Transboundary water management adaptation in the Amudarya basin to climate change uncertainties

Planning zone model

Report on positions

3.1.2.10. Finalizing planning zone testing for 2010-2015

Calculations of various scenarios for 2016-2055

4.1.1 Planning zone model and user manual

Project manager __________Prof. V.A.Dukhovniy

Responsible for position 3.1.2 __________ A.G.Sorokin

Executor __________ R.R.Khafazov

1 Objectives and tasks

1. Finalizing planning zone model testing for a base period of 2010-2015

2. Calculations of various combinations of scenarios for 2016-2055:

- Calculation methodology

- Results of calculation by the planning zone model for 2016-2055

3. Developing a user manual for planning zone model.

2 Finalizing planning zone model testing for a base period of 2010-2015

The testing methodology consists in comparison of simulated and actual values of major indicators in the model.

More detailed description of the methodology and its automation for testing the planning zone model was given in the previous report (position 2.8.3. Testing).

Figures 2.1 and 2.2 show the testing results for the Surkhandarya planning zone and “Total water intake” indicator.

The testing results for other planning zones are available on http://cawater-info.net/pzm/basic/web in the section “Analysis of simulated data” (Figure 2.3).

Коэффициент корреляции		$r_{XY} = \frac{cov_{XY}}{\sigma_X \sigma_Y} = \frac{\sum(X-\bar{X})(Y-\bar{Y})}{\sqrt{\sum(X-\bar{X})^2}\sqrt{\sum(Y-\bar{Y})^2}}.$	0.94
Коэффициент детерминации		$R^2=(r_{XY})^2$.	0.88

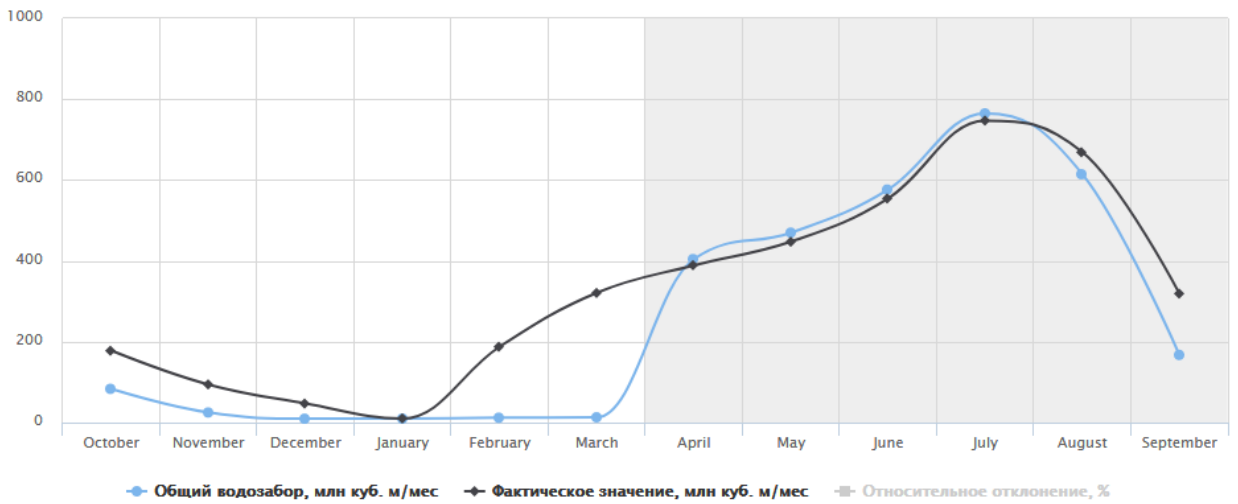


Figure 2.1

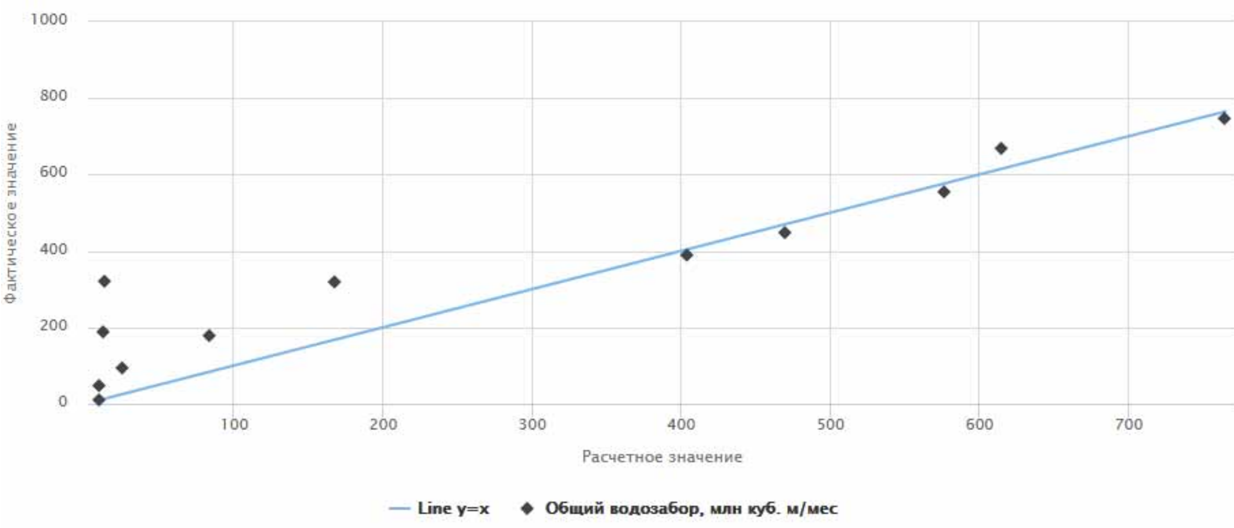


Figure 2.2

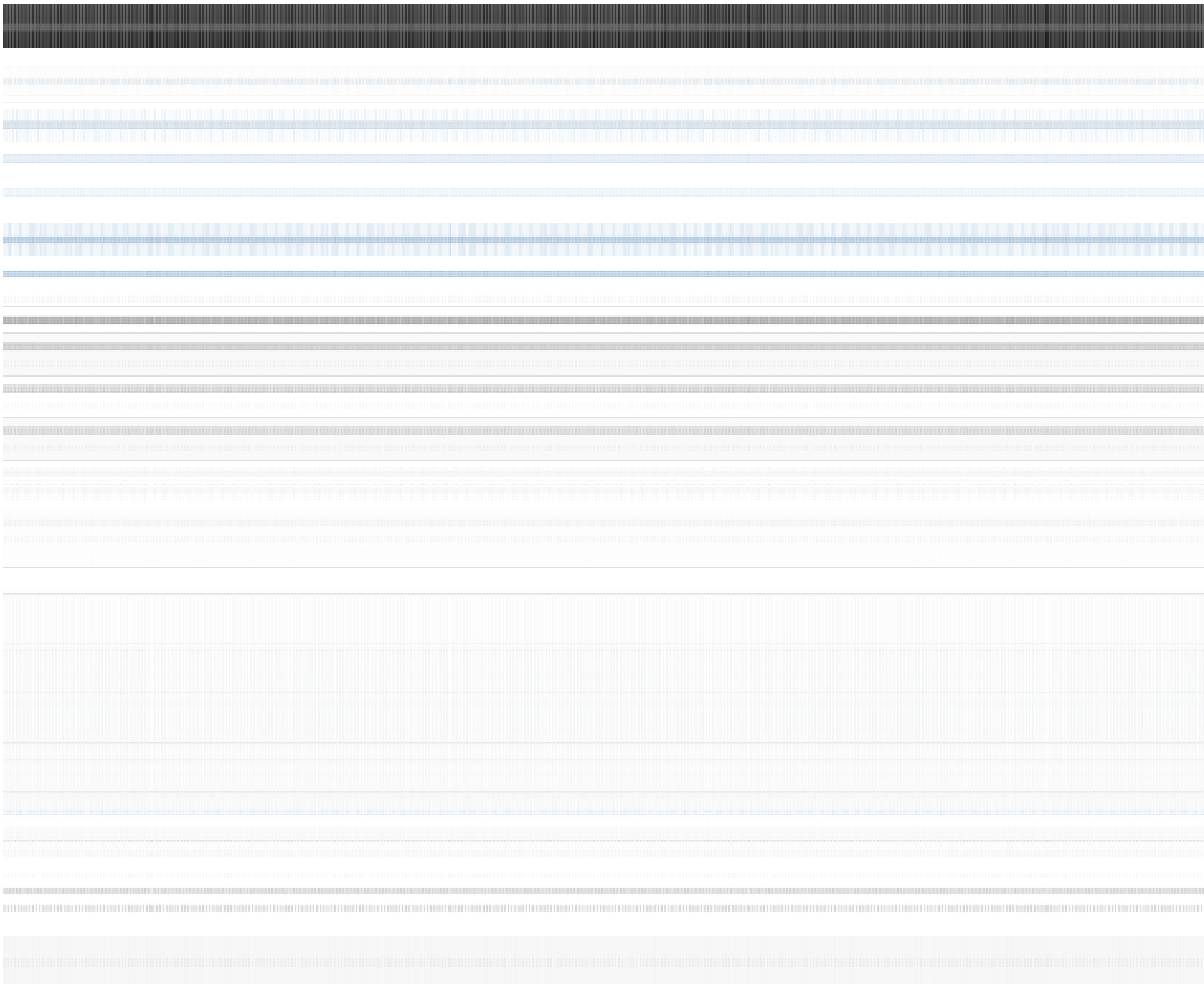


Figure 2.3

3. Calculations of various combinations of scenarios for 2016-2055

3.1 Calculation methodology

Calculations for 2016-2055 are made for various combinations of scenarios in the planning zone model. The graph of the system of scenarios is shown in Figure 3.1. The Figure shows that the user can enable/disable climate scenario and choose one of the scenarios – Food Security and Diet change (FSD), Export-oriented Sustainable Adaptation (ESA) or Business As Usual (BAU). The Figure also shows that 8 combinations of scenarios are available for the user.

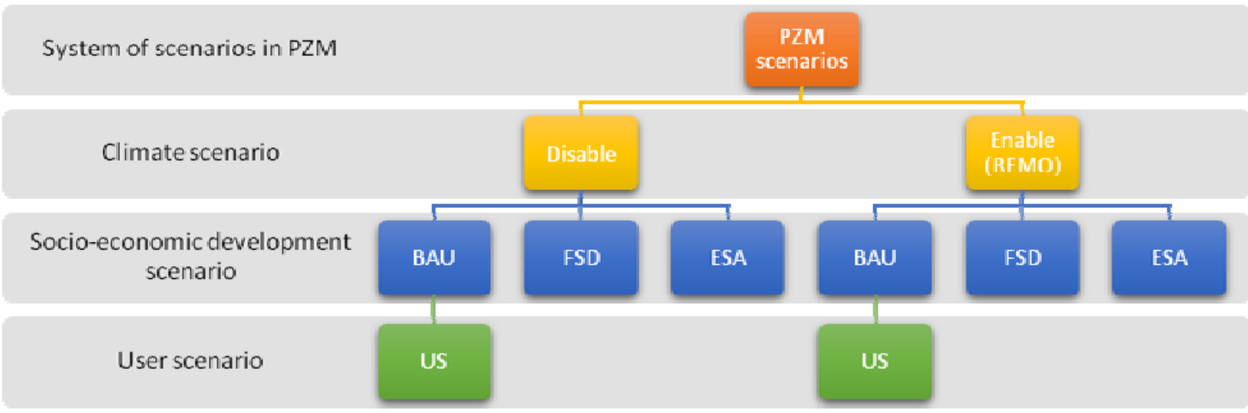


Figure 3.1

The User scenario (US) is based on BAU scenario, with the opportunity to modify input data in the planning zone model (Figure 3.2, indicators of the User scenario).

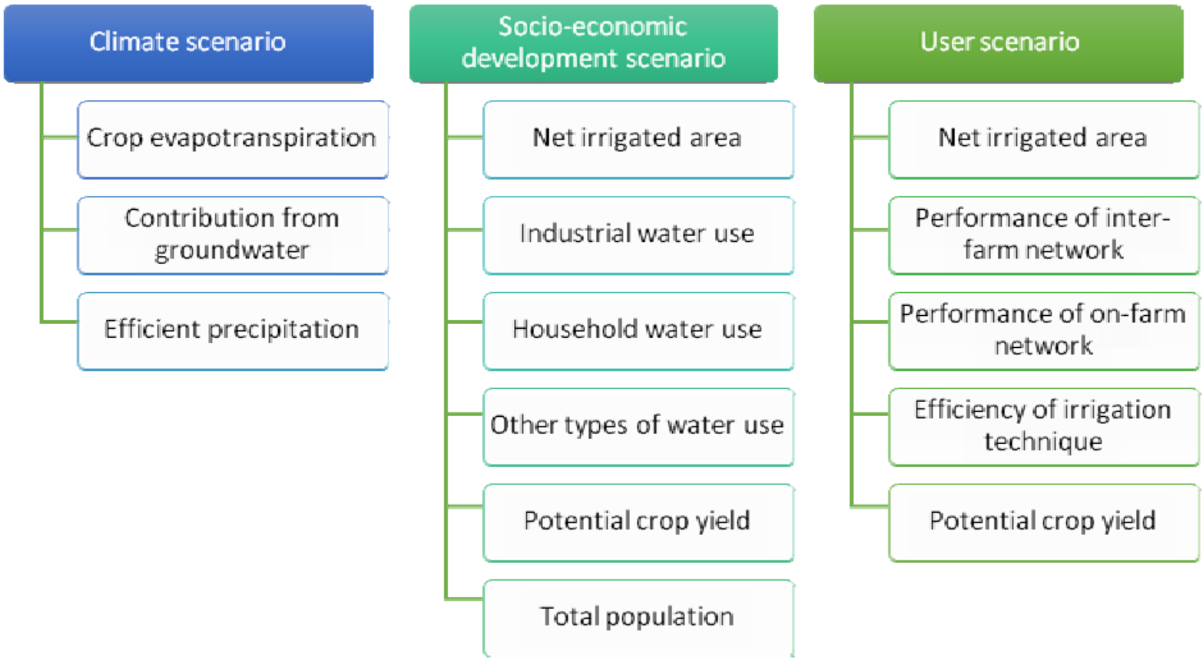


Figure 3.2

The system of scenarios in the planning zone model also includes water and innovation scenarios. The respective scenario is selected via the client interface of the planning zone model on http://cawater-info.net/pzm/basic/web.

The water scenario is selected via the coefficient of provision of water withdrawal limit from transboundary sources (Figure 3.3). This coefficient of provision varies from 5% to 100% with a 5% increment.

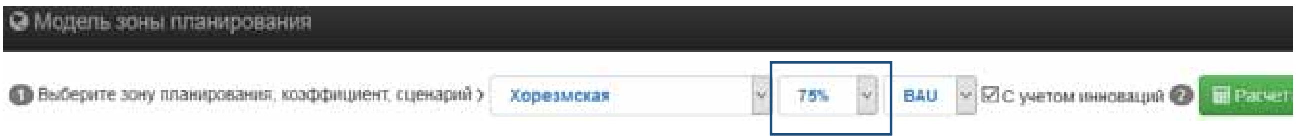


Figure 3.3

The innovation scenario is selected via respective control element (Figure 3.4).

Figure 3.4

In algorithms of the planning zone model, the innovation scenario is determined through indicators of the area with innovative irrigation and efficiency of innovative irrigation technique. Thus, performance of irrigation network and irrigation technique in planning zone is calculated by the following formulas:

Efficiency of irrigation technique *n3_c(y,z,c)*

$$n3_{c(y,z,c)} = \frac{n3_{reg_c} * (F_c - F_{inn_c}) + n3_{inn_c} * F_{inn_c}}{F_c}$$

where *n3_reg_c(y,z,c)* – Efficiency of traditional irrigation technique,

n3_inn_c(y,z,c) – Efficiency of innovative irrigation technique,

F_c(y,z,c) – Irrigated area,

F_inn_c(y,z,c) – Area with innovative irrigation.

Efficiency of irrigation technique *n3(y,z)* in given planning zone

$$n3(y,z) = \frac{\sum(n3_c * F_c)}{\sum F_c}$$

Performance of irrigation network and irrigation technique *n(y,z)* in given planning zone

$$n(y,z) = n1 * n2 * n3$$

where *n1(y,z)* – Efficiency of inter-farm network,

n2(y,z) - Efficiency of on-farm network.

Thus, 120 combinations of scenarios are available for the user, including water and innovation scenarios:

*Number of combinations of scenarios = (climate=2) * (water=10) * (economic=3) * (innovation=2) = 120.*

3.2 Results of calculation by the planning zone model for 2016-2055

The results of calculation by the planning zone model for 2016-2055 are shown in tables and figures below for 10 main combinations of scenarios. Those results are given for the Khorezm planning zone; other results are available on http://cawater-info.net/pzm/basic/web in the section “Model calculations” (Figure 2.3).

The calculation results are provided for the following main indicators: crop water requirements for the growing season, water deficit during the growing season, revenue in irrigated agriculture, revenue losses in irrigated agriculture, irrigated land productivity, and irrigation water productivity. For each indicator, the average, the maximum, and frequency of occurrence of absolute value, which is higher than the average, are calculated.

Table 3.1 shows the results of calculation of crop water requirements and water deficit during the growing season.

The diagram in Figure 3.5 shows the relationship between the average crop water requirements during the growing season 2016-2055 and 10 main combinations of scenarios.

Figures 3.6 and 3.7 show the curves of crop water requirements and water deficit during the growing season for three main combinations of scenarios: 75% BAU, 75% FSD with innovations, and 75% ESA with innovations.

Table 3.1

№	Combination of scenarios	Crop water requirements during the growing season, mcm			Water deficit during the growing season, mcm		
		Average	Max	Freq	Average	Max	Freq
1	**75% BAU**	2,744.46	3,246.89	0.49	463.95	762.11	0.49
2	**100% BAU**	2,744.46	3,246.89	0.49	139.11	249.99	0.57
3	**75% FSD**	3,003.40	3,514.41	0.46	691.97	1053.42	0.46
4	**75% FSD with innovations**	2,894.78	3,367.44	0.40	606.18	917.32	0.46
5	**100% FSD**	3,003.40	3,514.41	0.46	263.24	449.41	0.51
6	**100% FSD with innovations**	2,894.78	3,367.44	0.40	218.63	366.17	0.49
7	**75% ESA**	2,980.67	3,499.39	0.49	668.35	1015.65	0.46
8	**75% ESA with innovations**	2,827.38	3,298	0.40	549.57	830.85	0.49
9	**100% ESA**	2,980.67	3,499.39	0.49	247.00	422.46	0.54
10	**100% ESA with innovations**	2,827.38	3,298	0.40	189.87	325.4	0.54

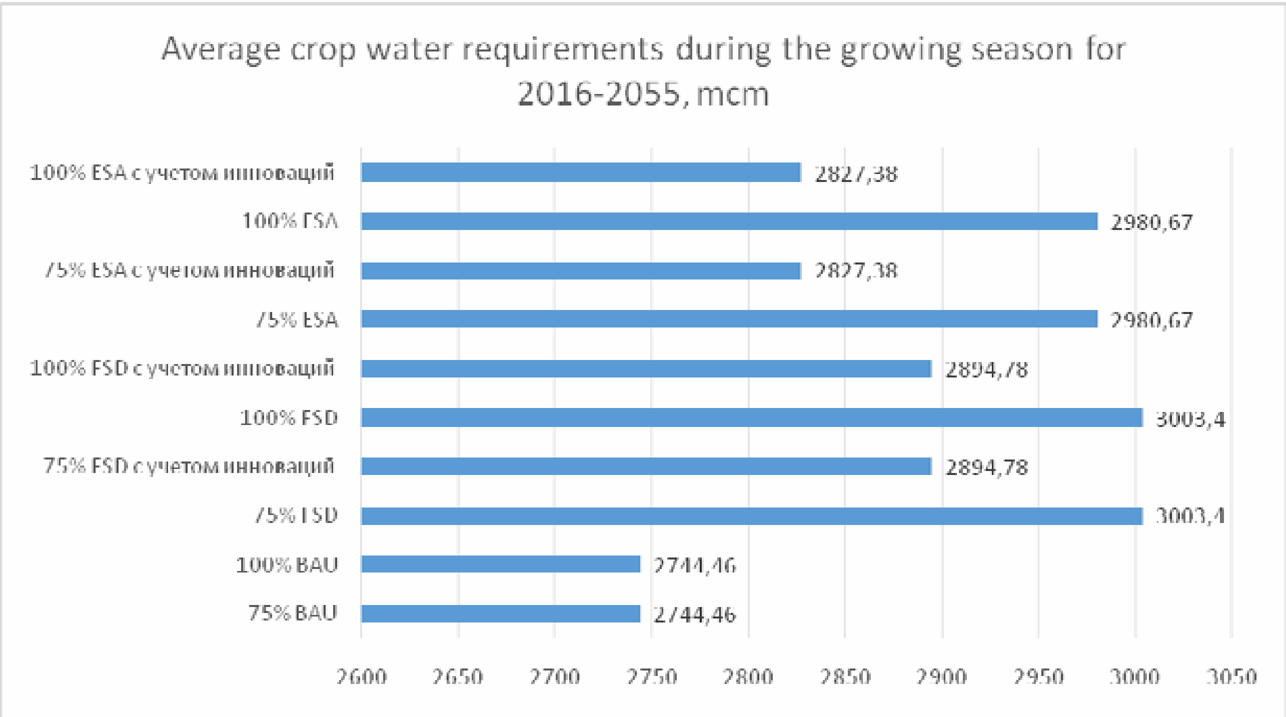
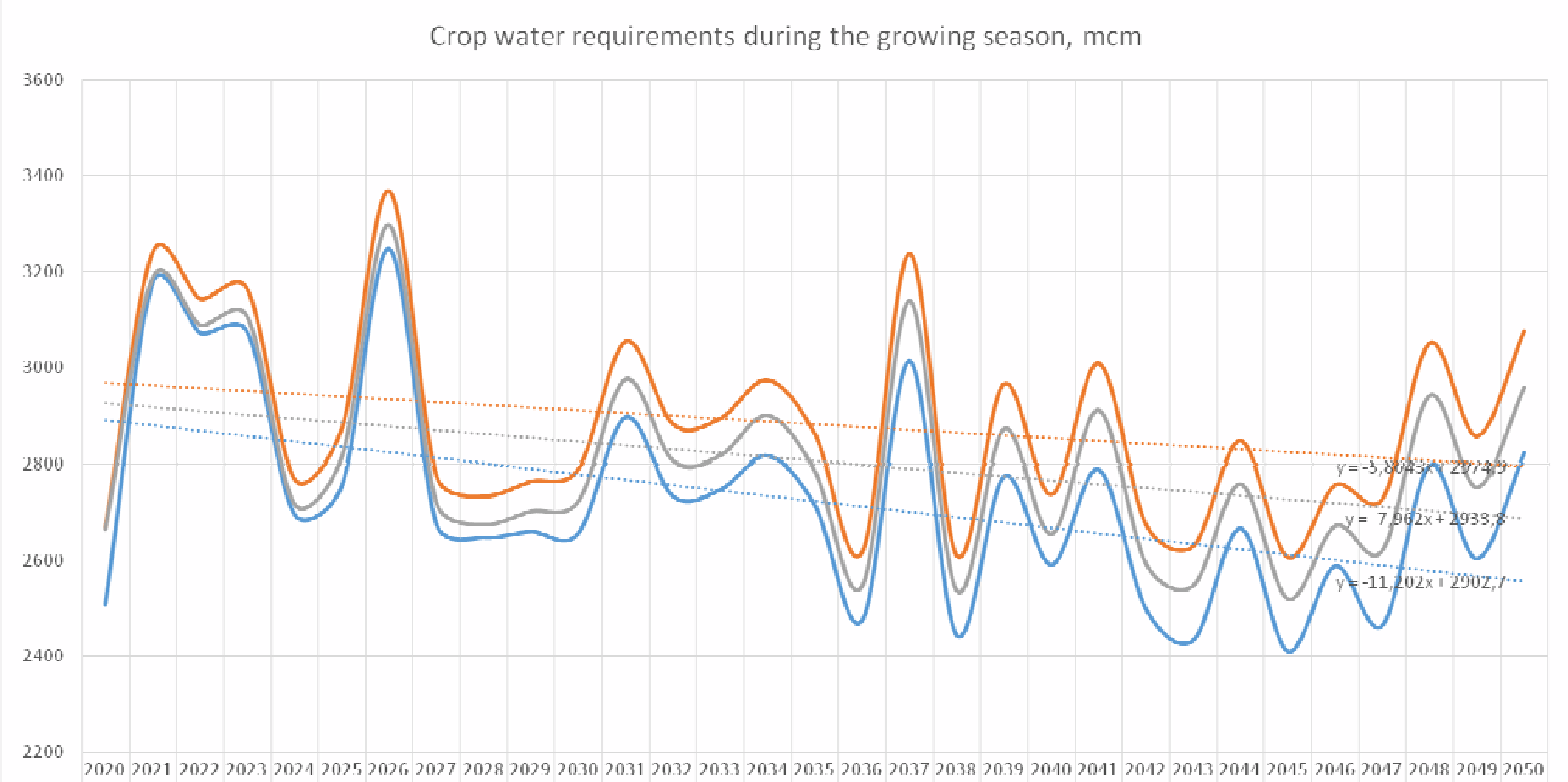
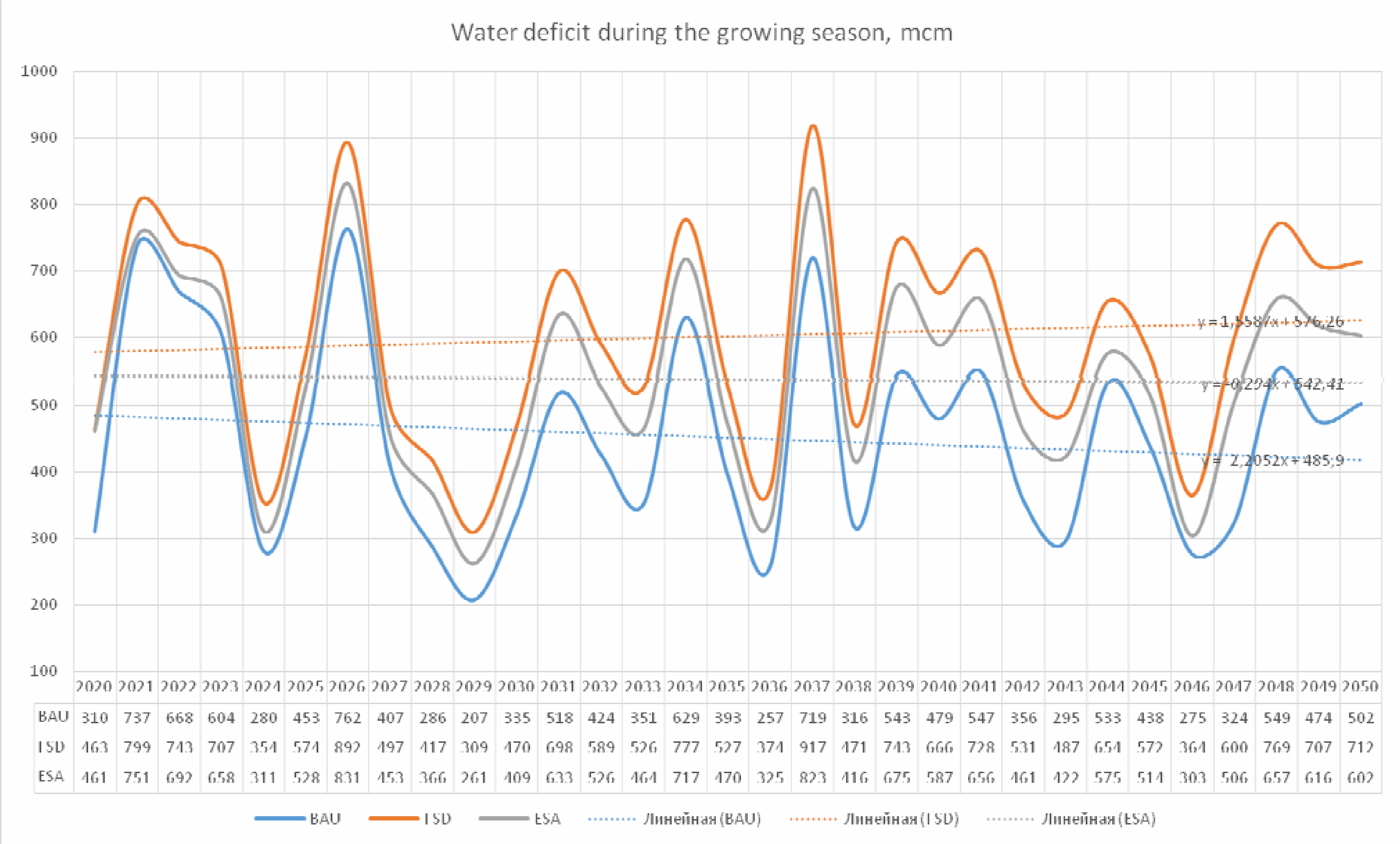


Figure 3.5



	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
BAU	2508	3176	3072	3074	2694	2755	3247	2674	2647	2659	2656	2896	2733	2747	2816	2714	2474	3013	2443	2774	2590	2788	2497	2432	2665	2409	2587	2464	2798	2603	2822
TSD	2667	3240	3143	3163	2768	2873	3367	2775	2733	2764	2789	3054	2881	2893	2973	2861	2617	3237	2609	2965	2736	3009	2674	2629	2847	2605	2756	2727	3050	2857	3076
ESA	2664	3188	3090	3107	2716	2816	3298	2719	2674	2702	2723	2976	2806	2817	2900	2785	2546	3140	2536	2872	2655	2911	2592	2546	2759	2519	2671	2620	2942	2752	2959

Figure 3.6



	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
BAU	310	737	668	604	280	453	762	407	286	207	335	518	424	351	629	393	257	719	316	543	479	547	356	295	533	438	275	324	549	474	502
TSD	463	799	743	707	354	574	892	497	417	309	470	698	589	526	777	527	374	917	471	743	666	728	531	487	654	572	364	600	769	707	712
ESA	461	751	692	658	311	528	831	453	366	261	409	633	526	464	717	470	325	823	416	675	587	656	461	422	575	514	303	506	657	616	602

Figure 3.7

Table 3.2 shows the results of calculation of revenue and its losses in irrigated agriculture.

Figure 3.8 shows the relationship between the average revenue in irrigated agriculture over 2016-2055 and the 10 main combinations of scenarios.

Figures 3.9 and 3.10 show the curve of revenue and its losses in irrigated agriculture for three main combinations of scenarios: 75% BAU, 75% FSD with innovations, and 75% ESA with innovations.

Table 3.3 shows the results of calculation of irrigated land and irrigation water productivity.

Figure 3.11 shows the relationship between the average productivity of irrigated agriculture over 2016-2055 and the 10 main combinations of scenarios.

Figures 3.12 and 3.13 show the curves of irrigated land and irrigation water productivity for three main combinations of scenarios: 75% BAU, 75% FSD with innovations, and 75% ESA with innovations.

Table 3.2

№	Combination of scenarios	Revenue in irrigated agriculture, M$			Revenue losses in irrigated agriculture, M$		
		Average	Max	Freq	Average	Max	Freq
1	**75% BAU**	442.73	496.68	0.54	59.10	94.22	0.51
2	**100% BAU**	490.89	530.64	0.54	10.94	22.45	0.34
3	**75% FSD**	596.46	817.80	0.54	129.11	217.27	0.43
4	**75% FSD with innovations**	689.76	968.59	0.54	128.18	216.17	0.43
5	**100% FSD**	691.86	942.31	0.54	33.71	78.35	0.34
6	**100% FSD with innovations**	788.73	1,102.99	0.54	29.21	76.54	0.40
7	**75% ESA**	687.22	1,016.29	0.54	141.08	252.49	0.43
8	**75% ESA with innovations**	862.70	1,316.47	0.54	139.95	254.05	0.43
9	**100% ESA**	793.59	1,197.37	0.54	34.70	83.57	0.34
10	**100% ESA with innovations**	974.17	1,528.28	0.54	28.47	80.66	0.34

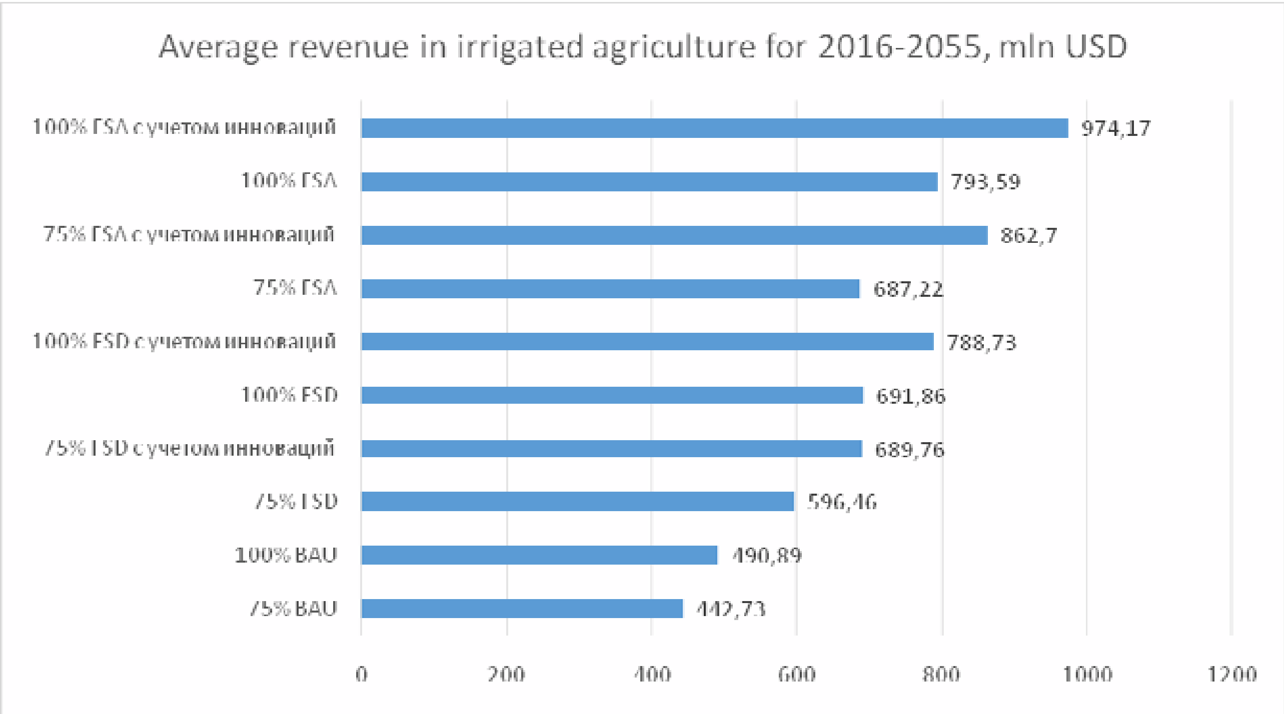


Figure 3.8

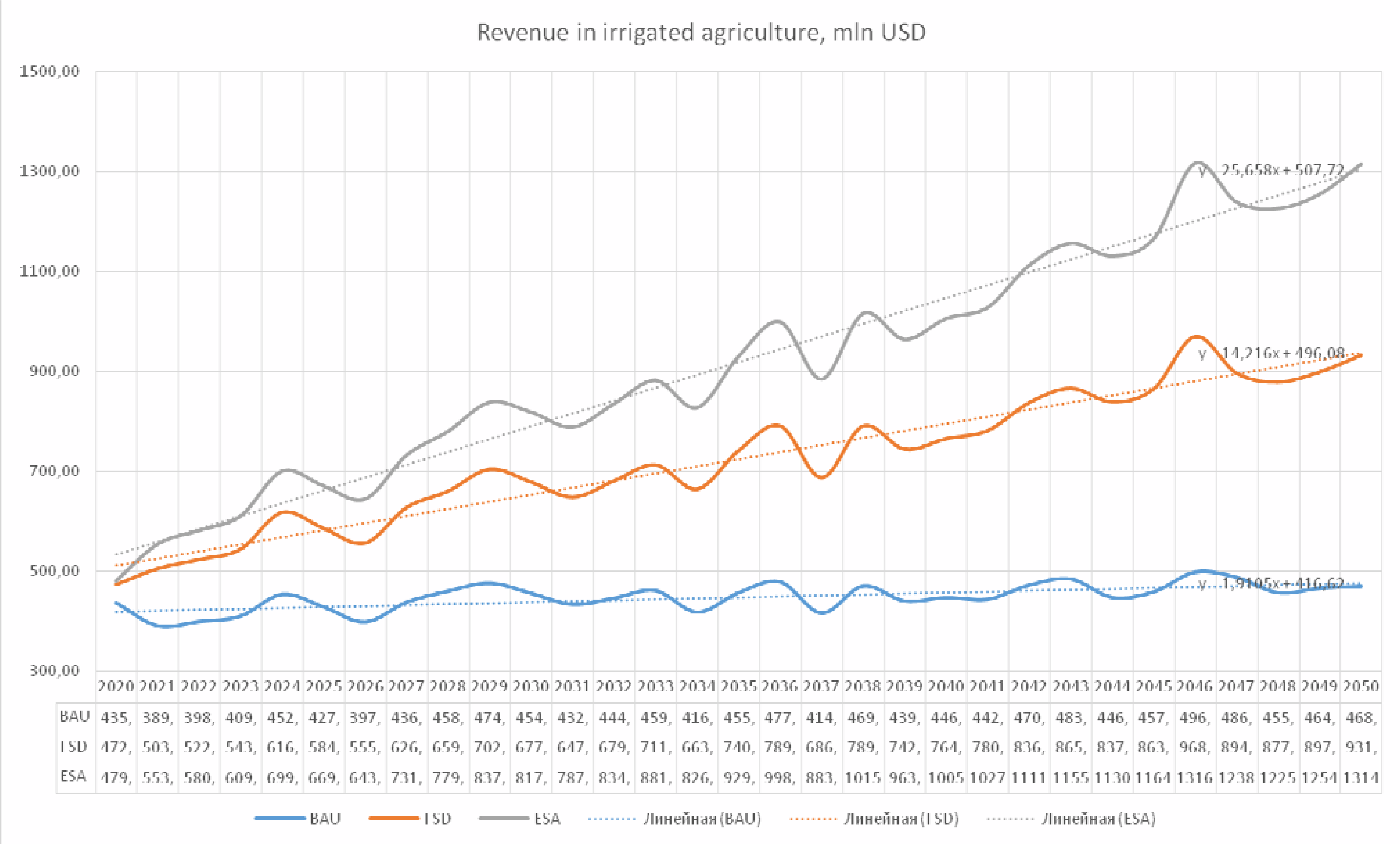
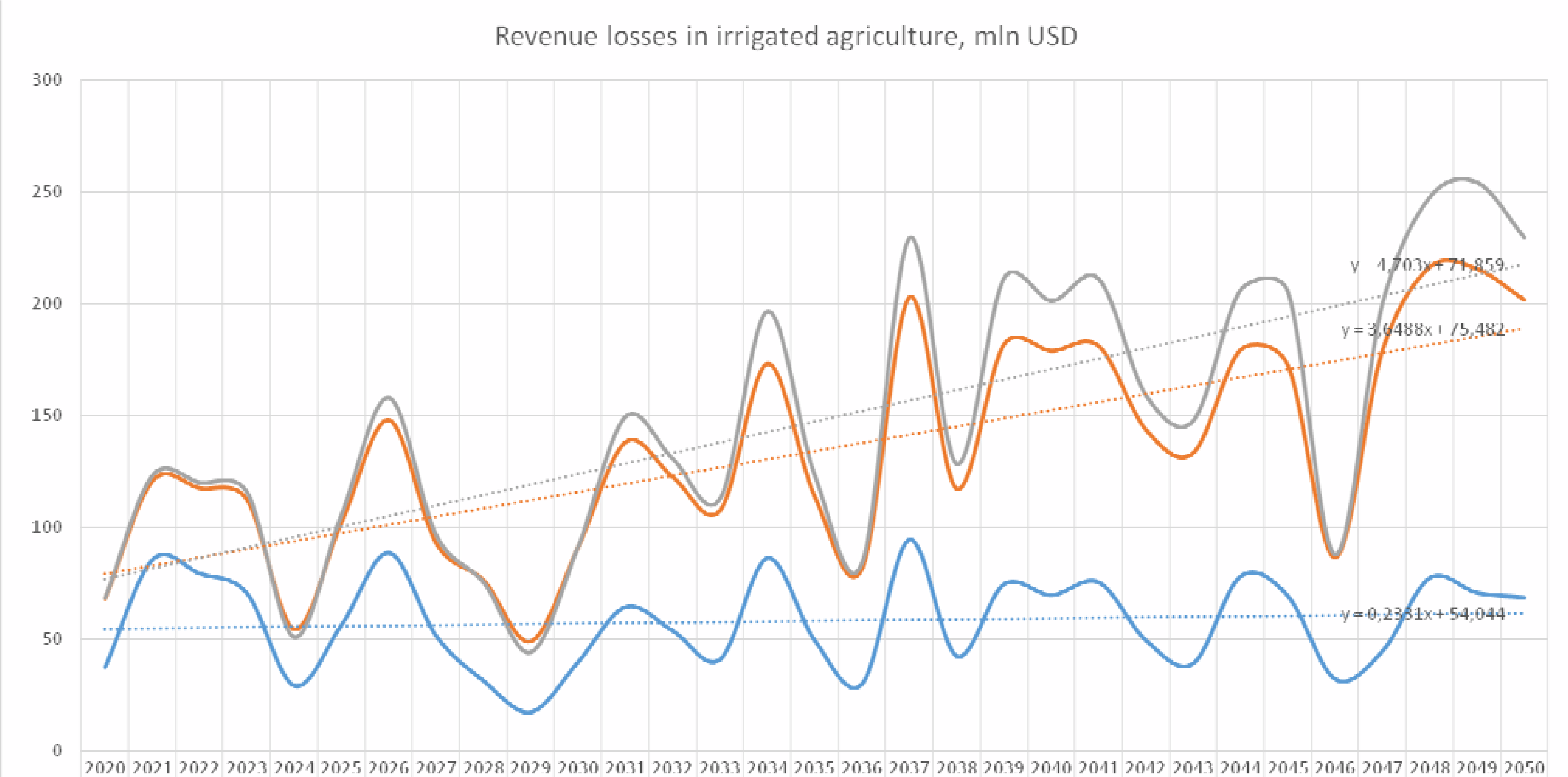

Revenue in irrigated agriculture, mln USD
1500,00
1300,00
1100,00
900,00
700,00
500,00
300,00
y = 25,658x + 507,72
y = 14,216x + 496,08
y = 1,9105x + 416,62
2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050
BAU 435, 389, 398, 409, 452, 427, 397, 436, 458, 474, 454, 432, 444, 459, 416, 455, 477, 414, 469, 439, 446, 442, 470, 483, 446, 457, 496, 486, 455, 464, 468,
TSD 472, 503, 522, 543, 616, 584, 555, 626, 659, 702, 677, 647, 679, 711, 663, 740, 789, 686, 789, 742, 764, 780, 836, 865, 837, 863, 968, 894, 877, 897, 931,
ESA 479, 553, 580, 609, 699, 669, 643, 731, 779, 837, 817, 787, 834, 881, 826, 929, 998, 883, 1015 963, 1005 1027 1111 1155 1130 1164 1316 1238 1225 1254 1314
BAU
TSD
ESA
Линейная (BAU)
Линейная (TSD)
Линейная (ESA)

Figure 3.9



	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
BAU	37,2	85,2	79,1	70,2	28,9	56,3	88,3	51,2	31,1	17,3	39,7	64,2	53,5	40,8	85,9	49,2
TSD	67,5	120	117	112	54,1	102	148	92,5	76	48,6	90,9	138	122	107	173	113
ESA	68,1	123	120	116	50,8	106	158	96,3	75,2	44	91,3	149	130	113	196	123

	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
BAU	29,8	94,2	42,3	74,4	69,4	75,2	49,3	39	77,9	69,1	31,9	44,5	77,2	70,4	68,4
TSD	81,3	203	117	182	179	181	143	133	179	172	86,1	179	216	215	201
ESA	84	229	128	211	201	211	159	147	206	205	87,6	200	247	254	229

Figure 3.10

Table 3.3

№	Combination of scenarios	Irrigated land productivity, $/ha			Irrigation water productivity, $/m³		
		Average	Max	Freq	Average	Max	Freq
1	**75% BAU**	1,829.36	2,033.69	0.54	0.20	0.23	0.49
2	**100% BAU**	2,028.35	2,165.39	0.46	0.19	0.23	0.60
3	**75% FSD**	2,436.26	3,338.74	0.49	0.26	0.36	0.43
4	**75% FSD with innovations**	2,817.36	3,954.34	0.49	0.30	0.42	0.43
5	**100% FSD**	2,825.92	3,846.17	0.49	0.26	0.35	0.43
6	**100% FSD with innovations**	3,221.59	4,501.99	0.51	0.30	0.42	0.49
7	**75% ESA**	2,806.90	4,149.08	0.46	0.30	0.44	0.43
8	**75% ESA with innovations**	3,523.64	5,374.6	0.49	0.38	0.59	0.43
9	**100% ESA**	3,241.38	4,887.21	0.46	0.29	0.44	0.43
10	**100% ESA with innovations**	3,978.95	6,237.86	0.51	0.38	0.58	0.43

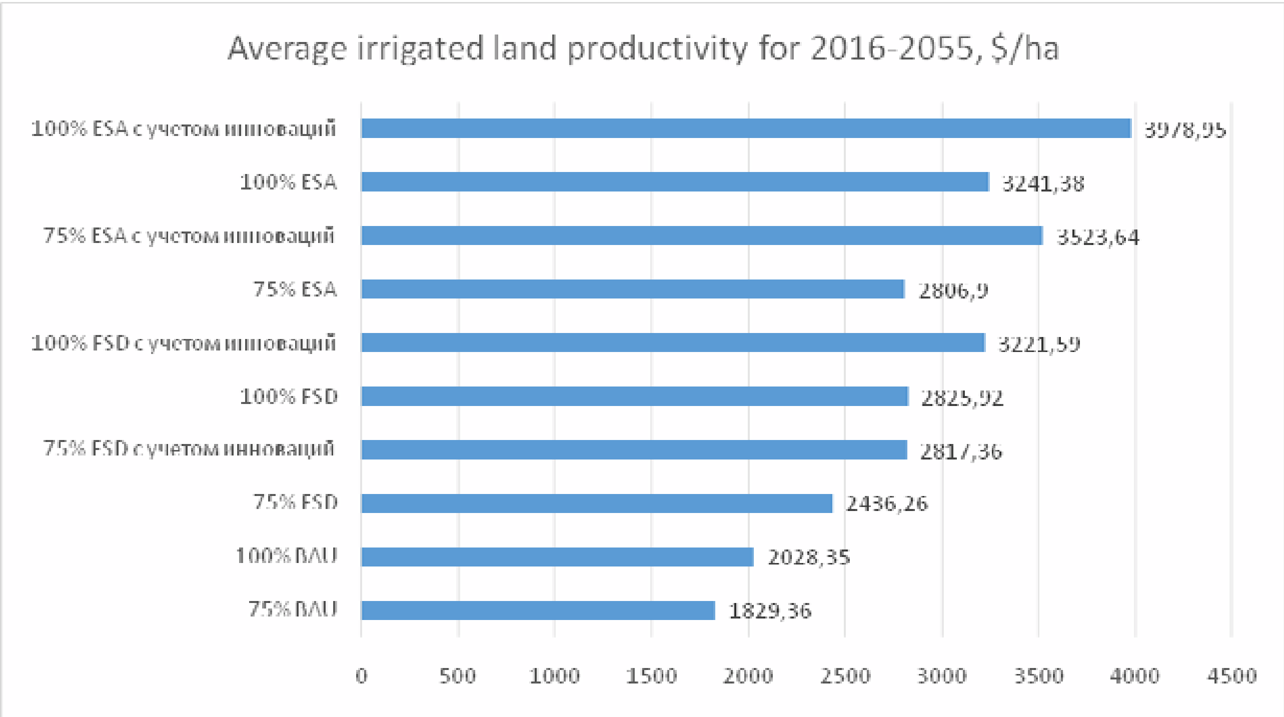
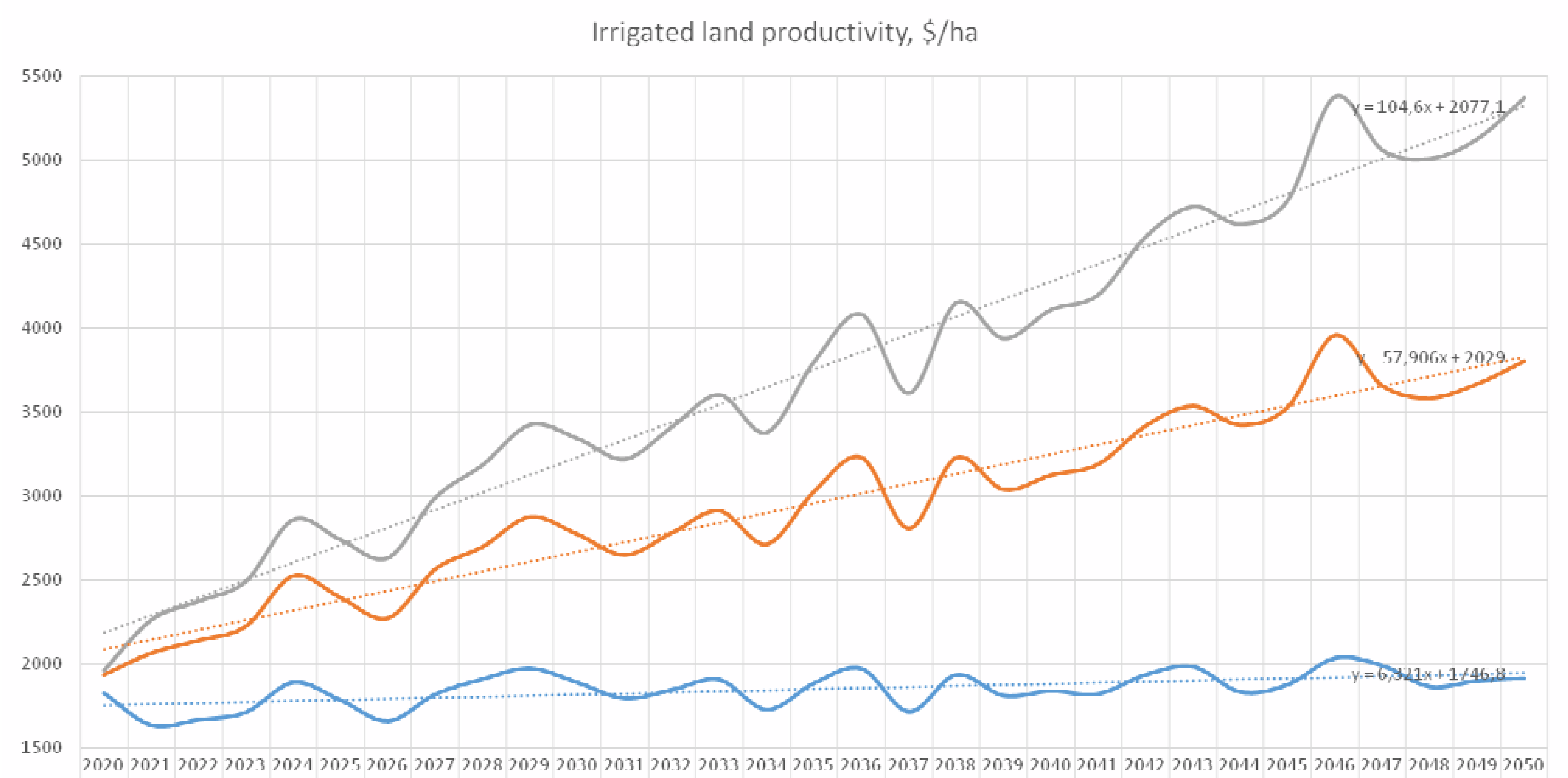


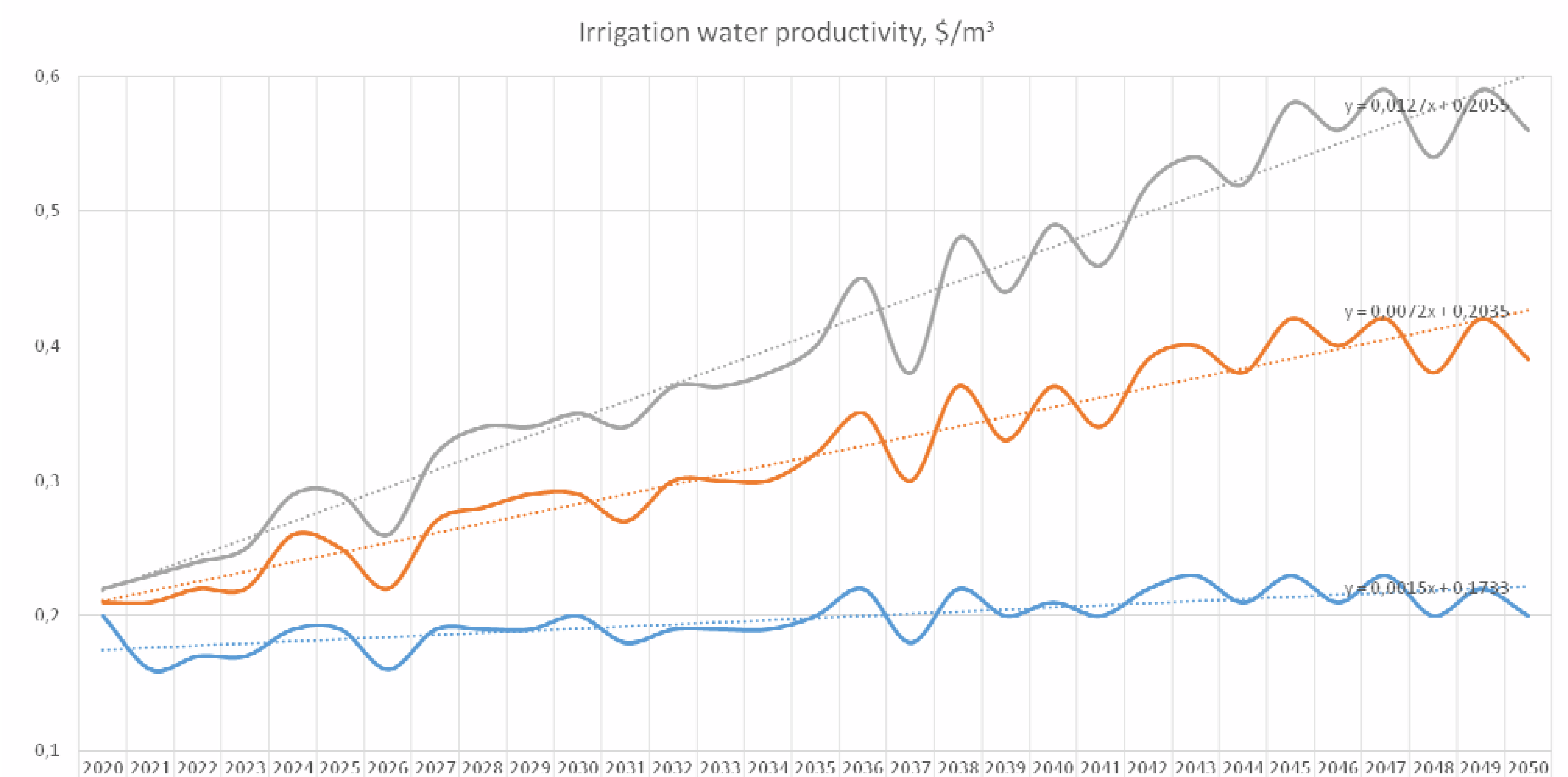
Figure 3.11



	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
BAU	1824	1631	1664	1708	1888	1781	1655	1817	1908	1973	1887	1792	1844	1904	1724	1884
TSD	1931	2060	2136	2221	2521	2390	2269	2560	2694	2873	2768	2644	2777	2908	2710	3023
ESA	1961	2261	2373	2491	2858	2738	2630	2989	3184	3422	3341	3218	3410	3600	3377	3796

	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
BAU	1971	1712	1934	1809	1837	1820	1934	1983	1831	1874	2034	1989	1863	1897	1913
TSD	3226	2803	3225	3035	3120	3186	3414	3532	3420	3525	3954	3654	3580	3663	3800
ESA	4078	3609	4147	3935	4105	4195	4539	4720	4616	4756	5375	5056	5004	5120	5366

Figure 3.12



	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
BAU	0,2	0,16	0,17	0,17	0,19	0,19	0,16	0,19	0,19	0,19	0,2	0,18	0,19	0,19	0,19	0,2
TSD	0,21	0,21	0,22	0,22	0,26	0,25	0,22	0,27	0,28	0,29	0,29	0,27	0,3	0,3	0,3	0,32
ESA	0,22	0,23	0,24	0,25	0,29	0,29	0,26	0,32	0,34	0,34	0,35	0,34	0,37	0,37	0,38	0,4

	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
BAU	0,22	0,18	0,22	0,2	0,21	0,2	0,22	0,23	0,21	0,23	0,21	0,23	0,2	0,22	0,2
TSD	0,35	0,3	0,37	0,33	0,37	0,34	0,39	0,4	0,38	0,42	0,4	0,42	0,38	0,42	0,39
ESA	0,45	0,38	0,48	0,44	0,49	0,46	0,52	0,54	0,52	0,58	0,56	0,59	0,54	0,59	0,56

Figure 3.13