PROJECT

Transboundary Water Management Adaptation in the Amudarya Basin to Climate Change Uncertainties

Report on position

3.1 Series of simulation for different scenarios over 2016-2055

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1. The model of planning zone is developed in GAMS (Version 24.5.6) with the use of MINOS5 solver.
   Methodology of the program: the module receives input data from the database. Then the program is calibrated in the following way: using the actual data on cropping pattern in PZ, as well as crop yields and coefficients of conversion into feed mass and feed units, the forage for meat production is calculated, with following calculation of meat and dairy output. Variable pasture coefficient is entered to determine consumption of forage produced in non-irrigated agriculture. Coefficients determining consumption of roughage and soft feed are inputted. Using those data, a system of linear equations with target function is constructed: standard deviation of the simulated meat and dairy output from the actual output (Annex 3). This is needed for adjustment of the coefficients against the actual data and to prepare them for the following phase of optimization of cropping patterns in PZ.

   Operation scheme of the model (Annex 2):

   Actual data is inputted, and this is followed by:

   1. Calibration of the model and calculation of coefficients to consider pastures.
      Parallel phases:
      1.1. Optimization of cropping pattern by the criterion of minimization of standard deviation of calculation results from actual food basket, with the capability to regulate completeness of the food basket.
      1.2. Optimization of cropping pattern by the criterion of maximum added value for export potential. In this phase, completeness of the food basket acts as a boundary condition in the model.
   2. Phase 2.1 is followed by optimization by the criterion of maximum added value. Restrictions and resources (water, land area) used in the optimization pf phase 2.1 are taken into account.
   3.
2. Data were received from SIC ICWC for simulation experiment (Annex 3)
   The food basket was composed based on medical standards:

Foodstuff:	**Consumption, kg\year**
Meat and meat products	55
Milk and dairy products	200
Fruits and berries	160
Bread products (bread and pasta converted into flour, flour, cereals, and legumes)	200
Vegetables and cucurbits	200

3. The optimization model made calculations for the Khorezm, North Karakalpakstan, and Surkhandarya PZs based on ESA and FSD scenarios for 2020 and 2050. According to optimization results represented in tables for PZs and graphs (see Annex 6), there is equal distribution of foodstuffs in the food basket of the population. However, according to the actual data (see Annex 3), there is strong differentiation in the amount of food consumed; food consumption is uneven. For instance, there is a deficit of some food

products and surplus of other food products. The use of the optimization model ensures more equal meeting of the population's needs for food.
The model runs in two phases. In the first phase, food needs are optimized; in the second phase, export potential is optimized. Optimization may be ceased in the first phase due to restriction of land and water resources. In this regard for ESA scenario, completeness of the food basket should be controlled by introducing specific coefficients for its restriction, and/or coefficients that stimulate increased production of a certain food item should be higher.
In addition, it is important to develop non-irrigated agriculture. This is evident from the output coefficients of the model (see Annex 4, table 1) and the conducted experiment, which shows positive correlation between pasture coefficient and meat production (see Annex 4, graph 1).

Hence, one should mention that the use of the optimization model allows more even production of foodstuffs included in the food basket. It is recommended to use restriction coefficients when planning production of foodstuffs in the food basket under the export-oriented scenario. On the other hand, it is necessary to expand non-irrigated areas, which would allow achieving the needed degree of meat production.

Annexes:

Annex 1:

Short description of the computer program:

Input data of the program include the actual cropping patterns, yield coefficients, feed mass coefficients, and feed conversion ratio. Gross output of crops is calculated, as well as unit parameters of foodstuff production.

$$FactAmountCrops = Fact\_Area\_Crops * productivity$$

$$SpecificFactAmountCrops = Fact\_Area\_Crops * productivity / Population$$

$$Calibration\_Feed\_Unit = FeedUnitCoef * Fact\_Area\_Crops * productivity * FeedMassCoef * 10000$$

$$Feed\_Cal = \sum FeedUnitCoef\_feedcrops * Fact\_Area * productivity * FeedMass * 10000$$

$$Roughage\_Cal = \sum FeedUnitCoef\_RoughageCrops * Fact\_Area * productivity * FeedMass * 10000$$

For calculation of dairy and meat output, variable coefficients are inputted to consider pastures and calculated when solving the optimization problem:

$$\begin{cases} FeedUnitPastureCal = \sum Calibration\_Feed\_Unit * PastureCoefCal \\ PastureMilkCal = FeedUnitPastureCal * CoefCalibration / (CoefCalibration + 1) \\ PastureMeatCal = FeedUnitPastureCal / (CoefCalibration + 1) \\ PercentRoughageMeat = Roughage\_Cal - Roughage\_Cal * PercentRoughage / 100 \\ PercentFeedMeat = Feed\_Cal - PercentFeed * Feed\_Cal / 100 + PastureMeatCal \\ ProdMilkCal = MilkUnit * ((TotalRoughage * PercentRoughage / 100 + PercentFeed * TotalFeed / 100) + PastureMilk) / 1000000 \\ ProdMeatCal = \sum ProdMeatByCattle / 1000 \\ SpecProdMeatCal = ProdMeatCal * 1000 / Population \\ SpecProdMilkCal = ProdMilkCal * 1000 / Population \\ DeviationCal = (ProdMeatCal - FactProdMeat)^2 + (ProdMilkCal - FactProdMilk)^2 \\ DeviationCal \to \min \end{cases}$$

Where the following parameters are inputted and permanent:

$Fact\_Area\_Crops$ - actual distribution of areas under crops

$productivity$ - crop yields

$Population$ - population in PZ

$FeedMassCoef$ - coefficient of conversion into feed mass

$Calibration\_Feed\_Unit$ - quantity of feed mass

And the following parameters are variable and subjected to optimization and then serve as input for the next phase as permanent parameters, where cropping patterns are to be optimized to achieve food security:

$CoefCalibration$ - coefficient of forage consumption

$PercentFeed$ - coefficient of soft feed consumption

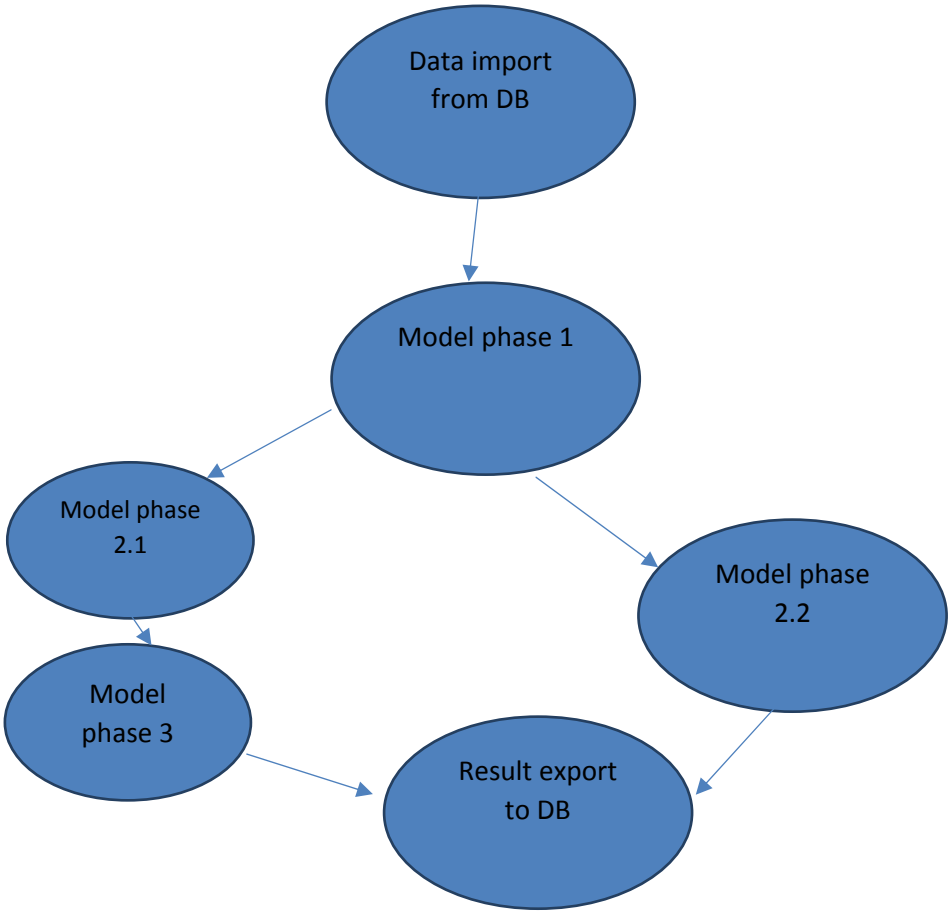
$PercentRoughage$ - coefficient of roughage consumption

$PastureCoefCal$ - pasture coefficient

Then, there is a block with restrictions for the model:

$$\begin{cases} AmountWater > \sum WaterRate * CropArea \\ TotalArea > \sum CropArea \end{cases}$$

Where:
AmountWate – restriction on water resources
TotalArea – PZ area to optimize crops
CropArea – crop area; this parameter is variable and determined when optimizing.



Annex 2:

Annex 3:

1. **Input data for the model:**

1.1. Khorezm PZ:

Demographics:

	FSD		ESA	
	2020	**2050**	**2020**	**2050**
Total population, ths people	1,864	2,756	1,864	2,756

Irrigated area

	FSD		ESA	
	2020	**2050**	**2020**	**205.**
Irrigated area, ths ha	244.6	245.0	244.6	245.0
of which under:cotton	90.9	61.3	90.9	63.7
forage	29.6	41.7	29.6	34.3
orchard	13.3	19.6	13.3	24.5
wheat	52.3	44.1	52.3	41.7
maize	2.8	4.9	2.8	3.7
cucurbits	7.2	11.0	7.2	12.3
potato	6.1	9.8	6.1	7.4
rice	19.5	24.5	19.5	22.1
vegetables	19.7	23.3	19.7	28.2
grapes	3.2	4.9	3.2	7.4
	244.6	245.0	244.6	245.0

Gross output of crops, ths tons

	FSD		ESA	
	2020	**2050**	**2020**	**2050**
cotton	254.5	261.8	263.2	334.4
forage	142.5	434.2	136.6	316.3
fruits and berries	193.6	461.0	196.1	710.3
wheat	236.4	298.7	233.4	224.1
maize	10.4	36.5	10.2	22.4
cucurbits	145.6	356.3	153.7	474.3
potato	110.4	308.2	109.6	205.1
rice	98.5	169.1	93.2	131.9
vegetables	490.8	919.6	497.9	1,401.3
grapes	49.7	99.8	51.2	176.9

Crop harvest, tons

	FSD		ESA	
	2020	**2050**	**2020**	**2050**
cotton	2.8	4.3	2.9	5.2
forage	4.8	10.4	4.6	9.2
fruits and berries	14.6	23.5	14.8	29.0
wheat	4.5	6.8	4.5	5.4
maize	3.7	7.4	3.7	6.1
cucurbits	20.1	32.3	21.2	38.7
potato	18.2	31.4	18.1	27.9
rice	5.1	6.9	4.8	6.0
vegetables	24.9	39.5	25.3	49.7
grapes	15.6	20.4	16.0	24.1

Number of livestock and poultry, ths heads

	FSD		ESA	
	2020	**2050**	**2020**	**2050**
Number of cattle	1,081.0	6,283.2	1,081.0	4,661.7
Of which: cows	410.4	2,385.4	410.4	1,769.8
sheep	490.0	2,557.2	490.0	1,822.2

Livestock production, ths tons

	FSD		ESA	
	2020	**2050**	**2020**	**2050**
Meat (slaughter weight)	128.3	532.6	128.3	395.2
Milk	1,877.7	7,795.9	1,877.7	5,784.0
Eggs, mln	527.7	2,435.7	527.7	1,870.2

Basic foodstuffs production per capita, kg/person/year

	FSD		ESA	
	2020	**2050**	**2020**	**2050**
Meat and meat products converted into meat	46.3	129.9	46.3	96.4
Milk and dairy products converted into milk	163.9	460.3	163.9	341.5
Eggs, pieces	283.2	883.9	283.2	678.7
Potato	59.3	111.8	58.8	74.4
Vegetables and cucurbits	341.4	463.0	349.6	680.7
Fruits and berries	103.9	167.3	105.2	257.8
Sugar	NA	NA	NA	NA
Vegetable oil	NA	NA	NA	NA
Bread products (bread and pasta converted into flour, flour, cereals, and legumes)	139.1	118.9	137.3	89.2
Fish and fish products	NA	NA	NA	NA

1.2. North Karakalpakstan PZ

Demographics:

	FSD		ESA	
	2020	**2050**	**2020**	**2050**
Total population, ths people	796	972	796	972

Irrigated area

	FSD		ESA	
	2020	**2050**	**2020**	**2050**
Irrigated area, ths ha	125.9	128.7	125.9	128.7
Of which under: cotton	39.7	30.9	39.7	32.2
forage	10.0	15.4	10.0	11.6
orchard	2.3	3.2	2.3	5.1
wheat	44.3	32.2	44.3	30.9
maize	1.7	3.2	1.7	2.6
cucurbits	6.7	9.0	6.7	11.6
potato	2.7	4.5	2.7	3.9
rice	10.7	18.0	10.7	15.4
vegetables	7.7	10.3	7.7	12.9
grapes	0.5	1.9	0.5	2.6

Gross output of crops, ths tons

	FSD		ESA	
	2020	**2050**	**2020**	**2050**
cotton	79.2	93.0	84.5	129.2
forage	27.4	91.2	25.5	45.6
orchard	21.5	40.3	22.4	82.9
wheat	125.7	161.6	120.8	123.3
maize	6.7	24.1	6.5	17.2
cucurbits	84.8	181.3	92.1	274.5
potato	30.1	104.2	27.7	78.8
rice	29.2	116.0	25.7	74.6
vegetables	151.2	312.7	164.9	444.6
grapes	4.1	23.7	4.5	37.8

Crop harvest, tons

	FSD		ESA	
	2020	**2050**	**2020**	**2050**
cotton	2.0	3.0	2.1	4.0
forage	2.8	5.9	2.6	3.9
orchard	9.6	12.5	10.0	16.1
wheat	2.8	5.0	2.7	4.0
maize	4.0	7.5	3.8	6.7
cucurbits	12.8	20.1	13.8	23.7
potato	11.3	23.1	10.4	20.4
rice	2.7	6.4	2.4	4.8
vegetables	19.7	30.4	21.4	34.5
grapes	9.2	12.3	10.0	14.7

Number of livestock and poultry, ths heads

	FSD		ESA	
	2020	**2050**	**2020**	**2050**
Number of cattle	694.3	4,838.3	694.3	3,796.9
Of which: cow	227.8	1,587.5	227.8	1,245.8
sheep	688.0	3,386.5	688.0	2,354.6

Livestock production, ths tons

	FSD		ESA	
	2020	**2050**	**2020**	**2050**
Meat (slaughter weight)	51.2	238.0	51.2	186.8
Milk	312.4	1 451.5	312.4	1 139.1
Eggs, mln	157.1	852.0	157.1	694.9

Basic foodstuffs production per capita, kg/person/year

	FSD		ESA	
	2020	**2050**	**2020**	**2050**
Meat and meat products converted into meat	43.3	164.6	43.3	129.2
Milk and dairy products converted into milk	63.9	243.0	63.9	190.7
Eggs, pieces	197.5	876.7	197.5	715.0
Potato	37.9	107.3	34.8	81.1
Vegetables and cucurbits	296.6	508.3	322.9	739.9
Fruits and berries	27.1	41.4	28.2	85.3
Sugar	NA	NA	NA	NA
Vegetable oil	NA	NA	NA	NA
Bread products (bread and pasta converted into flour, flour, cereals, and legumes)	173.2	182.3	166.5	139.1

Fish and fish products	NA	NA	NA	NA

1.3. Surkhandarya PZ:

Demographics:

	FSD		ESA	
	2020	**2050**	**2020**	**2050**
Total population, ths people	2,612.24	4,133.12	2,612.24	4,133.12

Irrigated area

	FSD		ESA	
	2020	**2050**	**2020**	**2050**
Irrigated area, ths ha	308.26	308.30	308.26	308.30
Of which under: cotton	105.33	77.08	105.33	80.16
forage	21.23	27.75	21.23	24.66
orchard	17.33	27.75	17.33	30.83
wheat	113.52	83.24	113.52	77.08
maize	0.39	6.17	0.39	3.08
cucurbits	3.42	9.25	3.42	12.33
potato	12.11	18.50	12.11	15.42
rice	-	-	-	-
vegetables	22.02	43.16	22.02	46.25
grapes	12.90	15.42	12.90	18.50

Gross output of crops, ths tons

	FSD		ESA	
	2020	**2050**	**2020**	**2050**
cotton	322.21	314.59	357.96	400.54
forage	252.57	678.86	254.51	498.68
orchard	182.16	412.10	210.62	605.44
wheat	587.14	604.27	583.96	454.48
maize	1.02	43.18	0.85	18.84
cucurbits	118.15	493.07	123.82	736.11
potato	259.78	772.75	252.19	560.00
rice	-	-	-	-
vegetables	510.17	1,742.50	538.16	2,357.96
grapes	134.04	240.75	159.45	345.61

Crop harvest, tons

	FSD		ESA	
	2020	**2050**	**2020**	**2050**
cotton	3.06	4.08	3.40	5.00
forage	11.90	24.47	11.99	20.22
orchard	10.51	14.85	12.16	19.64
wheat	5.17	7.26	5.14	5.90
maize	2.59	7.00	2.17	6.11
cucurbits	34.51	53.31	36.16	59.69
potato	21.45	41.77	20.82	36.33
rice	-	-	-	-
vegetables	23.17	40.37	24.44	50.99
grapes	10.39	15.62	12.36	18.68

Number of livestock and poultry, ths heads

	FSD		ESA	
	2020	**2050**	**2020**	**2050**
Number of cattle	1,065.00	4,888.55	1,065.00	3,823.55
Of which: cow	399.46	1,833.61	399.46	1,434.14
sheep	2,502.00	10,889.07	2,502.00	8,387.07

Livestock production, ths tons

	FSD		ESA	
	2020	**2050**	**2020**	**2050**
Meat (slaughter weight)	156.83	514.19	156.83	402.17
Milk	1,464.91	4,803.00	1,464.91	3,756.64
Eggs, mln	325.75	1,285.10	325.75	1,052.43

Foodstuffs production per capita, kg/person/year

	FSD		ESA	
	2020	**2050**	**2020**	**2050**
Meat and meat products converted into meat	40.35	83.61	40.35	65.39
Milk and dairy products converted into milk	91.24	189.08	91.24	147.89
Eggs, pieces	124.70	310.93	124.70	254.63
Potato	99.45	186.97	96.54	135.49
Vegetables and cucurbits	240.53	540.89	253.41	748.60
Fruits and berries	69.73	99.71	80.63	146.48
Sugar	NA	NA	NA	NA
Vegetable oil	NA	NA	NA	NA
Bread products (bread and pasta converted into flour, flour, cereals, and legumes)	246.45	160.31	245.12	120.57
Fish and fish products	NA	NA	NA	NA

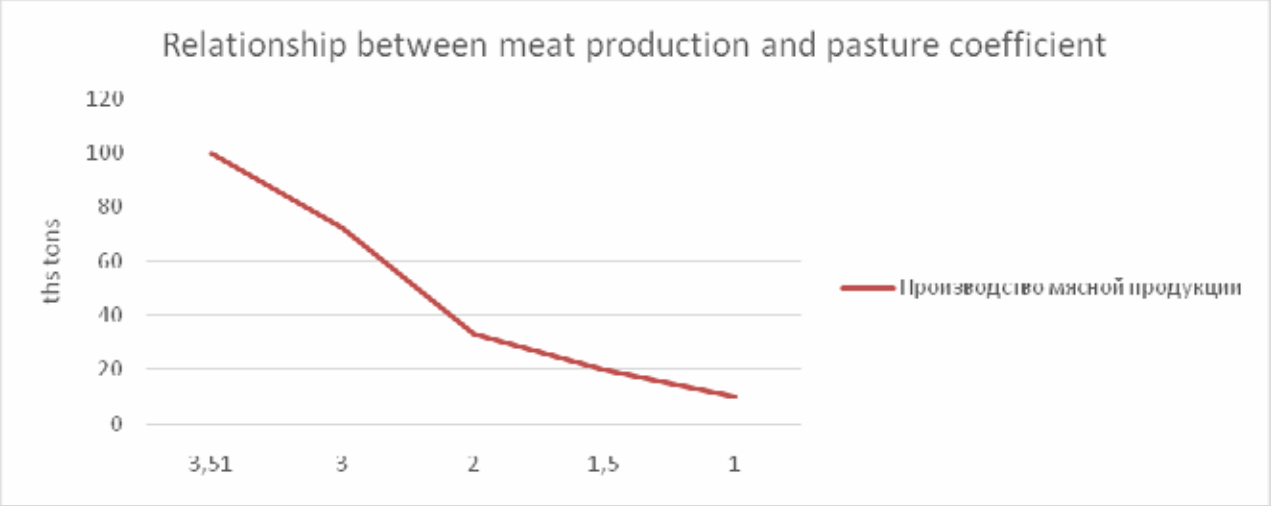
Annex 4:

Table 1

Output coefficients in the model

		Pasture coefficient	Use of roughage forage, %	Use of soft forage, %
Surkhandarya PZ	**ESA 2020**	0.7	1	99
	ESA 2050	1.21	5	95
	FSD 2020	0.9	5	95
	FSD 2050	1.35	5	95
Khorezm PZ	**ESA 2020**	1.17	1	99
	ESA 2050	1.68	5	95
	FSD 2020	1.17	1	99
	FSD 2050	1.43	1	99
North Karakalpakstan PZ	**ESA 2020**	2.25	2.03	97.97
	ESA 2050	3.76	1	99
	FSD 2020	2.33	1	99
	FSD 2050	3.44	1	99

Annex 4.1



Annex 5:

Comparing scenario-based and simulated production in PZs:

Khorezm PZ:

Basic foodstuffs production per capita, kg/person/year

	Scenario-based				Simulated			
	FSD		**ESA**		**FSD**		**ESA**	
	2020	**2050**	**2020**	**2050**	**2020**	**2050**	**2020**	**2050**
Meat and meat products converted into meat	46.3	129.9	46.3	96.4	27.29	55	27.08	41.55
Milk and dairy products converted into milk	163.9	460.3	163.9	341.5	200.08	200	199.96	200.18
Fruits and berries	103.9	167.3	105.2	257.8	169.49	170	169.48	169.65
Bread products (bread and pasta converted into flour, flour, cereals, and legumes)	139.1	118.9	137.3	89.2	199.13	200	199.05	198.84
Vegetables and cucurbits	341.4	463.0	349.6	680.7	199.79	200	199.81	499.86

North Karakalpakstan PZ:

Foodstuffs production per capita, kg/person/year

	Scenario-based				Simulated			
	FSD		**ESA**		**FSD**		**ESA**	
	2020	**2050**	**2020**	**2050.**	**2020**	**2050**	**2020**	**2050**
Meat and meat products converted into meat	43.3	164.6	43.3	129.2	63.26	167.41	62.57	151.21
Milk and dairy products converted into milk	63.9	243.0	63.9	190.7	123.73	177.57	123.09	172.51
Fruits and berries	27.1	41.4	28.2	85.3	143.61	169.24	146.4	170
Bread products (bread and pasta converted into flour, flour, cereals, and legumes)	173.2	182.3	166.5	139.1	119.75	199.59	116.1	188.71
Vegetables and cucurbits	296.6	508.3	322.9	739.9	190.91	199.4	192.22	360

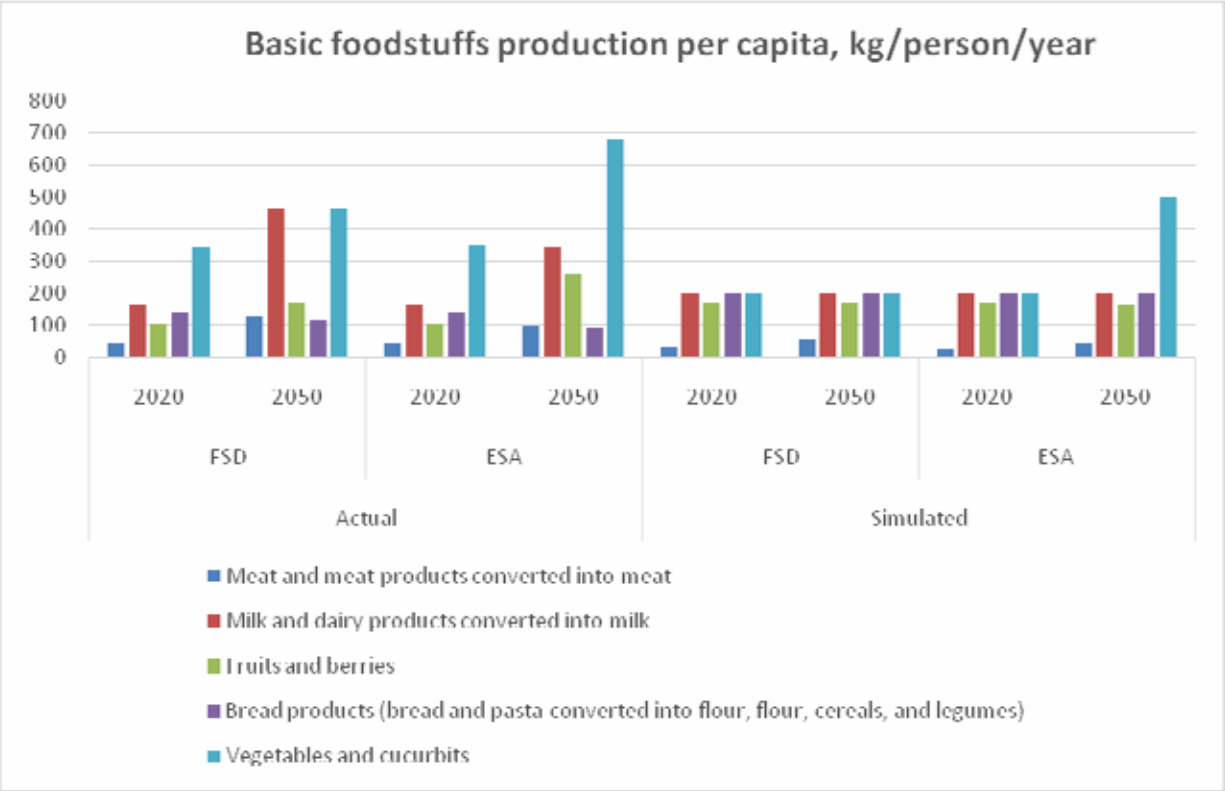
Surkhandarya PZ:

Foodstuffs production per capita, kg/person/year

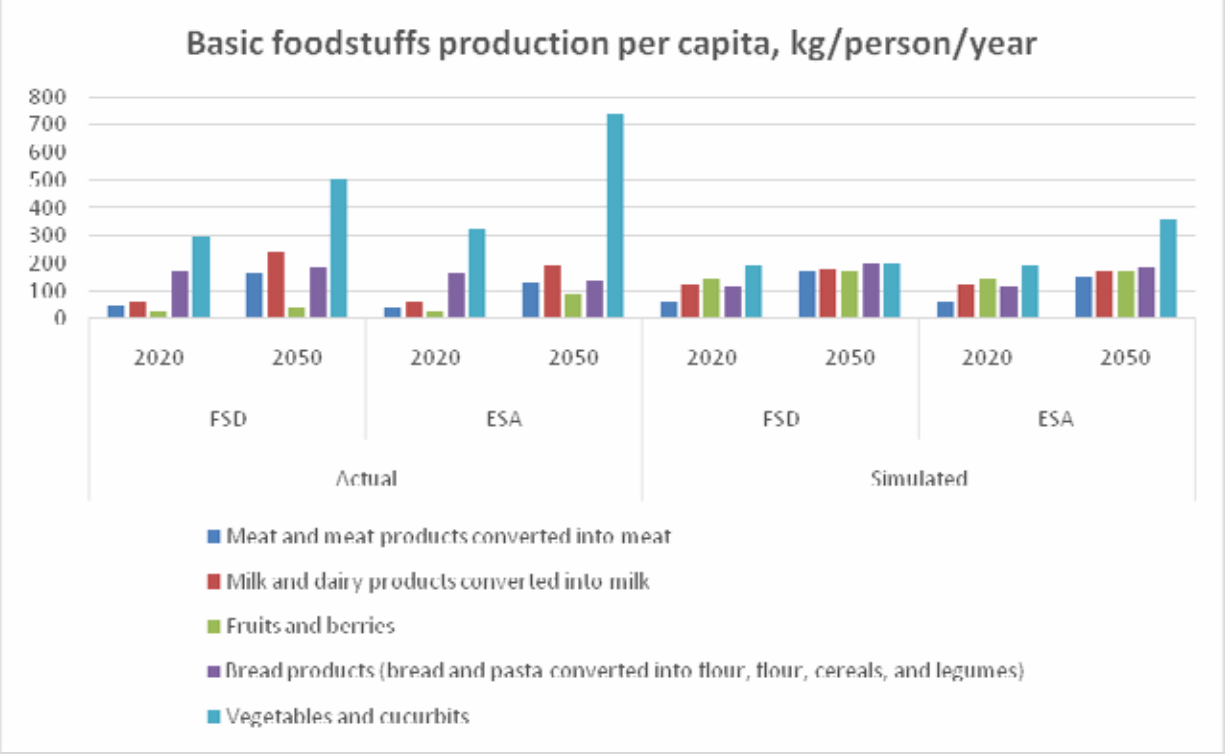
	Scenario-based				Simulated			
	FSD		**ESA**		**FSD**		**ESA**	
	2020	**2050**	**2020**	**2050**	**2020**	**2050**	**2020**	**2050**
Meat and meat products converted into meat	40.35	83.61	40.35	65.39	15.45	44.61	18.34	32.98
Milk and dairy products converted into milk	91.24	189.08	91.24	147.89	200.01	201.17	200.44	199.97
Fruits and berries	69.73	99.71	80.63	146.48	169.92	169.3	169.39	169.93
Bread products (bread and pasta converted into flour, flour, cereals, and legumes)	246.45	160.31	245.12	120.57	199.97	199.32	199.21	199.85
Vegetables and cucurbits	240.53	540.89	253.41	748.60	199.97	199.83	199.81	359.98

Annex 6:

Khorezm PZ:



North Karakalpakstan PZ:



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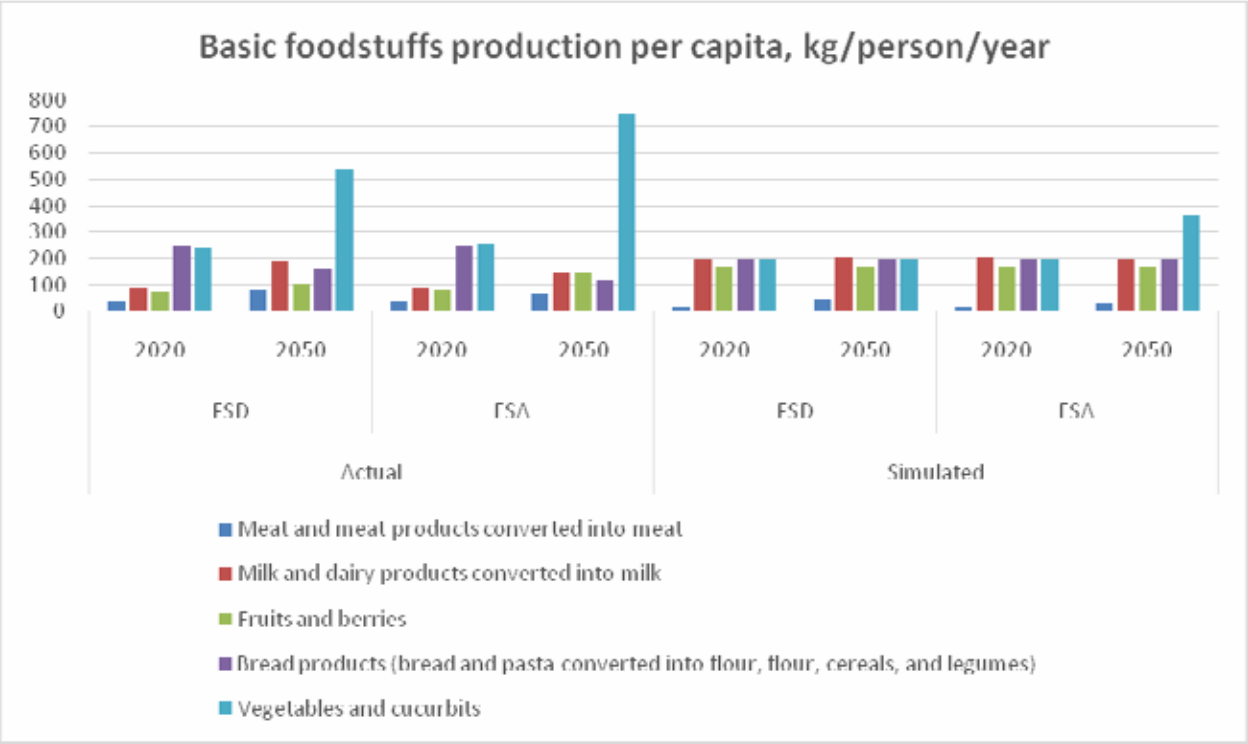

Annex 7:

Comparing distribution of areas under crops based on scenario and optimization assessments

Khorezm PZ:

	Scenario				Optimization			
	FSD		ESA		FSD		ESA	
	2020	2050	2020	2050	2020	2050	2020	2050
cotton	90.89	61.25	90.89	63.70	65.3	82.92	62.05	68.06
forage	29.61	41.65	29.61	34.30	67.55	45.75	70.45	51.67
orchard	16.47	24.50	16.47	31.85	20.95	21.35	20.51	17.62
wheat	52.34	44.10	52.34	41.65	45.08	73.47	47.68	64.81
maize	2.80	4.90	2.80	3.68	1	1	1	1
rice	19.47	24.50	19.47	22.05	30	1	30	30
vegetables	33.00	44.10	33.00	47.78	14.72	13.34	13.31	11.83

North Karakalpakstan PZ:

	Scenario				Optimization			
	FSD		ESA		FSD		ESA	
	2020	2050	2020	2050	2020	2050	2020	2050
cotton	39.67	30.89	39.67	32.18	50	50	50	55.53
forage	9.96	15.44	9.96	11.58	20.79	11.07	21	6.97
orchard	2.70	5.15	2.70	7.72	12.2	14.43	11.66	13.33
wheat	44.25	32.18	44.25	30.89	20	36.34	32.86	36.32
maize	1.69	3.22	1.69	2.57	1	4.05	1	4.91
rice	10.66	18.02	10.66	15.44	13.24	1	1	5.03
vegetables	17.01	23.81	17.01	28.31	8.67	11.81	8.39	6.61

Surkhandarya PZ:

	Scenario				Optimization			
	FSD		ESA		FSD		ESA	
	2020	2050	2020	2050	2020	2050	2020	2050
cotton	105.33	77.08	105.33	80.16	157.53	102.01	116.09	79.75
forage	21.23	27.75	21.23	24.66	18.79	30.66	38.85	36.84
orchard	30.23	43.16	30.23	49.33	42.48	45.91	36.1	36.66
wheat	113.52	83.24	113.52	77.08	71.95	113.47	101.23	140
maize	0.39	6.17	0.39	3.08	1	1	0	1
rice	-	-	-	-	-	-	-	-
vegetables	37.56	70.91	37.56	73.99	16.51	15.24	16.02	14.06