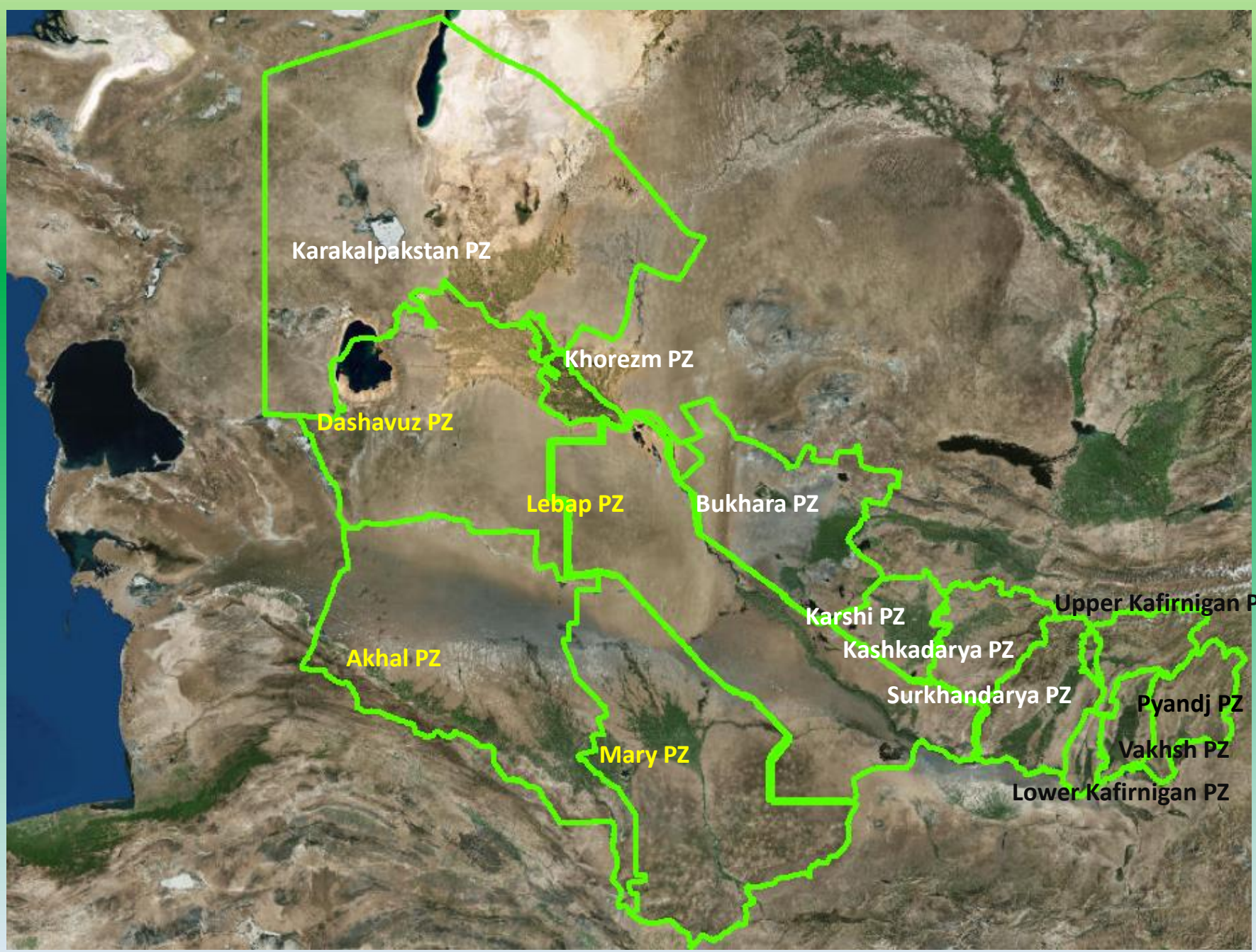
# PEER Project

## calculation of crop water requirements in climate change context and production agricultural crops

Prof. V.A. Dukhovniy
Dr. Sh. Muminov
Ir. G.F. Solodkiy
Dr. G.V. Stulina

# GENERAL LAYOUT OF PLANNING ZONES



# COLLECTION AND ANALYSIS OF DATA

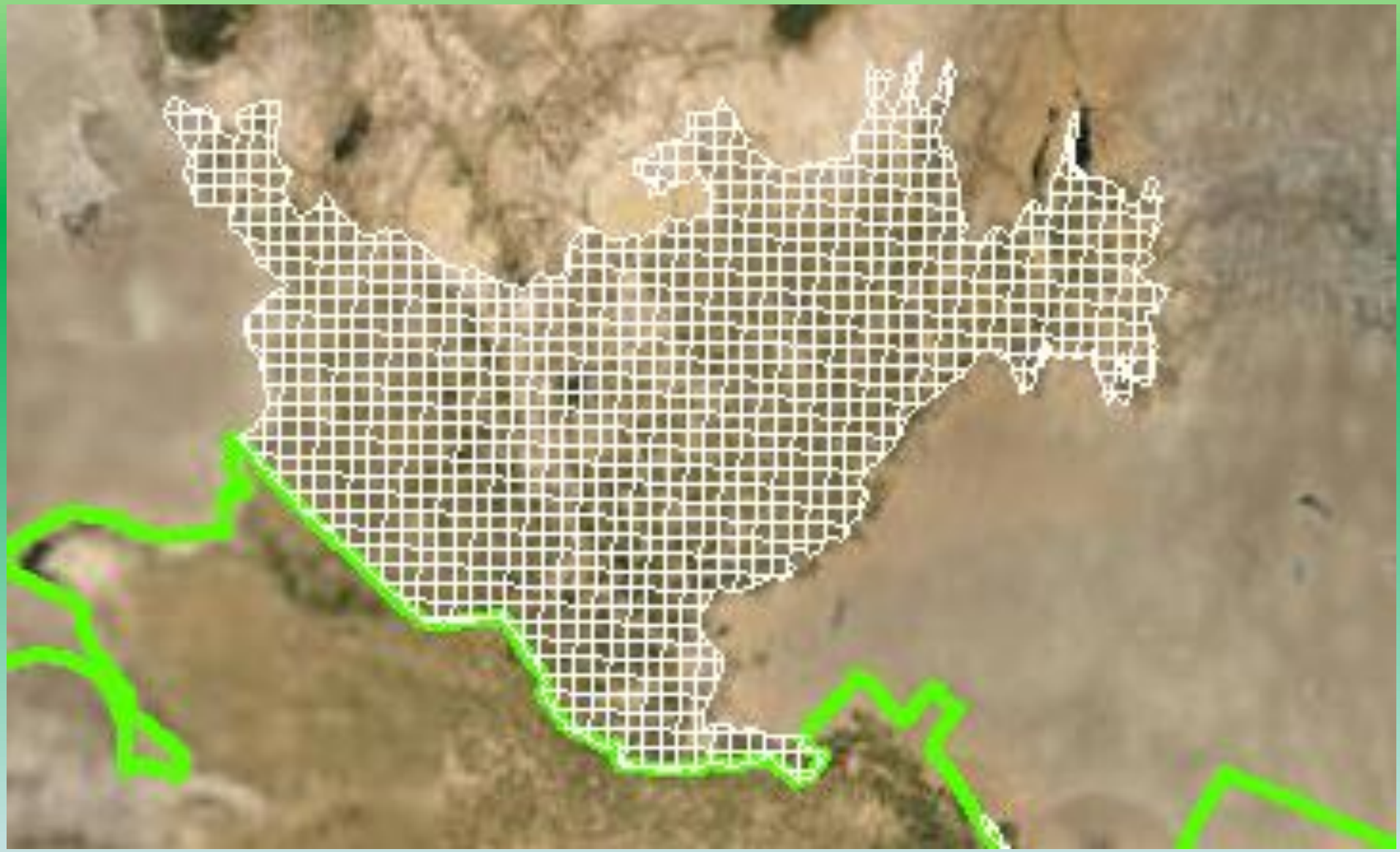
| # | Data | Status |
|---|---|---|
| 1 | GIS-files of all planning zones supplied from the Amudarya River | collected |
| 2 | GIS-files of Central Asia irrigated area | collected |
| 3 | Simulated climate data by REMO for 2000 - 2050 | collected |
| 4 | Climate data from aeronautical weather stations - http://gis.ncdc.noaa.gov/ | collected |
| 5 | GIS-files of soil map for planning zones in Uzbekistan and Turkmenistan | Prepared for Uzbekistan and Turkmenistan |
| 6 | Groundwater table for last 5 years by planning zone | Collected for Uzbekistan and Turkmenistan |
| 7 | Rainfall data by planning zone from http://climateserv.nsstc.nasa.gov/ | collected |
| 8 | GIS-files of administrative districts of planning zones in Uzbekistan | Prepared for Uzbekistan and Turkmenistan |
| 9 | Calculated matrices of PZ irrigated land | done |
| 10 | Temperature characteristics of crops | collected |

# DATA DESCRIPTION

- GIS-files of PZs and identification of PZs, as well as GIS-files of Central Asia irrigated area also were generated at SIC.
- REMO simulated climate data for 2000-2050 were received from the University of Wurzburg (Germany) as part of the CAWA Project.
- As the ground-based data we used the data of aeronautical meteorological stations (AMST) from the site http://gis.ncdc.noaa.gov/. This is explained by denser network of stations of the former as compared to that of the HYDROMET. AMST data were adjusted in line with HYDROMET's format.

- Historical rainfall data were taken from the site http://climateserv.nsstc.nasa.gov/. By using the data of aeronautical meteorological stations, we calibrated average daily temperatures and rainfall data from REMO.
- GIS-file of administrative districts of planning zones considered in the project has become needed as the data on groundwater table were provided in tables in the form of average ten-day values by district.
- The calculated matrices of PZ irrigated land areas are the grid of square polygons 3 kilometers on a side that fully cover the irrigated area of each PZ. Such matrices were prepared for each PZ.

# Northern Karakalpakstan PZ



# Irrigated land of Bukhara PZ

# Irrigated land of Mary PZ

# WATER REQUIREMENTS MODELING TECHNIQUE

- Water requirements are determined for each cell of the grid as crop evapotranspiration minus effective rainfall and minus groundwater contribution.
- Evapotranspiration is calculated using the Penman-Monteith formula and the Blaney-Criddle method.
- Effective rainfall was calculated by the formula of the United States Department of Agriculture Soil Conservation Service.
- Contribution from groundwater was estimated by Laktaev-Kharchenko formula.

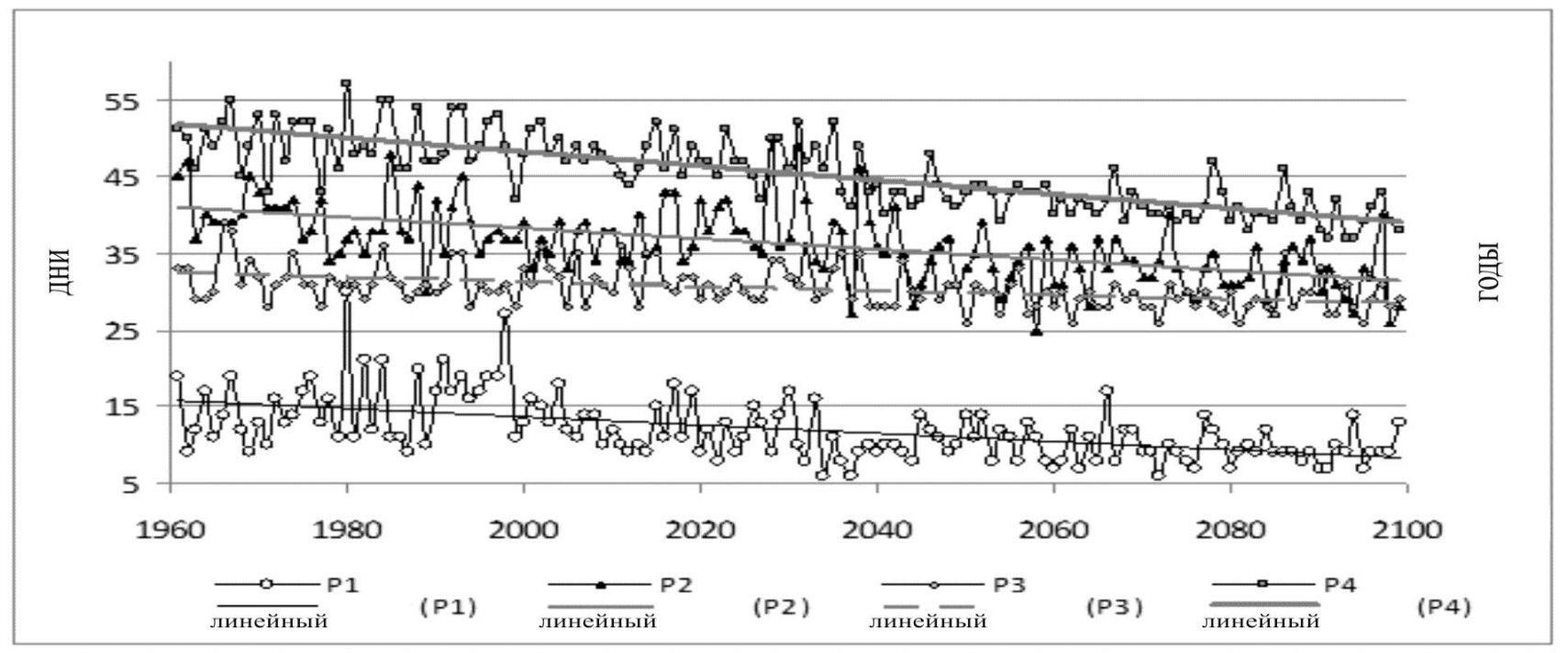
# CONSIDERATION OF CLIMATE CHANGE

- Climate change is accounted through the following :
- 1. Application of the REMO model. The model is based on greenhouse gas emission forecast and calculates climate parameters up to 2050.
- 2. Shift in crop sowing to earlier dates as temperature grows.
- 3. Shortening of crop development phases.

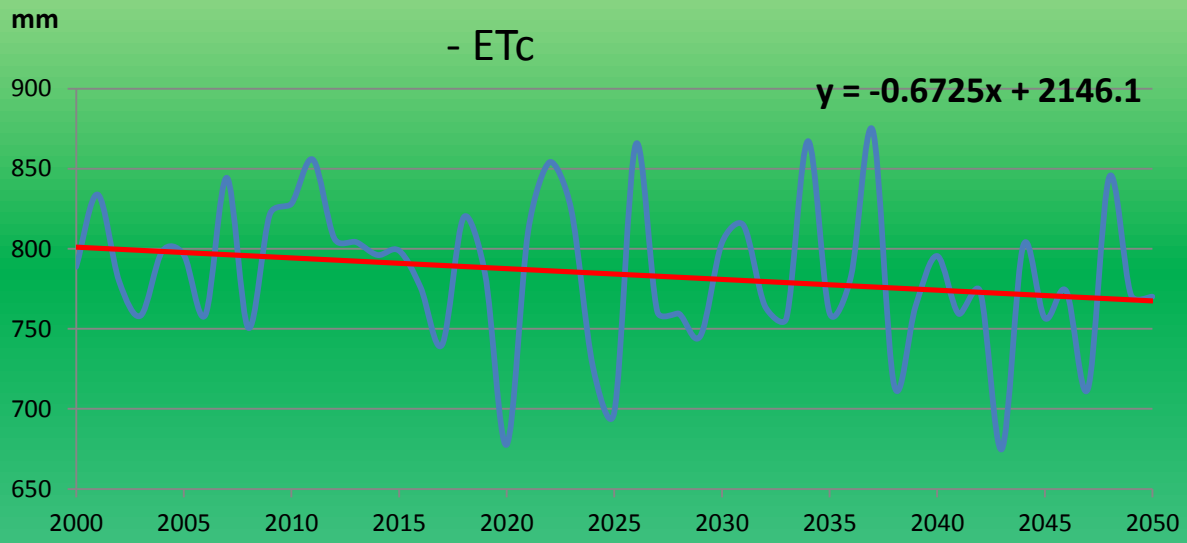
# RESULTS

- Irrigated land area of each PZ covered by the grid.
- ETo, Rain and T calibrated.
- ETo, EffRAIN and GWT calculated for each cell
- Sowing dates and plant development phase duration calculated for each PZ for each crop and year.
- Ten-day and monthly water requirements calculated. The output was inputted into the planning zone model.
- As the crop sowing dates shifted to early spring and the total time of plant growing has shortened, a period of growing time fell into a space of increased humidity and intensive rainfall. As a consequence, crop water requirements have decreased.

# The rate of reduction vegetation period of cotton and its' different phases by REMO

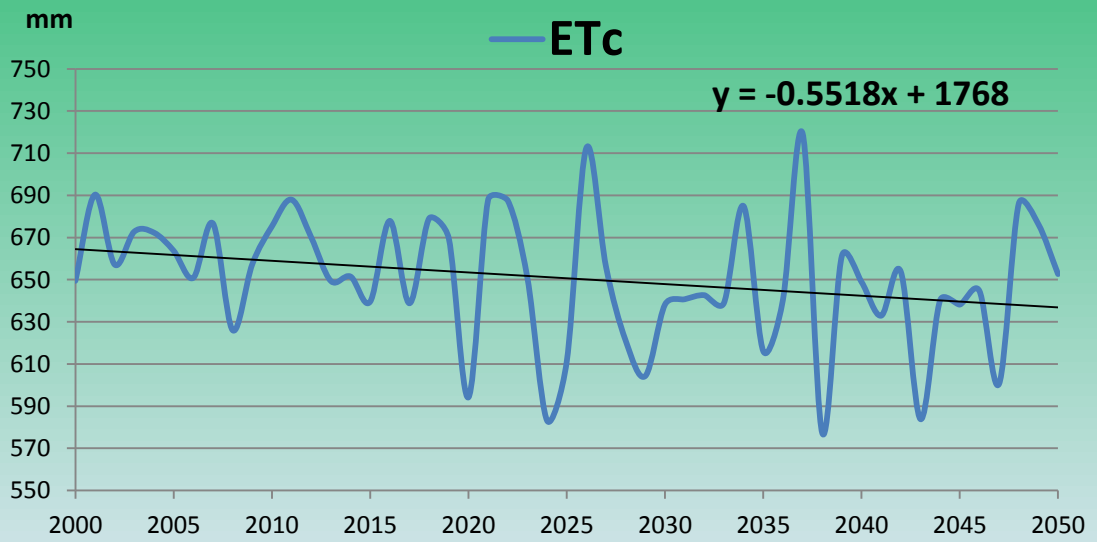


# BUKHARA evapotranspiration trends

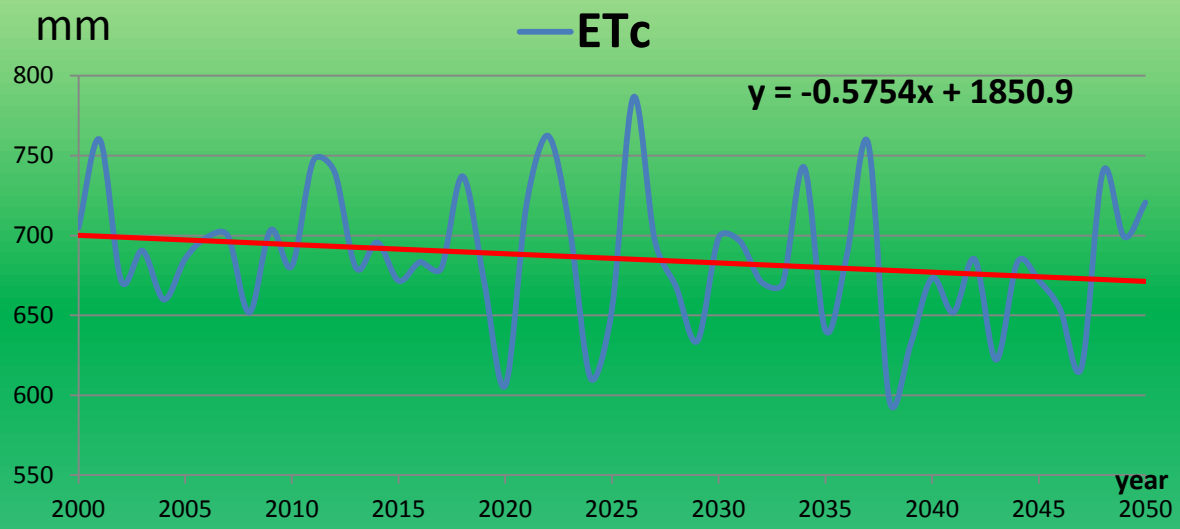



**VEGETABLES**

**FRUITS/GRAPES**

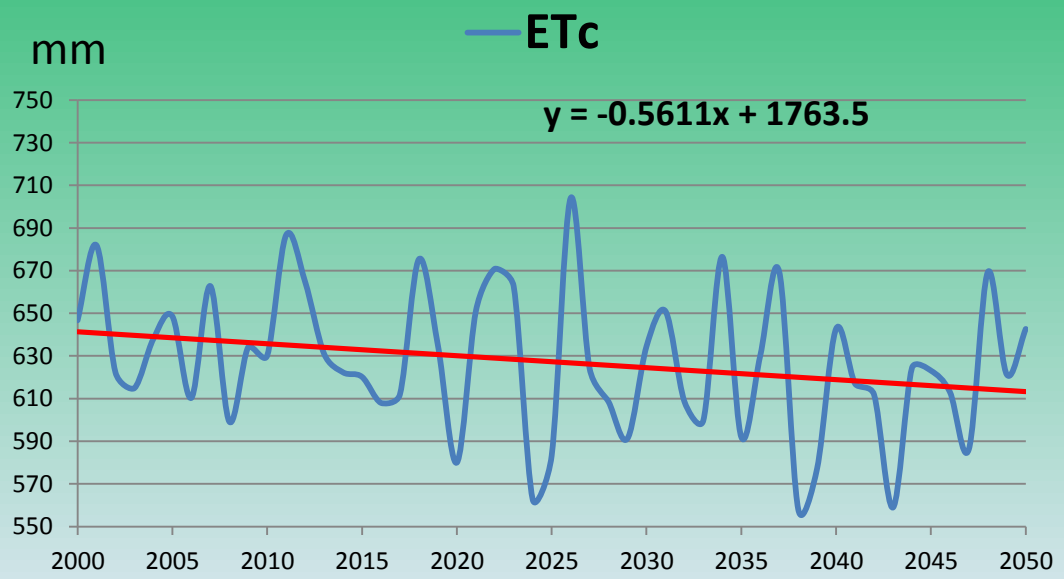


# BUKHARA evapotranspiration trends - 2

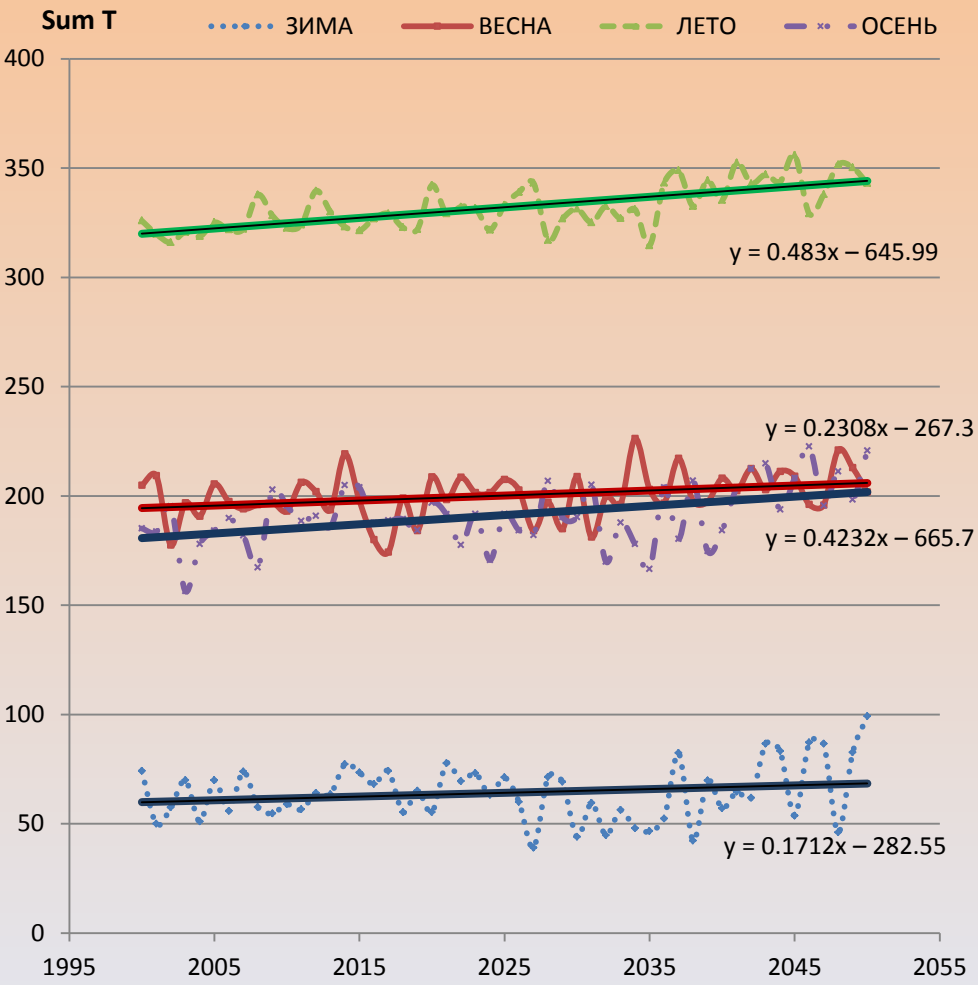



**FODDER**

**OTHER CROPS**



# BUKHARA – Dynamics of air temperature growth in year seasons




**The growth rate of mean temperature in summer combined with that in spring and autumn prolongs the period, during which crops can grow.**

# Shortening of crop growing (days)

| | legumes | potato | Maize corn | alfalfa | Winter wheat | Sweet melon | Early cotton | Late cotton | Maize silage | rice | orchards | Double-season maize silage | Double-season rice |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Akhal1 | -5,6 | -8,1 | -7,2 | -10,1 | -7,4 | -15,4 | -9,3 | -21,3 | -4,8 | -8,5 | 9,9 | -6,8 | 6,8 |
| Akhal2 | -3,7 | -8,1 | -7,2 | -9,6 | -8,1 | -16 | -9,4 | -18,5 | -4,7 | -8,1 | 9,3 | -6,4 | 6,4 |
| Bukhara | -6,5 | -7,6 | -7,5 | -7,6 | -5,6 | -8,2 | -9,3 | -15,4 | -5,9 | -3,9 | 8,3 | -5,4 | 7,7 |
| Dashoguz | -2,2 | -8,4 | -7,4 | -9,6 | -6,9 | -13,4 | -9,3 | -20,9 | -4,6 | -7,5 | 6,2 | -6 | 4,1 |
| Upper Kafirnigan | -10,5 | -17,8 | -15,1 | -12,1 | -4,9 | -30,2 | -21,5 | -18,2 | -8,9 | -26,7 | 9,1 | -12,7 | 5,4 |
| Lower Kafirnigan | -7,2 | -8,9 | -7,5 | -8,3 | -5,8 | -21,5 | -11,8 | -7,4 | -2,7 | -20,5 | 7,7 | -8,7 | 1,5 |
| Khorezm | -6,7 | -8,7 | -7,2 | -6 | -5,1 | -10,7 | -11,1 | 2,8 | -3,5 | -14 | 8,1 | -6,8 | 3,1 |
| Karakalpakstan | -8,2 | -8,1 | -6,4 | -6,1 | -5,3 | -11,9 | -10,4 | 5,2 | -3,1 | -19,8 | 9,1 | -6,7 | 4,2 |
| Karshi | -7,8 | -9,5 | -8,1 | -7,1 | -5,5 | -14,2 | -12,2 | -2,6 | -3,7 | -17,4 | 6,7 | -8,1 | 2,1 |
| Kashkadarya | -7,2 | -10,3 | -8,6 | -9,5 | -4,9 | -20,2 | -12,3 | -7,6 | -3,9 | -19,2 | 9,1 | -9,2 | 3,1 |
| Lebap 2 | -7,1 | -8,5 | -7,2 | -7,5 | -5,2 | -13,9 | -11,1 | 2,6 | -3 | -18,8 | 6,2 | -7,9 | 2,6 |
| Lebap 3 | -6,7 | -10,3 | -9,3 | -7,4 | -5,4 | -16,2 | -12,6 | -2,8 | -4,5 | -20,4 | 6,3 | -8,1 | 2 |
| Mary | -6,8 | -9,6 | -8,5 | -8,7 | -4,3 | -14,7 | -12,7 | 0,6 | -3,8 | -20,2 | 5,1 | -8 | 2 |
| Pyandj | -8,1 | -11,2 | -9 | -10,9 | -6,9 | -25,1 | -14 | -12,4 | -3,2 | -21,9 | 10,5 | -11,4 | 3,1 |
| Surkhandarya | -9,8 | -12,5 | -10,9 | -9,1 | -5,1 | -24,9 | -15,9 | -12,3 | -5,5 | -22 | 8,7 | -10,5 | 2,9 |
| Vakhsh | -7,7 | -8,8 | -7,2 | -9,6 | -6,3 | -23,5 | -12,4 | -8,6 | -1,9 | -22,4 | 10,8 | -10,4 | |

# Min, max and average water requirements in 2010, 2025 and 2050, m3/ha

| PLANNING ZONE | YEAR | VEGETABLES | FRUITS/GRAPE | FODDER | OTHER | DOUBLE-SEASON |
|---|---|---|---|---|---|---|
| | | Ave | Ave | Ave | Ave | Ave |
| BUKHARA | 2010 | 6736 | 2981 | 5308 | 5169 | 5068 |
| BUKHARA | 2025 | 6396 | 2862 | 5139 | 5022 | 5148 |
| BUKHARA | 2050 | 6411 | 2946 | 5129 | 5048 | 4933 |
| KHOREZM | 2010 | 5012 | 3873 | 4431 | 3415 | 3792 |
| KHOREZM | 2025 | 5077 | 3789 | 4372 | 3444 | 3839 |
| KHOREZM | 2050 | 4929 | 3775 | 4334 | 3389 | 3705 |
| KARSHI | 2010 | 7203 | 4207 | 5688 | 5374 | 5451 |
| KARSHI | 2025 | 7032 | 4124 | 5663 | 5180 | 5169 |
| KARSHI | 2050 | 6930 | 4200 | 5604 | 5341 | 5169 |
| KARAKALPAKSTAN | 2010 | 6101 | 3612 | 4662 | 4546 | 4726 |
| KARAKALPAKSTAN | 2025 | 6241 | 3559 | 4709 | 4587 | 4802 |
| KARAKALPAKSTAN | 2050 | 6035 | 3478 | 4509 | 4496 | 4656 |
| SURKHANDARYA | 2010 | 7050 | 3755 | 5511 | 5268 | 5285 |
| SURKHANDARYA | 2025 | 6895 | 3721 | 5543 | 5097 | 5046 |
| SURKHANDARYA | 2050 | 6560 | 3691 | 5351 | 5069 | 4926 |

Hence, it is found that by using the suggested technique it is possible to avoid an increase in water requirements throughout the Amudarya Basin and, vice versa, achieve from 2 to 8% reduction of water requirements if the growing season prolongs as a whole and plant development phases become shorter.

# Forecast of crop production by 2050 per planning zone, Uzbek part

**Demographic indicators:**

| | Reporting period | | BAU | | FSD | | ESA | |
|---|---|---|---|---|---|---|---|---|
| | 2010 | 2015 | 2020 | 2050 | 2020 | 2050 | 2020 | 2050 |
| Total population, thousand | 7 883 | 8 599 | 9 216 | 13 877 | 9 216 | 13 877 | 9 216 | 13 877 |

**Crop irrigated area**

| | Reporting period | | BAU | | FSD | | ESA | |
|---|---|---|---|---|---|---|---|---|
| | 2010 | 2015 | 2020 | 2050 | 2020 | 2050 | 2020 | 2050 |
| Irrigated land area, thousand ha | 1353,6 | 1338,3 | 1334,6 | 1364,0 | 1324,5 | 1333,6 | 1324,5 | 1333,7 |
| Of which: cotton | 566,2 | 552,7 | 542,2 | 513,7 | 498,2 | 341,0 | 498,2 | 354,4 |
| fodder | 121,3 | 113,5 | 114,6 | 121,5 | 125,5 | 181,5 | 125,5 | 150,2 |
| orchards | 49,2 | 54,2 | 55,3 | 64,4 | 58,7 | 101,7 | 58,7 | 118,2 |
| wheat | 445,8 | 447,5 | 448,6 | 462,3 | 433,6 | 325,1 | 433,6 | 308,5 |
| maize | 4,9 | 6,5 | 6,5 | 8,4 | 7,7 | 34,8 | 7,7 | 24,7 |
| cucurbits | 19,8 | 25,2 | 26,1 | 33,4 | 26,7 | 57,3 | 26,7 | 73,4 |
| potato | 22,5 | 24,9 | 27,0 | 33,4 | 32,6 | 63,8 | 32,6 | 52,4 |
| rice | 47,6 | 30,0 | 26,2 | 22,9 | 31,0 | 46,5 | 31,0 | 40,5 |
| vegetables | 46,6 | 55,0 | 58,3 | 73,4 | 80,2 | 137,8 | 80,2 | 154,9 |
| grape | 29,7 | 28,9 | 29,9 | 30,5 | 30,2 | 44,0 | 30,2 | 56,7 |

# Forecast of crop production by 2050 per planning zone, Uzbek part

**Gross harvest per irrigated crop, thousand tons**

| | Reporting period | | BAU | | FSD | | ESA | |
|---|---|---|---|---|---|---|---|---|
| | 2010 | 2015 | 2020 | 2050 | 2020 | 2050 | 2020 | 2050 |
| Of which: cotton | 1 456,8 | 1 478,2 | 1 455,3 | 1 424,7 | 1 481,7 | 1 442,0 | 1 631,5 | 1 829,1 |
| fodder | 1 172,5 | 1 975,9 | 1 903,6 | 2 300,9 | 2 191,9 | 4 771,3 | 2 110,2 | 3 507,3 |
| fruits and berries | 420,9 | 663,6 | 700,7 | 952,6 | 834,1 | 2 096,5 | 910,8 | 3 081,6 |
| wheat | 2 210,7 | 2 197,9 | 2 220,1 | 2 325,3 | 2 262,5 | 2 404,8 | 2 230,3 | 1 927,4 |
| maize | 19,3 | 25,3 | 26,5 | 40,9 | 34,8 | 275,3 | 33,0 | 162,9 |
| fodder | 319,7 | 457,6 | 468,7 | 641,7 | 534,8 | 1 956,1 | 566,4 | 3 148,3 |
| potato | 341,5 | 509,4 | 486,4 | 675,6 | 654,3 | 2 422,4 | 635,4 | 1 705,1 |
| rice | 154,3 | 108,1 | 88,2 | 82,8 | 131,9 | 307,8 | 122,7 | 222,4 |
| vegetables | 1 037,5 | 1 326,9 | 1 318,3 | 1 799,8 | 1 989,1 | 5 517,1 | 2 094,1 | 7 591,6 |
| grape | 223,1 | 373,7 | 411,0 | 480,6 | 430,8 | 849,5 | 469,6 | 1 309,0 |

# Forecast of crop production by 2050 per planning zone, Tajik part

**Demographic indicators:**

| | Reporting period | | BAU | | FSD | | ESA | |
|---|---|---|---|---|---|---|---|---|
| | 2010 | 2015 | 2020 | 2050 | 2020 | 2050 | 2020 | 2050 |
| Total population, thousand | 5 374 | 5 939 | 6 508 | 10 196 | 6 508 | 10 196 | 6 508 | 10 196 |

**Crop irrigated area**

| | Reporting period | | BAU | | FSD | | ESA | |
|---|---|---|---|---|---|---|---|---|
| | 2010 | 2015 | 2020 | 2050 | 2020 | 2050 | 2020 | 2050 |
| Irrigated land area, thousand ha | 629,8 | 608,8 | 603,9 | 574,6 | 632,1 | 632,1 | 632,1 | 632,1 |
| Of which: cotton | 108,5 | 125,7 | 127,9 | 121,1 | 124,5 | 93,3 | 124,5 | 97,6 |
| fodder | 51,0 | 53,5 | 37,0 | 32,4 | 54,9 | 66,2 | 54,9 | 60,5 |
| orchards | 55,1 | 73,2 | 76,3 | 91,7 | 86,5 | 91,4 | 86,5 | 97,4 |
| wheat | 309,2 | 244,3 | 245,7 | 204,5 | 245,4 | 223,4 | 245,4 | 216,5 |
| maize | 6,5 | 8,6 | 8,6 | 9,2 | 9,9 | 16,6 | 9,9 | 10,6 |
| cucurbits | 16,4 | 13,4 | 11,8 | 9,5 | 14,8 | 16,6 | 14,8 | 23,0 |
| potato | 20,4 | 23,6 | 27,2 | 30,7 | 25,1 | 33,3 | 25,1 | 28,3 |
| rice | 6,3 | 3,8 | 3,4 | 2,1 | 4,8 | 14,0 | 4,8 | 8,7 |
| vegetables | 31,3 | 37,5 | 40,7 | 47,7 | 39,0 | 45,2 | 39,0 | 51,5 |
| grape | 25,0 | 25,0 | 25,4 | 25,6 | 27,2 | 32,2 | 27,2 | 38,0 |

# Forecast of crop production by 2050 per planning zone, Tajik part

**Gross harvest per irrigated crop, thousand tons**

| | Reporting period | | BAU | | FSD | | ESA | |
|---|---|---|---|---|---|---|---|---|
| | 2010 | 2015 | 2020 | 2050 | 2020 | 2050 | 2020 | 2050 |
| Of which: cotton | 218,4 | 272,4 | 299,2 | 314,3 | 293,7 | 353,2 | 322,3 | 440,8 |
| fodder | 251,6 | 263,6 | 200,2 | 178,6 | 332,6 | 567,0 | 319,3 | 451,3 |
| fruits and berries | 155,6 | 226,7 | 473,7 | 645,4 | 542,1 | 934,6 | 599,4 | 1 422,6 |
| wheat | 738,4 | 776,6 | 751,4 | 685,2 | 866,0 | 1 426,5 | 798,7 | 1 194,6 |
| maize | 56,4 | 63,6 | 49,2 | 64,0 | 71,3 | 154,9 | 68,1 | 88,5 |
| cucurbits | 391,9 | 409,2 | 296,5 | 253,5 | 460,1 | 679,0 | 511,0 | 1 100,5 |
| potato | 469,0 | 523,1 | 619,5 | 704,8 | 634,4 | 1 404,4 | 638,7 | 1 046,1 |
| rice | 25,3 | 22,2 | 15,1 | 9,8 | 24,1 | 95,0 | 22,8 | 52,3 |
| vegetables | 753,1 | 1 062,0 | 954,9 | 1 246,2 | 1 067,2 | 1 883,2 | 1 180,0 | 2 645,9 |
| grapes | 87,3 | 129,6 | 143,0 | 165,5 | 182,6 | 324,4 | 206,9 | 476,5 |

# A degree of adaptability of the water allocation system in the Amudarya basin: Legal & institutional analysis

**Analytical framework:**

1. Availability of treaties & institutions for water allocation;
2. Flexibility of water allocation principles;
3. Provisions & procedures for modifications of water allocation;
4. Emergency response.

**Key findings:**

- The water allocation structure and principles agreed upon in **treaties** and **regional institutions** established;
- The water allocation principles are **relatively flexible**;
- Management response to changes deals **only with operational matters** of water allocation adjustment;
- ICWC practices under extremes (droughts and floods) are **reactive rather than proactive**

# THANK YOU FOR ATTENTION