Climate changes and FOOD SECURITY *in ARMENIA Republic*

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Picture 1 – The location of the Armenia Republic

http://worldweather.wmo.int/en/country.html?countryCode=18

Existing body of knowledge

Main factors	Kind of Model	Relevance for author's research
Two regions, each having two sectors and two factors of production (capital and labour)	Trade Model	Interesting idea about using regions in model
All indicators of country economy development	IMPACT	Closer to my research objectives. But doesn't include direct impact of temperature and drought on self-sufficiency in food
With simplified representations of development, energy use, carbon cycle, and climate	FUND model	Cost approach, without food security. Useful in according with regional aspect.
Climate change, domestic tourism	Gravity Model	Adaptation to Author's Model, the most popular in CULS
Yields of crops, harvested lands, gross production	Matrix Model of competitiveness	Useful, but without food security and climate change

Step 1 – Theoretical Approach

new approach proved	The Higher Temperature, Water Shortage and reduced agricultural productivity, decline in food security among the rural poor	Construction of Author's Model (Matrix Model based on The method of multidimensional medium + Cluster Analyses + Multivariate analysis of variance)= New Model	Yes, classification and scenarios of food security threats for Armenian regions, identifying the problem zones for private-government investing

Step 2 - Calculation of indexes

$$SPEI = \frac{p_i^{(T)} - \mu}{\sigma}, \quad (1)$$

- SPEI – index of dryness/wetness conditions;
- p - dryness/wetness conditions, mm.

$$SYRS = \frac{y_i^{(T)} - \mu}{\sigma}, \quad (2)$$

- SYRS - index of crop yields;
- y – yield, hundredweight/he.

Table 2 - Classes of moisture categories according to the SPEI

SPEI	Moisture category
≥ 2,0	Extreme wet
1,5-1,99	Severe wet
1,49-1,00	Moderate wet
0,99 to -0,99	Normal
-1,0 to – 1,49	Moderate drought
-1,50 to -1,99	Severe drought
≤2,0	Extreme drought

Table 3 - The moisture categories according to the SPEI for the Armenia Republic during 1997-2013

Year	SPEI for Armenia Republic	Moisture category
1997	-0,04	Normal
1998	-2,59	Extreme drought
1999	-0,62	Normal
2000	-1,03	Normal
2001	-0,23	Normal
2002	0,03	Extreme drought
2003	1,18	Extreme drought
2004	-0,50	Normal
2005	0,35	Extreme drought
2006	-0,60	Extreme drought
2007	0,64	Extreme drought
2008	-0,46	Moderate drought
2009	1,23	Extreme drought
2010	0,35	Extreme drought
2011	1,77	Severe wet
2012	0,50	Extreme drought
2013	0,03	Extreme drought

Table 3 - Classes of yield categories according to the SYRS

SYRS	Moisture category
≥ 1,5	High yield increment
1,0-1,49	Moderate yield increment
0,51-0,99	Low yield increment
0,50 to -0,50	Normal
-0,51 to – 0,99	Low yield losses
-1,00 to -1,49	Moderate yield losses
≤1,50	High yield losses

Table 5 - The yield categories according to the SYRS of grain for the Armenia Republic during 1997-2013

Year	SYRS grain	Moisture category
1997	-1,30	Moderate yield losses
1998	-0,76	Low yield losses
1999	-0,61	Low yield losses
2000	-1,33	Moderate yield losses
2001	-0,40	Normal
2002	0,23	High yield losses
2003	-0,93	Extreme drought
2004	0,40	Normal
2005	-0,25	Low yield losses
2006	-1,41	Moderate yield losses
2007	0,99	Low yield increment
2008	0,64	Low yield increment
2009	0,36	High yield losses
2010	0,00	High yield losses
2011	1,37	Moderate yield increment
2012	1,10	Moderate yield increment
2013	1,92	High yield increment

Table 6 - The yield categories according to the SYRS of potatoes for the Armenia Republic during 1997-2013

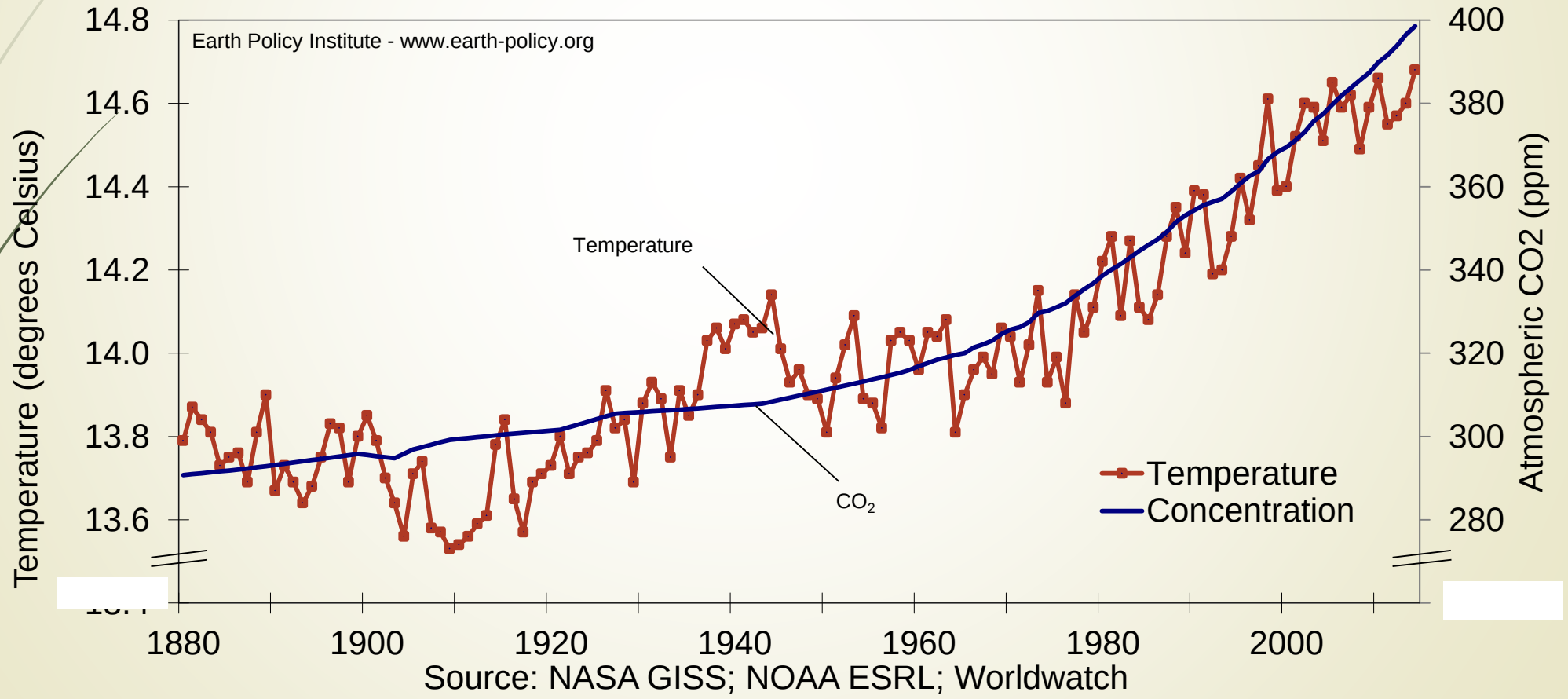
Year	SYRS potatoes	Moisture category
1997	-1,33	Moderate yield losses
1998	-0,65	Low yield losses
1999	-0,76	Low yield losses
2000	-1,95	High yield losses
2001	-1,20	Moderate yield losses
2002	-0,97	Low yield losses
2003	-0,03	High yield losses
2004	0,09	High yield losses
2005	0,18	High yield losses
2006	0,15	High yield losses
2007	0,69	Low yield increment
2008	0,84	Low yield increment
2009	0,72	Low yield increment
2010	0,33	High yield losses
2011	1,00	Moderate yield increment
2012	1,34	Moderate yield increment
2013	1,55	High yield increment

Table 7 - The yield categories according to the SYRS of vegetables for the Armenia Republic during 1997-2013

Year	SYRS vegetables	Moisture category
1997	-1,63	High yield losses
1998	-1,25	Moderate yield losses
1999	-1,11	Moderate yield losses
2000	-1,49	Moderate yield losses
2001	-0,84	Low yield losses
2002	-0,69	Low yield losses
2003	-0,44	Normal
2004	-0,06	Low yield losses
2005	0,36	High yield losses
2006	0,75	High yield losses
2007	1,01	Moderate yield increment
2008	0,96	Low yield increment
2009	1,07	Moderate yield increment
2010	0,46	High yield losses
2011	0,69	High yield losses
2012	1,03	High yield losses
2013	1,19	Moderate yield increment

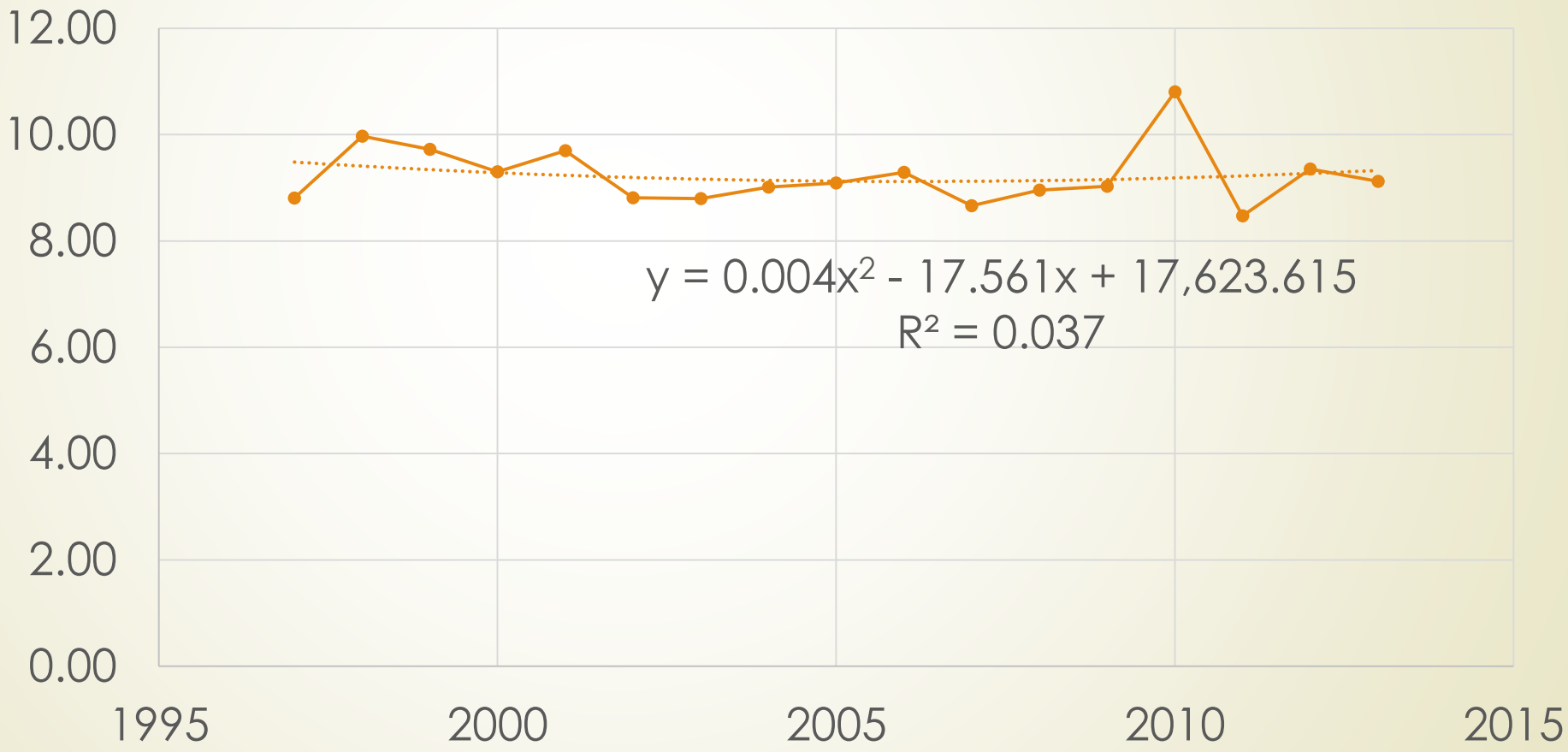
Step 3 – Construction of the Climate Changes Model

Picture 1 - Average Global Temperature and Atmospheric Carbon Dioxide Concentration, 1880-2014



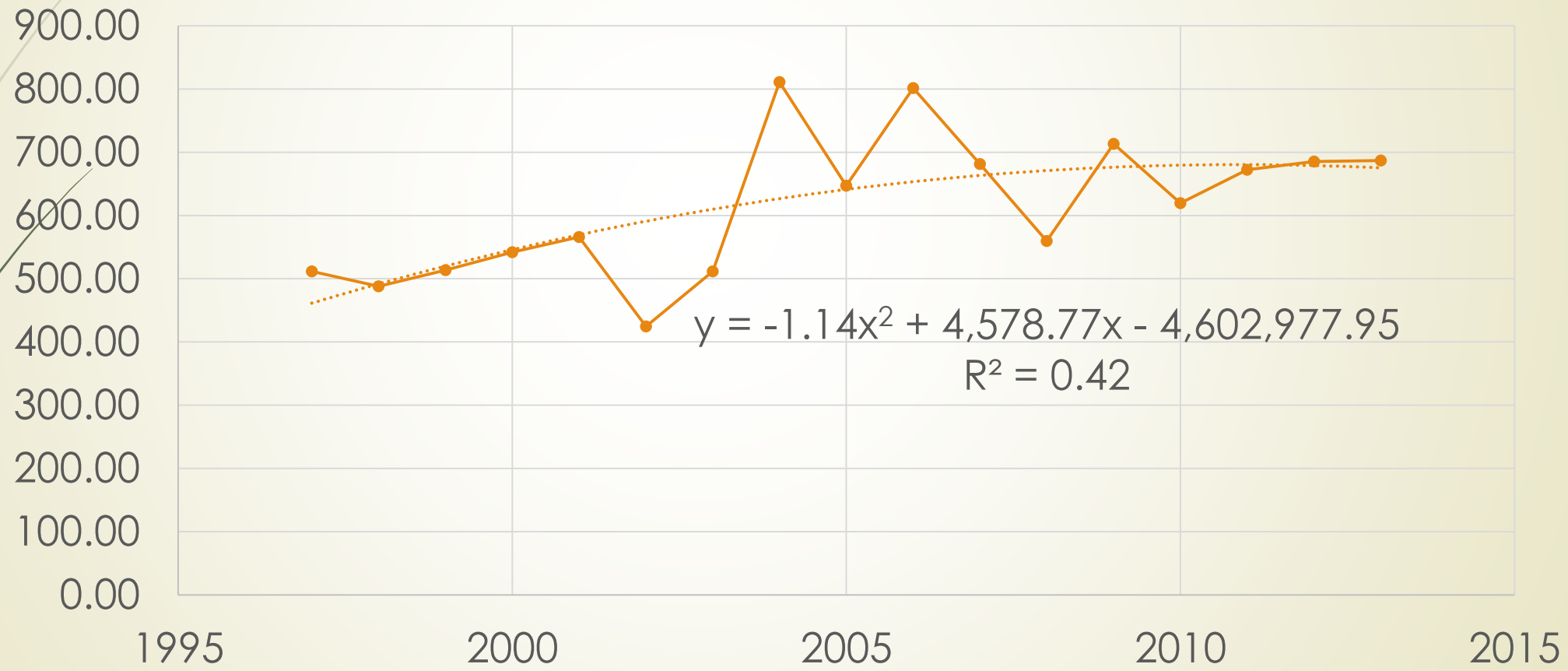
Picture 2 - Climate change is a function of temperature for the Armenia Republic, °t

$$y_{temperature} = 0{,}004 \times x^2 - 17{,}561 \times x + 17623{,}615$$



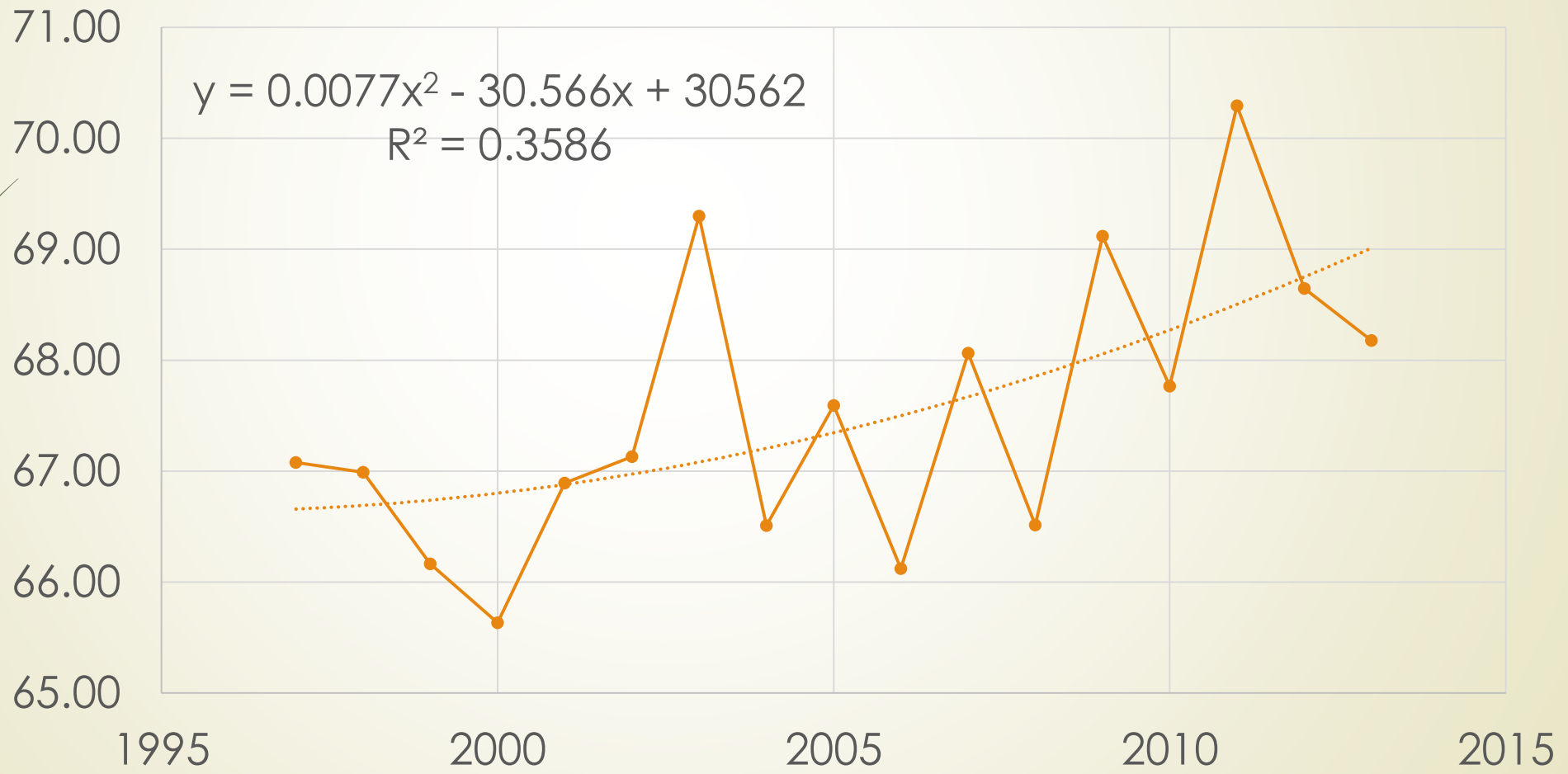
Picture 3 - Climate change is a function of rainfall for the Armenia Republic, mm

$$y_{precipitation} = -1{,}14 \times x^2 + 4578{,}77 \times x - 4602977{,}95$$



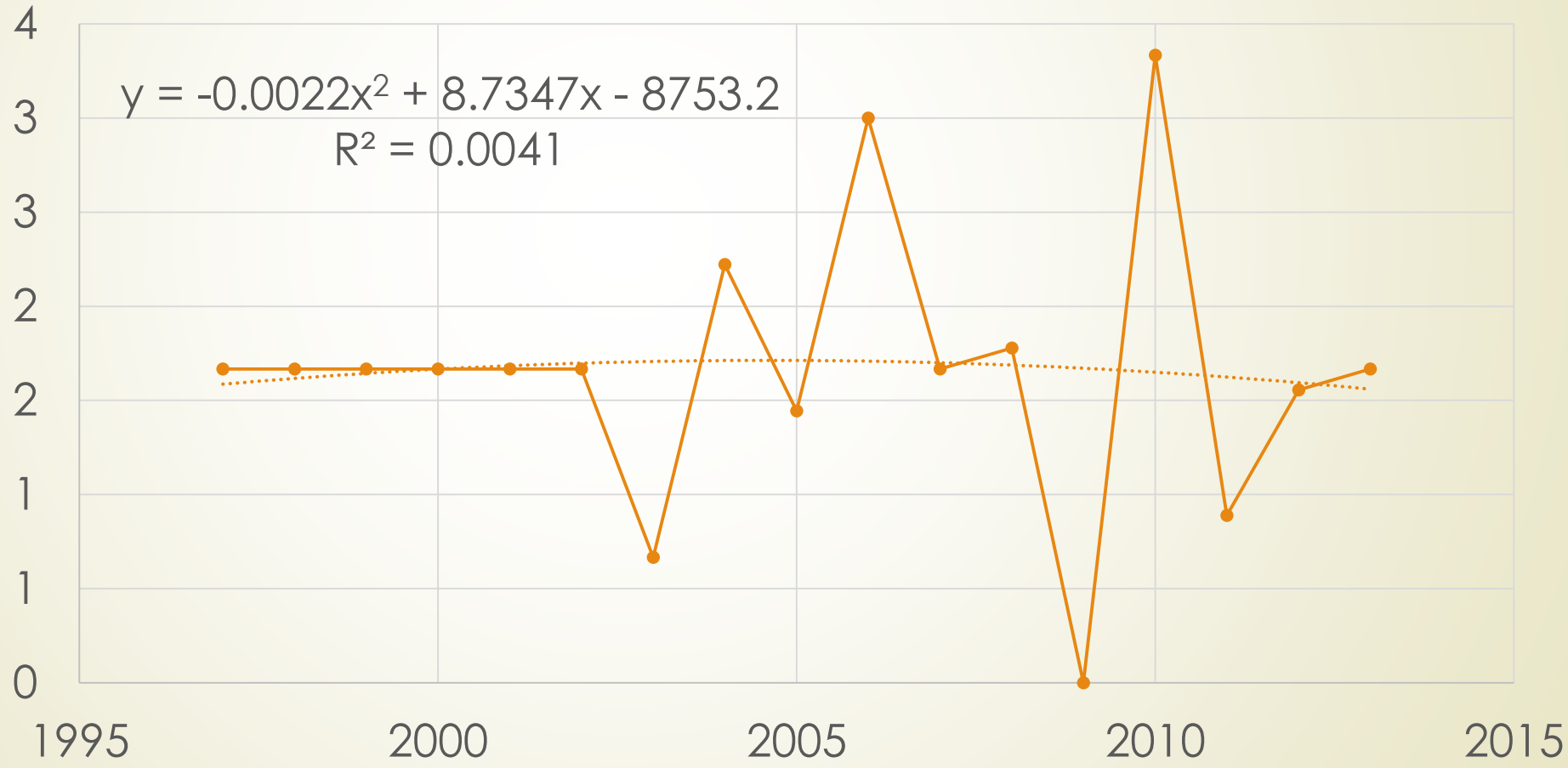
Picture 4 - Climate change is a function of wetness for the Armenia Republic, %

$$y_{wet} = 0{,}0077 \times x^2 - 30{,}566 \times x + 30562$$



Picture 5 - Climate change is a function of drought for the Armenia Republic, times

$$y_{drought} = -0{,}0022 \times x^2 - 8{,}7347 \times x + 8753{,}2$$



Step 4 – Modeling of Climate impact on main crop yields

y_1 – yield;

x_2 – temperature; x_3 – rainfall; x_4 – wetness; x_5 – drought.

$$y_{grain} = -199{,}525 - 1{,}819 \times x_2 - 0{,}026 \times x_3 + 3{,}627 \times x_4 + 2{,}317 \times x_5$$

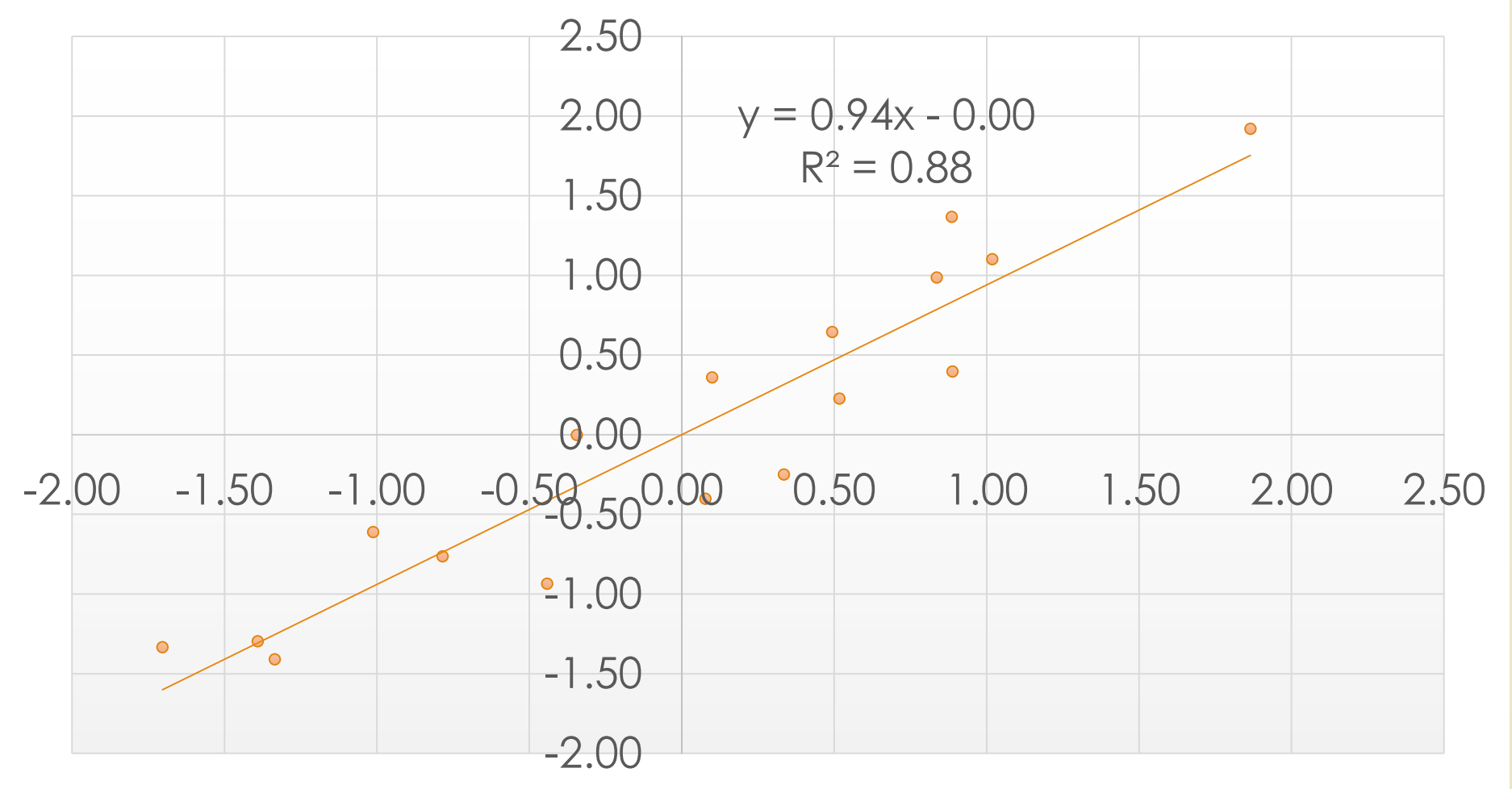
$$y_{potatoes} = -1510{,}254 - 6{,}028 \times x_2 - 0{,}093 \times x_3 + 25{,}695 \times x_4 + 17{,}616 \times x_5$$

$$y_{vegetables} = -1366{,}653 - 12{,}995 \times x_2 + 0{,}073 \times x_3 + 24{,}854 \times x_4 + 23{,}913 \times x_5$$

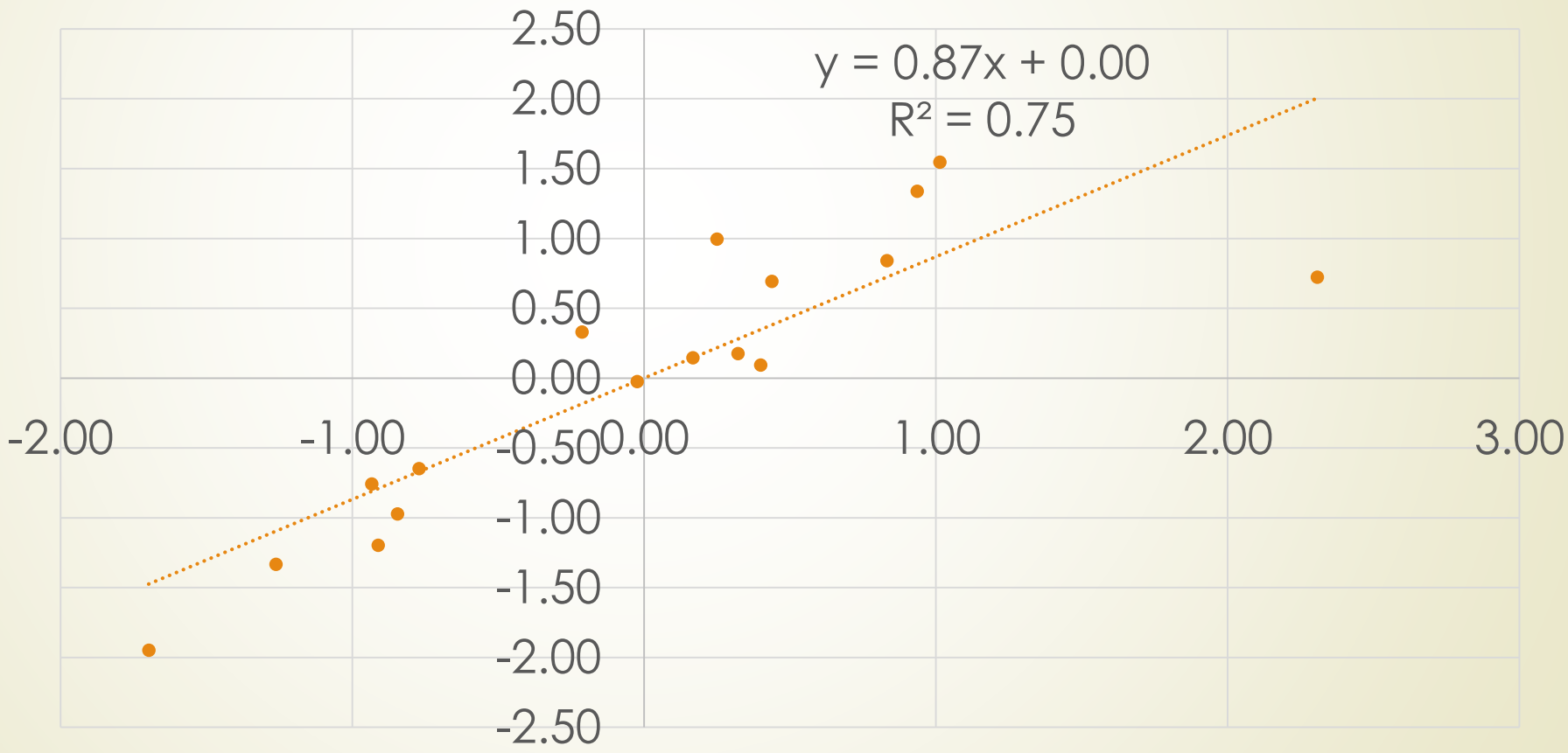
Step 5 - Modeling of the food security

- x-index of the yield for crop (SYRS);
- y-index of the food security for crop (IFSC).

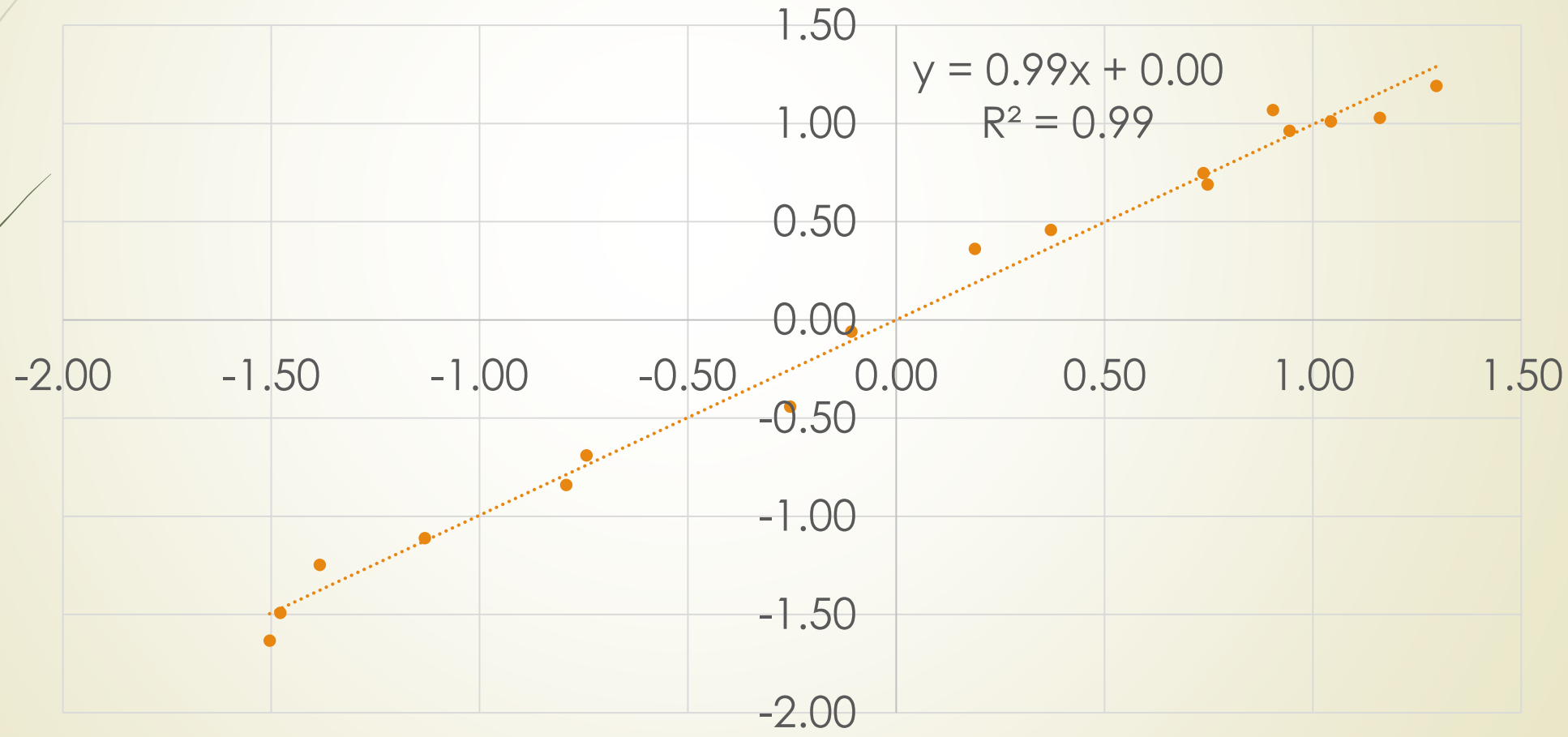
Picture 6 – Equation of the food security liner model for the grain



Picture 7 – Equation of the food security liner model for the potatoes



Picture 8 – Equation of the liner model food security for the vegetables



Systems of equations for the forecasting of the food security in the Grain industry

$$\begin{cases} y_{temperature} = 0{,}004 \times x^2 - 17{,}561 \times x + 17623{,}615 \\ y_{precipitation} = -1{,}14 \times x^2 + 4578{,}77 \times x - 4602977{,}95 \\ y_{wet} = 0{,}0077 \times x^2 - 30{,}566 \times x + 30562 \\ y_{drought} = -0{,}0022 \times x^2 - 8{,}7347 \times x + 8753{,}2 \\ y_{yield\ grain} = -199{,}525 - 1{,}819 \times X_2 - 0{,}026 \times X_3 + 3{,}627 \times X_4 + 2{,}317 \times X_5 \\ y_{fsg} = 0{,}94x \end{cases}$$

Systems of equations for the forecasting of food security in the potatoes industry

$$\begin{cases} y_{temperature} = 0{,}004 \times x^2 - 17{,}561 \times x + 17623{,}615 \\ y_{precipitation} = -1{,}14 \times x^2 + 4578{,}77 \times x - 4602977{,}95 \\ y_{wet} = 0{,}0077 \times x^2 - 30{,}566 \times x + 30562 \\ y_{drought} = -0{,}0022 \times x^2 - 8{,}7347 \times x + 8753{,}2 \\ y_{yield\ potatoes} = -1510{,}254 - 6{,}028 \times x_2 - 0{,}093 \times x_3 + 25{,}695 \times x_4 + 17{,}616 \times x_5 \\ y_{fsp} = 0{,}87x \end{cases}$$

Systems of equations for the forecasting of food security in the vegetables

$$\begin{cases} y_{temperature} = 0{,}004 \times x^2 - 17{,}561 \times x + 17623{,}615 \\ y_{precipitation} = -1{,}14 \times x^2 + 4578{,}77 \times x - 4602977{,}95 \\ y_{wet} = 0{,}0077 \times x^2 - 30{,}566 \times x + 30562 \\ y_{drought} = -0{,}0022 \times x^2 - 8{,}7347 \times x + 8753{,}2 \\ y_{yield\ vegetables} = -1366{,}653 - 12{,}995 \times x_2 + 0{,}073 \times x_3 + 24{,}854 \times x_4 + 23{,}913 \times x_5 \\ y_{fsp} = 0{,}99x \end{cases}$$

Forecasting of the Climate Changes and Food Security from 2016 till 2020 in Armenia Republic (grain industry)

Year	Temperature, t °C	Precipitation, mm	Wet, %	Drought, units	Yield, center/ha
2016	9,55	650,40	69,89	1	23,00
2017	9,64	637,58	70,21	1	24,22
2018	9,74	622,48	70,55	1	25,53
2019	9,85	605,10	70,90	1	26,93
2020	9,96	585,45	71,27	1	28,42

Thank you for your attention!

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