urban ones (47% of Rural Employment in Agriculture Sector)
5. There was hope for a bit, but then more extreme climate events threw it all away

LINK TO THE COURSE

Carleton et al. (2022)	▪ Temperature fluctuations increase mortality more than previously thought ▪ High-income countries can adapt, while low-income countries suffer higher mortality rate and GDP loss
Donaldson et al. (2017)	▪ Rural regions in India suffer much more from rising temperatures than urban areas ▪ Mechanism due to higher structural dependence on agriculture (farmers)
Jayachandran (2006)	▪ Households close to subsistence level have high wage sensitivity to shocks ▪ Mechanism: Drought -> food insecurity -> labour supply more inelastic
Dell et al. (2012)	▪ Rising temperatures have economic consequences on agricultural and industrial output ▪ Effect not only short term but long term due to factors

LITERATURE REVIEW

Climate Literature

Dell & al.(2012) ; Aufhammer (2018) ; Zaveri et al. (2023)

- Macroeconomic impacts of climate and droughts in lower-income countries
  → Negative climate shocks due to droughts and heat reduce agricultural production, lowering economic growth and increasing poverty and political instability

FAO (2018)

- Crop losses in high-value crops worldwide
  → Droughts cause large yield losses in cereals, legumes, tubers, vegetables and fruits with especially high sensitivity at critical growth stages

FAO/UN (2021)

- Disasters in agri-food systems in low & lower-middle income countries
  → Around 34% of crop and livestock production losses are attributable to droughts, making it one of the most economically damaging hazards for agriculture

LITERATURE REVIEW

Armenian Context

Dell & Coppola & al. (2021) ; Galanaki & al. (2023); IPCC (2023)

- Regional climate change hotspots and observed warming
  → Armenia lies in a Mediterranean/Middle Eastern climate « hotspot » and has experienced strong warming since mid-20th century with warmest years recorded after 2018

Melkonyan (2019)

- Climate projections and crop yield impacts
  → Projects an additional 1.6°C warming by 2040, leading to soil-water deficits of +25-30% and expected crop yield declines of about 8-14% by 2030

World Bank (2024); UNDP (2010)

- Agricultural vulnerability and irrigation systems
  → Agriculture remains a key sector in a water-scare country, around 40% of agriculutral land is irrigated but limited eater resources and weak irrigation infrastructure make yields highly sensitive to rainfall deficits and system reliability

FAO (2000)

- Impact of the 2000 drought in Armenia
  → Up to 70% reinfall deficit in key regions, ≅ 300'000 people affected and at least 100 million USD in total damages, including ≅ 40 million USD agriculutral losses, potato output -40%, wheat -27% and nearly 100'000 rural residents requiring food assistance

RESEARCH STRATEGY

DATA

Variables & Units				
Armenian Dram	Percentages	Tons	Tons per hectare	Other
▪ Monthly household income ▪ Monthly household income from agriculture ▪ Monthly household food consumption	▪ Households in poverty (according to NHS) ▪ Households in urban areas ▪ Share of SPEI observations above +1 ▪ Agricultural stress, percent of arable areas with VHI value below 35	▪ Gross agricultural output ▪ Harvest of grains & leguminous plants ▪ Harvest of fruits & berries ▪ Harvest of potatoes	▪ Yield of grains & leguminous plants ▪ Yield of fruits & berries ▪ Yield of potatoes	▪ Standardised Precipitation Evapotranspirati on Index ▪ Vegetation Health Index ▪ Temperature

(1 Armenian Dram = 0.0021 CHF)

DATA

Summary Statistics

Variable	Mean	SD	Median	Min	Max
Household Income	174691.18	87785.61	151666.73	43655.19	429931.04
Household Agricultural Income	39837.36	30467.86	30956.55	0.00	161496.48
Gross Agricultural Output	75974.74	47233.25	69050.00	4900.00	225100.00
Household food Consumption	13102.63	6403.40	12615.93	1931.74	40376.19
Rate of households in poverty	0.24	0.09	0.24	0.02	0.43
Rate of households in urban areas	0.59	0.22	0.50	0.31	1.00
SPEI (Drought Index)	0.06	0.51	0.05	-1.03	1.31
Share of observations of SPEI above +1	0.19	0.16	0.15	0.00	0.64
Fruits Yield	6.53	4.19	5.08	0.41	18.16
Grains Yield	2.55	0.98	2.55	0.00	4.87
Potatoes Yield	20.12	7.40	19.02	4.44	39.69
Grains Harvest	35332.81	33626.56	26200.00	0.00	157500.00
Fruits Harvest	27519.59	31090.43	12150.00	1000.00	115100.00
Potatoes Harvest	48996.39	63787.63	28350.00	400.00	325700.00

EMPIRICAL METHODOLOGY

Use TWFE to exploit Panel Data structure

Fixed Effects control for time-fixed and national variables

Set outcome variable in Logs to linearize growth

β interpreted as a semi-elasticity

$$Y_{dt} = \alpha + \lambda_d + \gamma_t + \beta X_{dt} + \epsilon_{dt}$$

$$Y_{dt} = \alpha + \lambda_d + \gamma_t + \beta_1 X_{dt} + \beta_2 X_{d,t-1} + \epsilon_{dt}$$

$$Y_{dt} = \alpha + \underbrace{\lambda_d}_{\text{District FE}} + \underbrace{\gamma_t}_{\text{Year FE}} + \beta_1 X_{dt} + \beta_2 \underbrace{X_{d,t-1} + \beta_3 X_{d,t-2}}_{\text{Lags}} + \epsilon_{dt}$$

Y:

- Gross aggregate agricultural output
- Various individual crops harvest
- Various individual crops yield
- Household income

X:

- SPEI
- SPEI Share (above +1)
- Agricultural Stress
- Temperature (C°)

IDENTIFICATION STRATEGY

Meteorological Regressors

SPEI, SPEI Share, and Temperature

- Identification relies on randomness of weather patterns
- Conditional on FE, deviations of SPEI are determined by atmospheric factors and are independent of local economic decisions in short-run
- Allows us to have a causal interpretation of net yearlyy equilibrium effect
- We do not include controls

Vegetation Regressors

Agricultural Stress

- Flawed methodology
- Very likely endogenous
- VHI measures a biological response determined by weather inputs **and human action** (OVB)
- Recommend against interpretation
- Further research could use controls to avoid OVB

LIMITATIONS

Yearly Averages

- Data constraints force us to use district-year averages
- Ignores seasonal patterns
- Crops have "critical windows"
- Results in attenuation bias

Small sizes

- Small number of districts (11)
- Insufficient for cluster-robust SE
- Small country
- High spatial correlation in weather
- Hard to identify isolated district-level weather

Ex-Post Net Effect

- Univariate models
- Only capture net effect *after* farmer adaptation
- Can't separate biological damage vs adaptation effects

External Validity

- Armenia-specifics
- Semi-arid climate
- Mountains
- Lake Sevan (big)
- Particular crop portfolio
- Small

RESULTS

RESULTS

- Many more tables in appendix
- Today, focus mostly on agriculture output outcomes regressed on SPEI variables
- Aggregate agricultural output analysis doesn't wield any significant results
- Concentrate on crop-specific analysis
- Overall, find significant reductions for certain crops -> net effect of droughts is negative

Table 2: Regression results for Grains Harvest on SPEI

Dependent Variable:	(Log) Grains Harvest		
Model:	(1)	(2)	(3)
Variables			
SPEI	-0.4503***	-0.4573***	-0.4691***
	(0.1064)	(0.1065)	(0.1071)
SPEI (Lag 1)		-0.2992**	-0.3025**
		(0.1010)	(0.1207)
SPEI (Lag 2)			-0.2425*
			(0.1214)
Fixed-effects			
District (11)	Yes	Yes	Yes
Year (18)	Yes	Yes	Yes
Fit statistics			
Observations	191	191	191
R^2	0.94570	0.94719	0.94817
Within R^2	0.05653	0.08245	0.09939

Clustered (District) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

RESULTS

Table 3: Regression results for Grains Harvest on SPEI Share

Dependent Variable:	(Log) Grains Harvest		
Model:	(1)	(2)	(3)
Variables			
SPEI Share	-0.7772**	-0.9705***	-1.008***
	(0.2690)	(0.2807)	(0.2698)
SPEI Share (Lag 1)		-0.8358**	-1.012**
		(0.3403)	(0.3457)
SPEI Share (Lag 2)			-0.9098**
			(0.4027)
Fixed-effects			
District (11)	Yes	Yes	Yes
Year (18)	Yes	Yes	Yes
Fit statistics			
Observations	191	191	191
R^2	0.94375	0.94509	0.94660
Within R^2	0.02257	0.04590	0.07212

Clustered (District) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Table 4: Regression results for Grains Yield on SPEI Share

Dependent Variable:	(Log) Grains Yield		
Model:	(1)	(2)	(3)
Variables			
SPEI Share	-0.4843**	-0.4983**	-0.5060**
	(0.2120)	(0.2098)	(0.2134)
SPEI Share (Lag 1)		-0.0607	-0.0972
		(0.2006)	(0.1848)
SPEI Share (Lag 2)			-0.1884
			(0.2824)
Fixed-effects			
District (11)	Yes	Yes	Yes
Year (18)	Yes	Yes	Yes
Fit statistics			
Observations	191	191	191
R^2	0.78048	0.78055	0.78114
Within R^2	0.02055	0.02084	0.02348

Clustered (District) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

RESULTS

Table 5: Regression results for Potatoes Harvest on SPEI Share

Dependent Variable:	(Log) Potatoes Harvest		
Model:	(1)	(2)	(3)
Variables			
SPEI Share	-0.3500	-0.5348*	-0.5406*
	(0.2041)	(0.2540)	(0.2604)
SPEI Share (Lag 1)		-0.8109**	-0.8300**
		(0.3189)	(0.3329)
SPEI Share (Lag 2)			-0.0928
			(0.2677)
Fixed-effects			
District (11)	Yes	Yes	Yes
Year (18)	Yes	Yes	Yes
Fit statistics			
Observations	194	194	194
R^2	0.97369	0.97481	0.97482
Within R^2	0.00872	0.05073	0.05126

Clustered (District) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Table 6: Regression results for Fruits Yield on SPEI Share

Dependent Variable:	(Log) Fruits Yield		
Model:	(1)	(2)	(3)
Variables			
SPEI Share	0.5624	0.7888**	0.8309**
	(0.3438)	(0.2894)	(0.3019)
SPEI Share (Lag 1)		0.9934**	1.132**
		(0.3737)	(0.4357)
SPEI Share (Lag 2)			0.6764
			(0.4382)
Fixed-effects			
District (11)	Yes	Yes	Yes
Year (18)	Yes	Yes	Yes
Fit statistics			
Observations	194	194	194
R^2	0.79960	0.80578	0.80853
Within R^2	0.01088	0.04136	0.05493

Clustered (District) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

RESULTS

Table 7: Regression results for Household Agricultural Income on SPEI Share

Dependent Variable:	(Log) Household Agricultural Income		
Model:	(1)	(2)	(3)
Variables			
SPEI Share	-0.3389	-0.3282	-0.3893
	(0.4318)	(0.4687)	(0.4920)
SPEI Share (Lag 1)		0.0552	-0.1080
		(0.7967)	(0.8750)
SPEI Share (Lag 2)			-0.8570*
			(0.4538)
Fixed-effects			
District (11)	Yes	Yes	Yes
Year (18)	Yes	Yes	Yes
Fit statistics			
Observations	197	197	197
R^2	0.71444	0.71445	0.71667
Within R^2	0.00166	0.00170	0.00946

Clustered (District) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Table 8: Regression results for Household food consumption on SPEI Share

Dependent Variable:	(Log) Household food Consumption		
Model:	(1)	(2)	(3)
Variables			
SPEI Share	-0.0860	-0.1811	-0.1932
	(0.1944)	(0.2304)	(0.2334)
SPEI Share (Lag 1)		-0.4673	-0.5340*
		(0.2695)	(0.2667)
SPEI Share (Lag 2)			-0.3819
			(0.3588)
Fixed-effects			
District (11)	Yes	Yes	Yes
Year (20)	Yes	Yes	Yes
Fit statistics			
Observations	220	220	220
R^2	0.90574	0.90757	0.90875
Within R^2	0.00073	0.02016	0.03261

Clustered (District) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

CONCLUSION


GEORGIA
Tashir
Alaverdi
Noyemberyan
Stepanavan
Debed
Lori
Tavush
Berd
Gyumri
Vanadzor
Ijevan
Spitak
Shirak
Dilijan
Arpaçay Barajı
Artik
Aparan
Hrazdan
Chambarak
Maralik
Sevan
Hrazdan
AZERBAIJAN
Charentsavan
Talin
Aragatsotn
Kotayk
Gavar
Sevana lich
Yeghvard
Ashtarak
Akhurian
Abovyan
Vardenis
Echmiadzin
Aras
Armavir
YEREWAN
Metsamor
Martuni
Gegharkunik
Armavir
Masis
Ararat
Aras
Artashat
Vedi
Ararat
Jermuk
Vayots Dzor
Yeghegnadzor
TURKEY
Vayk
Sisian
Goris
Vorotan
AZERBAIJAN
(Nakhchivan)
Syunik
Kapan
Kajaran
Meghri
Aras
IRAN

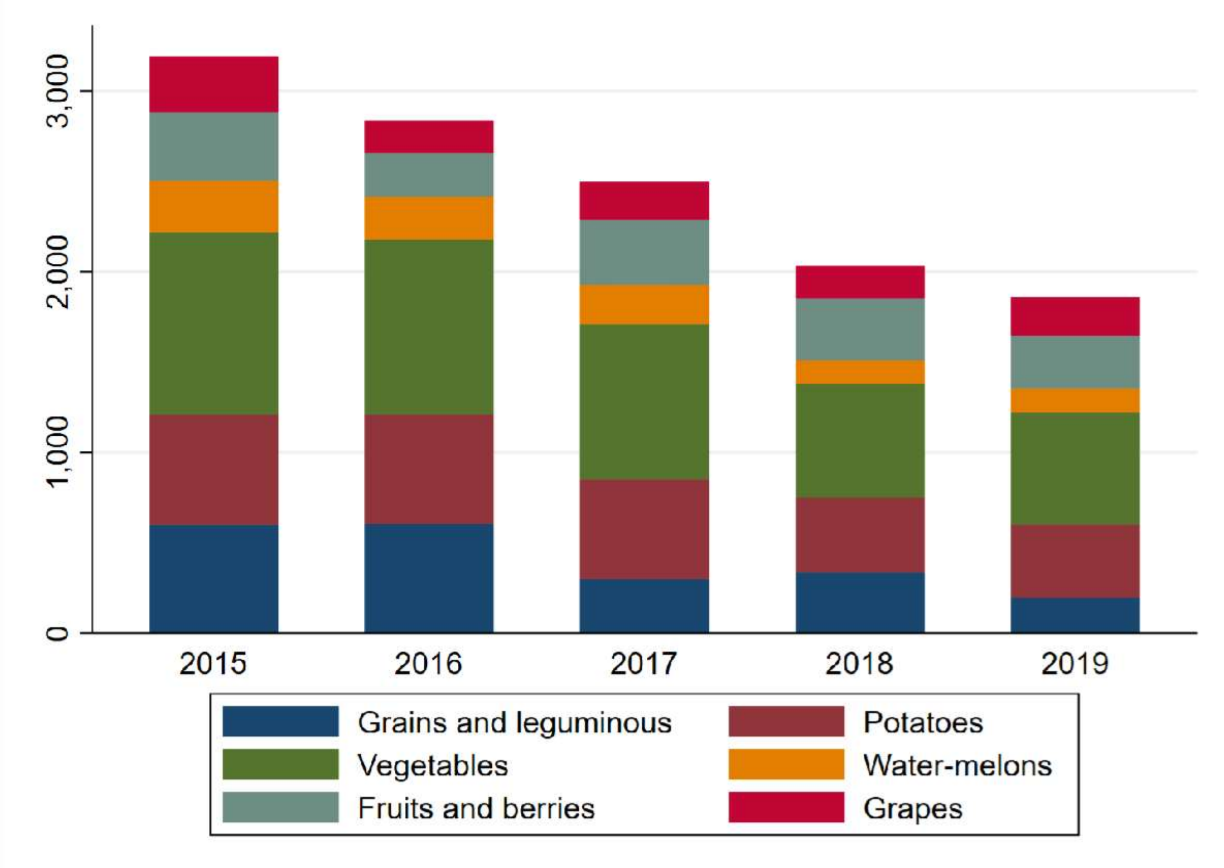

Figure 1: Agricultural production (1,000 tonnes)

Source: (NSS 2020c)

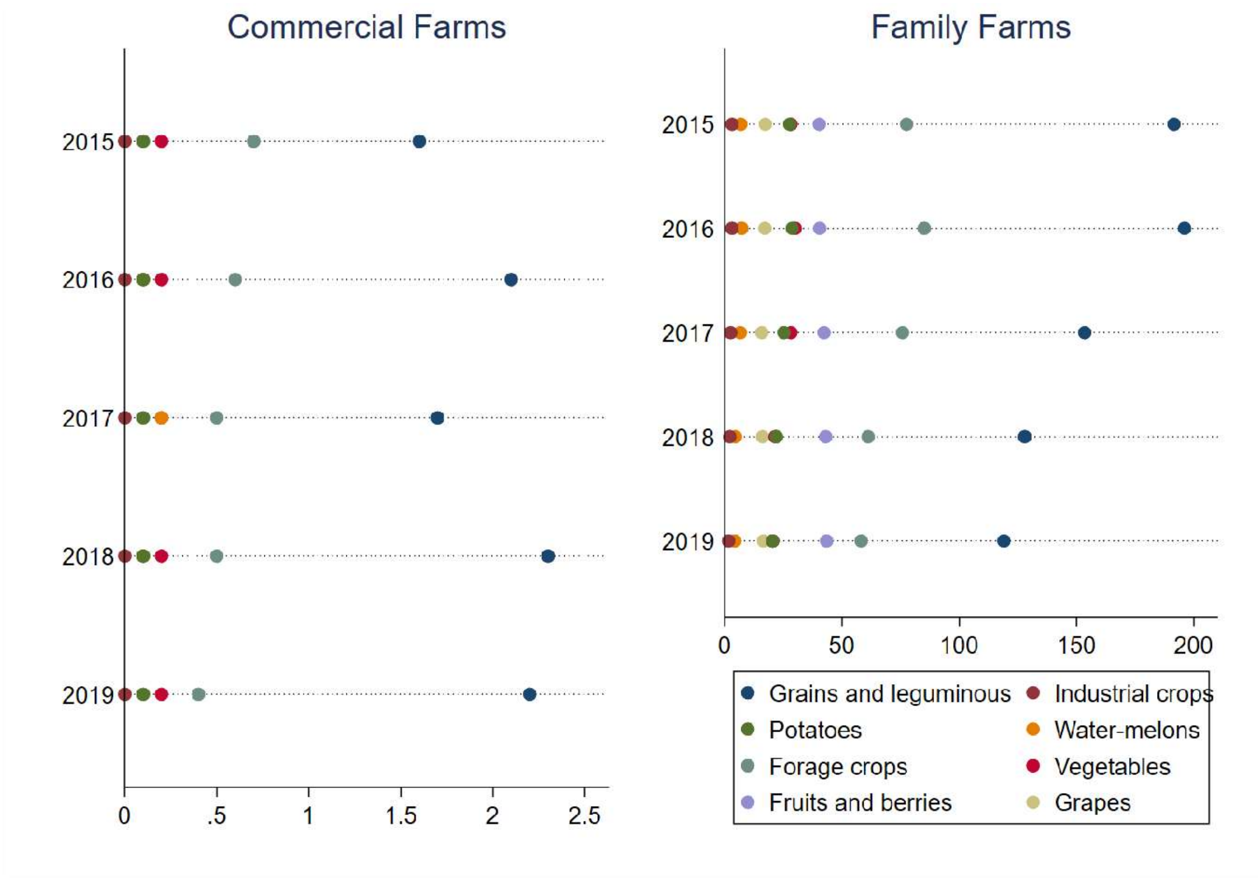

Figure 2: Sown areas by farm structure in 2019 (1,000 ha)

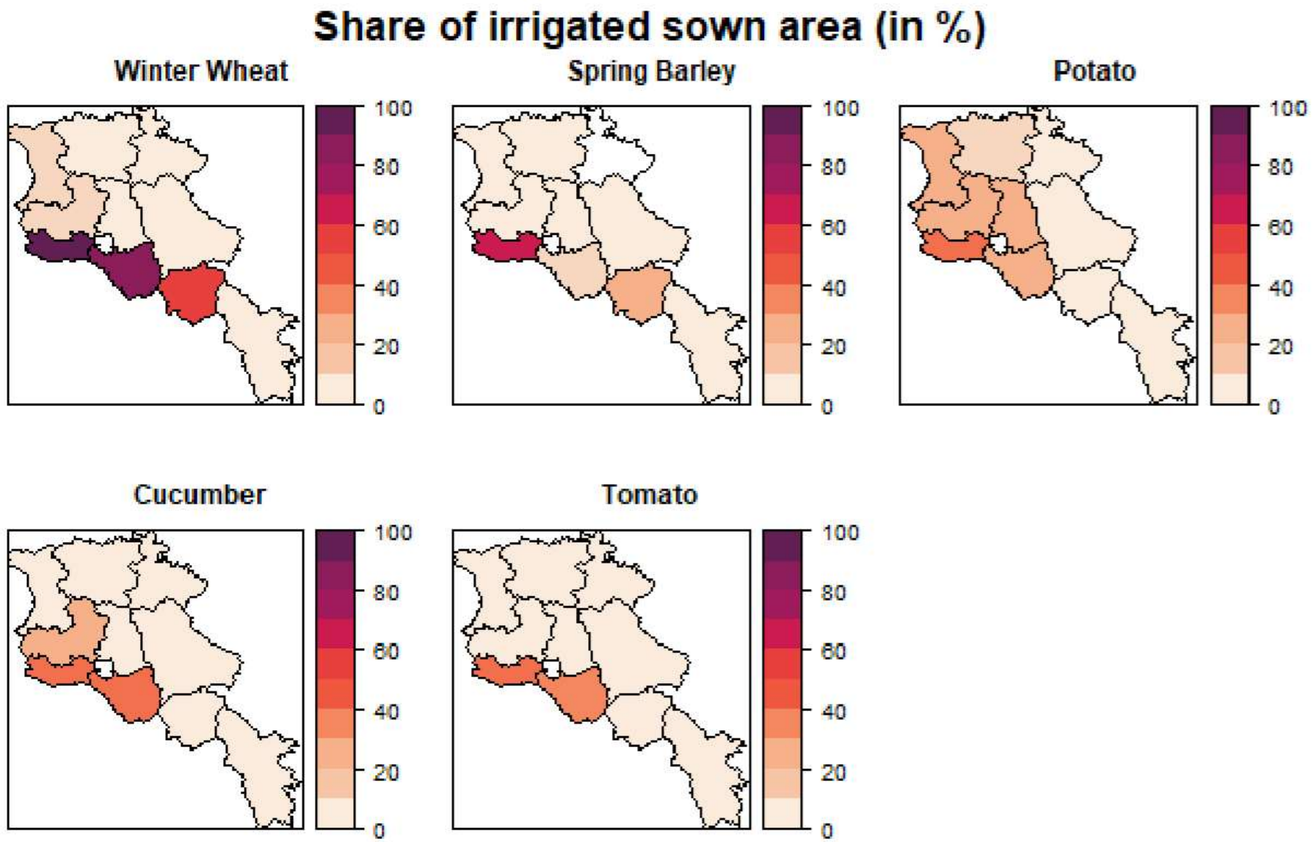

Figure 3: Share or irrigated sown area by crop in 2014, in %.