Partnerships for Enhanced Engagement in Research

Ministry of Agriculture and Water Resources in Uzbekistan

Geodatabase and Diagnostic Atlas: Kashkadarya Province, Uzbekistan

Zafar Gafurov, Sarvarbek Eltazarov, Bekzod Akramov, Kakhramon Djumaboev, Oyture Anarbekov and Umida Solieva
About USAID PEER
The United States Agency for International Development (USAID) is the U.S. Government’s preeminent foreign assistance agency. The agency is dedicated to helping nations meet the needs of their citizens by providing health-care, education, and economic opportunity to end extreme poverty and promote democratic, resilient societies. The U.S. Global Development Lab (The Lab) at USAID is bringing together a diverse set of partners to discover, test, and scale breakthrough solutions to address critical challenges in international development. A key element of this strategy is the support of scientific and technological research through the Partnerships for Enhanced Engagement in Research (PEER) program. PEER is a competitive awards program that invites scientists in developing countries to apply for funds to support research and capacity-building activities on topics of importance to USAID and conducted in partnership with U.S. Government (USG)-funded and selected private sector partners. The program is supported by USAID but implemented by the U.S. National Academies of Sciences, Engineering, and Medicine (referred to as the National Academies).

Through PEER, the Lab leverages investments by other USG-supported agencies and private sector companies in scientific research and training in order to enhance the development priorities of USAID. USG-funded partners must be investigators who will contribute to the scientific merit and impact of PEER projects through expertise, skills, methodologies, laboratory access, and synergies with ongoing projects.

About IWMI
The International Water Management Institute (IWMI) is a non-profit, scientific research organization focusing on the sustainable use of water and land resources in developing countries. IWMI works in partnership with governments, civil society and the private sector to develop scalable agricultural water management solutions that have a real impact on poverty reduction, food security and ecosystem health. Headquartered in Colombo, Sri Lanka, with provincial offices across Asia and Africa, IWMI is a CGIAR Research Center and leads the CGIAR Research Program on Water, Land and Ecosystems (WLE).
Geodatabase and Diagnostic Atlas: Kashkadarya Province, Uzbekistan

Zafar Gafurov, Sarvarbek Eltazarov, Bekzod Akramov, Kakhramon Djumaboev, Oytur Anarbekov and Umida Solieva

International Water Management Institute (IWMI)
The authors:

Zafar Gafurov is a Research Officer / Project Leader (Remote Sensing and GIS Specialist) at Central Asia Office of the International Water Management Institute (IWMI), Tashkent, Uzbekistan.

Sarvarbek Eltazarov is a provincial Consultant (Remote Sensing and GIS Specialist) at Central Asia Office of the International Water Management Institute (IWMI), Tashkent, Uzbekistan.

Bekzod Akramov is a Consultant (Monitoring and Evaluation Specialist) at Central Asia Office of the International Water Management Institute (IWMI), Tashkent, Uzbekistan.

Kakhramon Djumaboev is a Senior Research Officer / Project Leader (Water Resource Management Specialist) at Central Asia Office of the International Water Management Institute (IWMI), Tashkent, Uzbekistan.

Oyture Anarbekov is a Senior Research Officer / Project Leader (Water Governance/Institutional Specialist) at Central Asia Office of the International Water Management Institute (IWMI), Tashkent, Uzbekistan.

Umida Solieva is a Consultant (Ecosystem Services) at Central Asia Office of the International Water Management Institute (IWMI), Tashkent, Uzbekistan.


Copyright © 2018 by IWMI. All rights reserved. IWMI encourages the use of its material provided that the organization is acknowledged and kept informed in all such instances.

Please send inquiries and comments to IWMI-Publications@cgiar.org
Acknowledgments

The ‘Geodatabase and Diagnostic Atlas: Kashkadarya Province, Uzbekistan’ is based on data and information generated and collected data within the framework of the USAID PEER Cycle 4 project ‘Mitigating the competition for water in Amudarya River basin, Central Asia by improving water use efficiency’. Also data obtained from published and grey literature as well as spatial analyses carried out using publicly available sources. The authors would like to thank project partners in both Uzbekistan for their input and feedback to content of the atlas. Additionally, the authors would like to acknowledge Shovkat Khodjaev for his technical assistance.

Project

The geodatabase and digital diagnostic atlas were generated within the framework of the “Mitigating the competition for water in Amudarya River basin, Central Asia by improving water use efficiency” project being implemented by the International Water Management Institute (IWMI) in collaboration with USDA-ARS, UZGIP (Uzbekistan), and Sogd Water Authority (Tajikistan). Since 2015, the project has been supporting the two Central Asian states (Uzbekistan and Tajikistan) to evaluate the potential for improving water-use efficiency by mitigating measures for water and energy use in the Amu Darya and Syr Darya river basins.

For further details about the project, visit: http://sites.nationalacademies.org/PGA/PEER/PEERscience/PGA_168055

Donor

This project is funded by the following:

The United States Agency for International Development (USAID)
Partnerships for Enhanced Engagement in Research (PEER) Program
Part I: Geodatabase Overview

Introduction

The geodatabase and digital diagnostic atlas were generated within the framework of USAID PEER Cycle 4 project “Mitigating the competition for water in Amudarya River basin, Central Asia by improving water use efficiency” being implemented by the International Water Management Institute (IWMI) in collaboration with USDA-ARS, UZGIP (Uzbekistan) and Sogd Water Authority (Tajikistan). Since 2015, the project has been supporting Uzbekistan and Tajikistan to evaluate the potential for improving water-use efficiency by mitigating measures for water and energy use in the Amu Darya and Syr Darya river basins.

A strong and permanent element of the project is data generation in water-related state aspects, with a view to specifically developing a geodatabase and digital diagnostic atlas using open source data. The geodatabase consists of various input data, which were obtained from open domains of several government and non-government organizations, and present the data through visually appealing maps and other visually informative forms (i.e., charts, infographics, etc.) to show the spatial and temporal distribution of water and land resources and the way they are used.

Data Accuracy and Reliability

The geodatabase was created using open source GIS, Remote Sensing and local analogue information, some of which has been published by world renowned organizations and used in public projects and scientific research certified by international agencies.

Availability and Accessibility

The geodatabase can be obtained in digital form for use by external parties with the approval of the International Water Management Institute. In order to obtain the geodatabase please contact with the office in the province.

Software Employed

This geodatabase and the associated maps were created on a computer machine running Windows 10 Professional and using ArcGIS 10.5, QGIS, Google Earth Engine. End users should download the package that is most appropriate for the version of ArcGIS software that they are using. It is important to note that ArcGIS is not only required to make use of the map package and the associated geodatabase.
Data Sources

International Water Management Institute (IWMI)

National Aeronautics and Space Administration - Land Data Products and Services (NASA LP DAAC)

International Center for Agricultural Research in the Dry Areas (ICARDA)

The State Committee of The Republic of Uzbekistan on Statistics (UZSTAT)

European Space Agency (ESA)

World Climate Research Programme (WCRP), Coupled Model Intercomparison Project (CMIP)

Ministry of Agriculture and Water Resources in Uzbekistan (MAWR)

“UzGIP” Design and Research Institute

Map Projection and Coordinate System

Map projections describe the techniques that represent the Earth’s curved surface on a flat map. Coordinate systems describe the grid referenced and measurement units, effectively translating the map projection. In order to overlay the GIS layers on each other, a single data frame is required. In the geodatabase, the layers are projected into a common coordinate system WG 1984 World Mercator.

Objective and Recommendation for Use

The main objective of the geodatabase development was to convert raw data into maps, charts, and infographics for visual interpretation of water and land resources in the province in a consolidated form. The authors hope that it can be used as a tool to inform management practices and support decision making at the local, national, and provincial levels.
Part II. ArcMap Users

ArcMap users may download and use the full geodatabase (.gdb) file and associated .mxd file. This option provides the highest functionality for users interested in carrying out spatial analyses processes. The .mxd document is available for ArcMap 10.5. To ensure you download the correct .mxd file, first verify your ArcMap version. To do this, go to Help > About ArcMap. Then, open the .mxd file to access the geodatabase.
Aral Sea Basin

Study area

Basin and country boundaries

Kazakhstan

Uzbekistan

Turkmenistan

Afghanistan

Tajikistan

Kyrgyzstan
Kashkadarya province covers an area of 28,400 km² and is located in the south-eastern part of Uzbekistan on the western slopes of the Pamir-Alay mountains. Within the country, it borders Bukhara, Navai, Samarkand, and Surkhandarya provinces. It also shares borders with Tajikistan in the northeast and Turkmenistan in the south.
Kashkadarya province is currently divided into thirteen administrative districts. The provincial capital is the city of Karshi. In terms of area, Dekhanbad, Chirakchi, Mubarak, and Mirshikor are the largest districts, while Kasbi and Karshi are the smallest.
## District wise population

<table>
<thead>
<tr>
<th>District</th>
<th>Total population</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mubarak</td>
<td>80700</td>
<td>40700</td>
<td>40000</td>
</tr>
<tr>
<td>Mirishkor</td>
<td>111500</td>
<td>56900</td>
<td>54600</td>
</tr>
<tr>
<td>Dekhkanabad</td>
<td>136100</td>
<td>68400</td>
<td>67700</td>
</tr>
<tr>
<td>Nishan</td>
<td>139100</td>
<td>69500</td>
<td>69600</td>
</tr>
<tr>
<td>Kasbi</td>
<td>182500</td>
<td>92600</td>
<td>90000</td>
</tr>
<tr>
<td>Guzar</td>
<td>190700</td>
<td>96400</td>
<td>94200</td>
</tr>
<tr>
<td>Kamashi</td>
<td>251800</td>
<td>126800</td>
<td>124800</td>
</tr>
<tr>
<td>Yakkabag</td>
<td>244600</td>
<td>123600</td>
<td>121000</td>
</tr>
<tr>
<td>Kitab</td>
<td>247000</td>
<td>125400</td>
<td>121600</td>
</tr>
<tr>
<td>Kasan</td>
<td>263600</td>
<td>133200</td>
<td>130400</td>
</tr>
<tr>
<td>Shakhrisabz</td>
<td>339900</td>
<td>172600</td>
<td>167300</td>
</tr>
<tr>
<td>Chirakchi</td>
<td>374000</td>
<td>189200</td>
<td>185000</td>
</tr>
<tr>
<td>Karshi</td>
<td>491300</td>
<td>244700</td>
<td>246600</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3052800</strong></td>
<td><strong>154000</strong></td>
<td><strong>1512800</strong></td>
</tr>
</tbody>
</table>

As of 2016, the population of Kashkadarya province was estimated to be about 3,052,800. In Uzbekistan, it is the third most populous province after Samarkand and Fergana provinces.

Men make up 50.4 percent of the total population, while women make up 49.6 percent of the total population.

Despite being one of the smaller districts in terms of area, Karshi district has the highest population with 491,300 people (making up 16.1 percent of the total population). Chirakchi and Shakhrisabz are the next most populous districts with populations of 374,000 and 339,900 respectively. Mubarak has the lowest population with 80,700 people, meaning it has a pretty low population density given its large area.
Note: The lightest color represents the lowest population, while the darkest color represents the highest population. See table on the previous page for details.

Source: UZSTAT, 2016
As of 2016, the urban population of Kashkadarya province was estimated to be about 1,311,600, making up about 43 percent of the total population in the province.

Men make up 50.5 percent of the total urban population, while women make up 49.5 percent of the total urban population.

Karshi district has the highest urban population in the province with 346,400 people, which means that more than 70 percent of the district’s total population lives in urban areas. Shakhrisabz (175,700) and Kasan (131,300) districts have the next two highest urban populations in the province. Dekhanabad has the lowest urban population with 25,800 people, meaning that only about 19 percent of the district’s total population lives in urban areas.

<table>
<thead>
<tr>
<th>District</th>
<th>Total urban population</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dekhanabad</td>
<td>25800</td>
<td>13100</td>
<td>12700</td>
</tr>
<tr>
<td>Mirishkhor</td>
<td>41800</td>
<td>21400</td>
<td>20400</td>
</tr>
<tr>
<td>Guzar</td>
<td>44800</td>
<td>22800</td>
<td>22000</td>
</tr>
<tr>
<td>Kamashi</td>
<td>59600</td>
<td>30800</td>
<td>28800</td>
</tr>
<tr>
<td>Mubarak</td>
<td>63900</td>
<td>32200</td>
<td>31700</td>
</tr>
<tr>
<td>Kasbi</td>
<td>70100</td>
<td>35400</td>
<td>34700</td>
</tr>
<tr>
<td>Yakkabag</td>
<td>79100</td>
<td>40200</td>
<td>38900</td>
</tr>
<tr>
<td>Nishan</td>
<td>84500</td>
<td>42200</td>
<td>42300</td>
</tr>
<tr>
<td>Chirakchi</td>
<td>89900</td>
<td>45800</td>
<td>44100</td>
</tr>
<tr>
<td>Kitab</td>
<td>92700</td>
<td>47300</td>
<td>45400</td>
</tr>
<tr>
<td>Kasan</td>
<td>131300</td>
<td>69500</td>
<td>67800</td>
</tr>
<tr>
<td>Shakhrisabz</td>
<td>175700</td>
<td>88900</td>
<td>86800</td>
</tr>
<tr>
<td>Karshi</td>
<td>346400</td>
<td>173100</td>
<td>173300</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1311600</strong></td>
<td><strong>662700</strong></td>
<td><strong>648900</strong></td>
</tr>
</tbody>
</table>

Source: UZSTAT, 2016
Note: The lightest color represents the lowest urban population, while the darkest color represents the highest urban population. See table on the previous page for details.
### District wise rural population

<table>
<thead>
<tr>
<th>District</th>
<th>Total rural population</th>
<th>Male rural population</th>
<th>Female rural population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mubarak</td>
<td>16800</td>
<td>8600</td>
<td>8200</td>
</tr>
<tr>
<td>Nishan</td>
<td>54600</td>
<td>27300</td>
<td>27300</td>
</tr>
<tr>
<td>Mirishkor</td>
<td>69700</td>
<td>35500</td>
<td>34200</td>
</tr>
<tr>
<td>Dekhkanabad</td>
<td>110300</td>
<td>55200</td>
<td>55100</td>
</tr>
<tr>
<td>Kasbi</td>
<td>112400</td>
<td>57200</td>
<td>55200</td>
</tr>
<tr>
<td>Kasan</td>
<td>126300</td>
<td>63700</td>
<td>62600</td>
</tr>
<tr>
<td>Karshi</td>
<td>144900</td>
<td>71600</td>
<td>73300</td>
</tr>
<tr>
<td>Guzar</td>
<td>145900</td>
<td>73600</td>
<td>72300</td>
</tr>
<tr>
<td>Kitab</td>
<td>154300</td>
<td>78100</td>
<td>76200</td>
</tr>
<tr>
<td>Shakhrisabz</td>
<td>164200</td>
<td>83800</td>
<td>80400</td>
</tr>
<tr>
<td>Yakkabag</td>
<td>165500</td>
<td>83400</td>
<td>82100</td>
</tr>
<tr>
<td>Kamashi</td>
<td>192200</td>
<td>96100</td>
<td>96100</td>
</tr>
<tr>
<td>Chirakchi</td>
<td>284100</td>
<td>143400</td>
<td>140700</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1741200</strong></td>
<td><strong>877500</strong></td>
<td><strong>863700</strong></td>
</tr>
</tbody>
</table>

As of 2016, the rural population of Kashkadarya province was estimated to be about 1,741,200, making up about 57 percent of the total population in the province.

Men make up 50.4 percent of the total rural population, while women make up 49.6 percent of the total rural population.

Chirakchi district has the highest rural population in the province with 284,100 people, which means that about 76 percent of the district’s total population lives in rural areas. Kamashi, Yakkabag, Shakhrisabz, and Kitab districts also have considerable rural populations. Mubarak has the lowest rural population with 16,800 people, meaning that only about 21 percent of the district’s total population lives in rural areas.

Source: UZSTAT, 2016
Note: The lightest color represents the lowest rural population, while the darkest color represents the highest rural population. See table on the previous page for details.
Districts with more males than females

1. Mubarak (26)
2. Dekhkanabad (34)
3. Mirishkor (35)
4. Nishan (64)
5. Guzar (72)
6. Kamashi (95)
7. Chirakchi (132)
8. Kasan (142)
9. Kitab (142)
10. Shakhrisabz (204)

Districts with more females than males

11. Yakkabag (221)
12. Kasbi (280)
13. Karshi (533)
Total (107)

Source: UZSTAT, 2016
Canal networks

Source: MAWR, 2017
Drainage and collector systems

Source: MAWR, 2017
Legend

- **Streams**
- **Watersheds**

Source: MAWR, 2017
<table>
<thead>
<tr>
<th>Soil types</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Shor” and other solonchaks on eluvium of parent rocks</td>
</tr>
<tr>
<td>Blown and poor fixed sands</td>
</tr>
<tr>
<td>Cinnamonic slightly leached clayey and loamy on deluvium</td>
</tr>
<tr>
<td>Cinnamonic slightly leached coarse-skeletal on eluvium and deluvium</td>
</tr>
<tr>
<td>Cinnamonic typical clayey and loamy on eluvium and deluvium</td>
</tr>
<tr>
<td>Dark sierozems coarse-skeletal on eluvium and proluvium</td>
</tr>
<tr>
<td>Dark sierozems eroded skeletal-loamy on eluvium and proluvium</td>
</tr>
<tr>
<td>Dark sierozems loamy and clayey on loesses</td>
</tr>
<tr>
<td>Desert -sierozem meadow</td>
</tr>
<tr>
<td>Desert sandy solonchak-like on wind deposits, proluvium and aluvium</td>
</tr>
<tr>
<td>Grey-brown eroded skeletal on skeleton eluvium</td>
</tr>
<tr>
<td>Grey-brown sierozem meadow</td>
</tr>
<tr>
<td>Grey-brown solonchak-like loamy-sandy on eluvium of sandstone in complex with sand ripples</td>
</tr>
<tr>
<td>Irrigated meadow-sierozem and meadow-oasis saline and leached on aluvium and proluvium</td>
</tr>
<tr>
<td>Light brown high-mountainous skeletal-loamy and coarse-skeletal on eluvium and deluvium</td>
</tr>
<tr>
<td>Light irrigated sierozem and sierozem-oasis loamy and loamy sandy on aluvium and proluvium</td>
</tr>
<tr>
<td>Light sierozem subtropical hot unfreeze through</td>
</tr>
<tr>
<td>Light sierozems</td>
</tr>
<tr>
<td>Light sierozems here and there solonchak-like, skeletal-loamy on proluvium</td>
</tr>
<tr>
<td>Light sierozems loamy on loess-like sediments</td>
</tr>
<tr>
<td>Light sierozems solonchak-like on alluvial and proluvial loess-like deposits</td>
</tr>
<tr>
<td>Light-brown desert subtropical unfreeze through</td>
</tr>
<tr>
<td>Meadow and marsh solonchak and solonchak-like</td>
</tr>
<tr>
<td>Meadow takirs and takirs</td>
</tr>
<tr>
<td>Meadow-like grey brown-sierozem</td>
</tr>
<tr>
<td>Meadow-oasis clay and loamy-sandy on aluvium and proluvium</td>
</tr>
<tr>
<td>Sands</td>
</tr>
<tr>
<td>Sierozem-grey-brown</td>
</tr>
<tr>
<td>Sierozem-oasis loamy and loamy sandy on aluvium and proluvium</td>
</tr>
<tr>
<td>Sierozem-oasis saline and typical irrigated soils</td>
</tr>
<tr>
<td>Sierozem-takir</td>
</tr>
<tr>
<td>Takir-like and takirs here and there in complex with sands</td>
</tr>
<tr>
<td>Takir-like solonchak-like on aluvium and proluvium</td>
</tr>
<tr>
<td>Typical sierozem subtropical hot unfreeze through</td>
</tr>
<tr>
<td>Typical sierozems loamy on loesses</td>
</tr>
<tr>
<td>Water</td>
</tr>
</tbody>
</table>
Aspect map

Source: IWMI, 2017
Spatio-temporal variation of vegetation coverage during 2001-2004 and 2013-2016

Source: ICARDA, 2012
Spatio-temporal variation of vegetation coverage during 2001-2004 and 2013-2016

Legend
- Minor decrease of vegetation
- Significant decrease of vegetation
- Minor increase of vegetation
- Significant increase of vegetation
- No vegetation
- Stable vegetation
- Water bodies

Percentage of variation
- No vegetation: 0.3%
- High increase: 0.3%
- Low increase: 6.3%
- High decrease: 1.4%
- Low decrease: 21.5%
- Stable vegetation: 70.1%

Source: IWMI, 2017
Annual average wind speed in 2017

Legend
Wind speed (m/s)
- 3.8 - 4.0
- 4.0 - 4.2
- 4.2 - 4.4
- 4.4 - 4.6
- 4.6 - 4.8
- 4.8 - 5.0
- 5.0 - 5.2

Note: Data were obtained using CMIP5 model simulations.

Source: IWMI, 2017
Annual average wind speed in 2030

Legend
Wind speed (m/s)
- 3.8 - 4.0
- 4.0 - 4.2
- 4.2 - 4.4
- 4.4 - 4.6
- 4.6 - 4.8
- 4.8 - 5.0
- 5.0 - 5.2

Note: Data were obtained using CMIP5 model simulations.
Annual average wind speed in 2050

Legend
Wind speed (m/s)
- 3.8 - 4.0
- 4.0 - 4.2
- 4.2 - 4.4
- 4.4 - 4.6
- 4.6 - 4.8
- 4.8 - 5.0
- 5.0 - 5.2
- 5.2 - 5.4

Note: Data were obtained using CMIP5 model simulations.

Source: IWMI, 2017
Note: Data were obtained using CMIP5 model simulations.
Annual precipitation in 2030

Legend

Annual precipitation (mm)

- 65 - 100
- 100 - 150
- 150 - 200
- 200 - 250
- 250 - 300
- 300 - 400
- 400 - 600
- 600 - 800
- 800 - 1000
- 1000 - 1200
- 1200 - 1400
- 1400 - 1600
- 1600 - 1800

Note: Data were obtained using CMIP5 model simulations.

Source: IWMI, 2017

A water-secure world
Annual precipitation in 2050

Legend

Annual precipitation (mm)
- 65 - 100
- 100 - 150
- 150 - 200
- 200 - 250
- 250 - 300
- 300 - 400
- 400 - 600
- 600 - 800
- 800 - 1000
- 1000 - 1200
- 1200 - 1400
- 1400 - 1600
- 1600 - 1800

Note: Data were obtained using CMIP5 model simulations.

Source: IWMI, 2017
Annual average maximum temperature in 2017

Legend

- - - - Contour lines

Annual average maximum temperature (C)

High : 24.2

Low : 3.2

Note: Data were obtained using CMIP5 model simulations.

Source: IWMI, 2017
Annual average maximum temperature in 2030

Legend
- - - - Contour lines

Annual average maximum temperature (C)
High: 24.5
Low: 3.8

Note: Data were obtained using CMIP5 model simulations.

Source: IWMI, 2017
Annual average maximum temperature in 2050

Legend

Contour lines

Annual average maximum temperature (C)

High : 26.3

Low : 5.9

Note: Data were obtained using CMIP5 model simulations.

Source: IWMI, 2017
Annual average minimum temperature in 2017

Legend
- - - - Contour lines

Annual average minimum temperature (C)
High: 10.2
Low: -9.7

Note: Data were obtained using CMIP5 model simulations.

Source: IWMI, 2017
Annual average minimum temperature in 2030

Legend
- Contour lines

Annual average minimum temperature (C)
High: 10.6
Low: -8.0

Note: Data were obtained using CMIP5 model simulations.

Source: IWMI, 2017
Annual average minimum temperature in 2050

Legend
- - - Contour lines

Annual average minimum temperature (C)
- High: 12.4
- Low: -5.8

Note: Data were obtained using CMIP5 model simulations.

Source: IWMI, 2017
Reference Evapotranspiration Zones

Legend
- District boundaries
- Reference Evapotranspiration Zones

Source: IWMI, 2016
## Monthly Average Reference Evapotranspiration by ETo Zone (mm/month)

<table>
<thead>
<tr>
<th>Class</th>
<th>Jan</th>
<th>Feb</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>42.9</td>
<td>45.0</td>
<td>97.9</td>
<td>158.2</td>
<td>233.7</td>
<td>241.8</td>
<td>273.8</td>
<td>225.4</td>
<td>174.9</td>
<td>108.2</td>
<td>59.2</td>
<td>29.9</td>
<td>1690.8</td>
</tr>
<tr>
<td>2</td>
<td>40.2</td>
<td>41.2</td>
<td>89.2</td>
<td>149.4</td>
<td>223.8</td>
<td>234.9</td>
<td>264.5</td>
<td>221.5</td>
<td>169.8</td>
<td>104.0</td>
<td>55.2</td>
<td>28.3</td>
<td>1622.1</td>
</tr>
<tr>
<td>3</td>
<td>36.2</td>
<td>36.3</td>
<td>76.1</td>
<td>132.3</td>
<td>208.6</td>
<td>224.9</td>
<td>250.7</td>
<td>214.5</td>
<td>162.8</td>
<td>98.4</td>
<td>48.2</td>
<td>26.2</td>
<td>1515.2</td>
</tr>
<tr>
<td>4</td>
<td>34.9</td>
<td>35.1</td>
<td>72.2</td>
<td>125.0</td>
<td>203.9</td>
<td>221.2</td>
<td>245.2</td>
<td>211.3</td>
<td>160.9</td>
<td>97.2</td>
<td>45.8</td>
<td>25.8</td>
<td>1478.4</td>
</tr>
<tr>
<td>5</td>
<td>34.7</td>
<td>35.0</td>
<td>71.7</td>
<td>123.1</td>
<td>202.9</td>
<td>219.9</td>
<td>243.6</td>
<td>210.2</td>
<td>160.8</td>
<td>97.2</td>
<td>45.4</td>
<td>25.8</td>
<td>1470.5</td>
</tr>
<tr>
<td>6</td>
<td>34.3</td>
<td>35.1</td>
<td>71.0</td>
<td>121.4</td>
<td>202.2</td>
<td>219.1</td>
<td>242.9</td>
<td>210.1</td>
<td>161.3</td>
<td>97.7</td>
<td>45.1</td>
<td>25.8</td>
<td>1466.0</td>
</tr>
<tr>
<td>7</td>
<td>34.0</td>
<td>35.5</td>
<td>70.9</td>
<td>118.1</td>
<td>201.5</td>
<td>217.1</td>
<td>240.8</td>
<td>208.7</td>
<td>161.8</td>
<td>98.2</td>
<td>44.9</td>
<td>25.9</td>
<td>1457.2</td>
</tr>
<tr>
<td>8</td>
<td>33.0</td>
<td>34.9</td>
<td>69.4</td>
<td>113.2</td>
<td>197.8</td>
<td>212.3</td>
<td>235.7</td>
<td>204.6</td>
<td>160.2</td>
<td>97.0</td>
<td>43.8</td>
<td>25.2</td>
<td>1427.1</td>
</tr>
<tr>
<td>9</td>
<td>31.3</td>
<td>33.4</td>
<td>66.2</td>
<td>106.4</td>
<td>191.3</td>
<td>205.3</td>
<td>228.5</td>
<td>198.8</td>
<td>157.1</td>
<td>94.5</td>
<td>41.9</td>
<td>23.8</td>
<td>1378.3</td>
</tr>
<tr>
<td>10</td>
<td>30.2</td>
<td>32.3</td>
<td>64.3</td>
<td>103.1</td>
<td>186.9</td>
<td>201.6</td>
<td>224.7</td>
<td>195.7</td>
<td>154.9</td>
<td>92.8</td>
<td>40.8</td>
<td>22.9</td>
<td>1350.2</td>
</tr>
<tr>
<td>11</td>
<td>29.2</td>
<td>31.1</td>
<td>62.5</td>
<td>100.8</td>
<td>182.0</td>
<td>198.9</td>
<td>222.0</td>
<td>193.2</td>
<td>152.6</td>
<td>91.0</td>
<td>39.8</td>
<td>22.2</td>
<td>1325.2</td>
</tr>
<tr>
<td>12</td>
<td>29.1</td>
<td>30.8</td>
<td>61.8</td>
<td>99.9</td>
<td>180.0</td>
<td>198.8</td>
<td>221.7</td>
<td>192.5</td>
<td>151.8</td>
<td>90.5</td>
<td>39.3</td>
<td>22.0</td>
<td>1318.2</td>
</tr>
</tbody>
</table>
Innovative water saving technologies, so called gated pipes are being introduced in the areas of Uzbekistan. This map illustrates introduced technologies for Kashkadarya province.

Source: IWMI, 2016
Land use land cover change map of Kashkadarya river basin for years 1987 and 2016

<table>
<thead>
<tr>
<th>LULC</th>
<th>% LULC</th>
<th>% of ES in land use class</th>
<th>1987</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>N retention</td>
<td>P retention</td>
<td>Carbon</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>residential</td>
<td>4.1</td>
<td>0.0</td>
<td>0.0</td>
<td>0.8</td>
</tr>
<tr>
<td>baresoil</td>
<td>38.5</td>
<td>9.5</td>
<td>1.2</td>
<td>35.2</td>
</tr>
<tr>
<td>water</td>
<td>0.27</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>cropland</td>
<td>23.3</td>
<td>11.0</td>
<td>20.7</td>
<td>10.6</td>
</tr>
<tr>
<td>grassland</td>
<td>23.5</td>
<td>70.9</td>
<td>74.9</td>
<td>25.4</td>
</tr>
<tr>
<td>shrubland</td>
<td>10.5</td>
<td>8.6</td>
<td>3.2</td>
<td>28.0</td>
</tr>
</tbody>
</table>

Source: IWMI, 2017
Carbon cycle comprises exchange of carbon between atmosphere and biosphere. Vegetation fixes carbon from the atmosphere through photosynthesis process and produces organic matter. The organic matter is then stored in above and below ground parts of the plant which consequently transfers to dead organic pool.

In order to find mitigation strategies of carbon emission, forest conservation, or during the selection of land management practices, it is required to estimate carbon stock pools by making carbon inventory in given area. For this reason the estimation and monitoring of current carbon pools, their changes and projection of carbon pools are necessary.

Carbon Storage and Sequestration: Climate Regulation model of InVEST shows the amount of carbon presently stored in megagramme (mg) for each grid cell. The result is sum of all four carbon pools gained according to the IPCC methodologies. The biggest carbon share comes to shrublands and grasslands. The total carbon storage capacity of Kashkadarya area in 1987 was 50 megaton (mt) of carbon, while for 2016 it was 42 mt. Decrease of ecosystem capacity on holding carbon in the thirty year period is mostly due to the increase of residential area and cropland augmentation. On average, 1 ha of land in Kashkadarya River Basin is able to hold 1000 mg of carbon.

As the map shows, baresoil does not hold aptitude as much as vegetation cover by involving into only soil organic matter pools. But according to model outcomes, 32 mt of carbon is stored in soil carbon pools in the study area, which is 76 per cent of all carbon stored in the area. It was stated by Wilfred and his peers (1982) that soil organic carbon in active exchange with the atmosphere constitutes around two-thirds of the carbon in terrestrial ecosystems proving the reliability of outcome of the model. The interesting point is in that table in previous page shows that carbon holding capacity of baresoil is 35 percent which contradicts the statement given above. The plausible explanation of it is that, any land no matter what type of land management is practiced, exists soil cover and it has the capacity to hold carbon in different amounts, whereas baresoil does not have either aboveground, belowground or litter carbon pools. Consequently, soil carbon storage has the biggest capacity to hold carbon. Therefore it has 35 percent, while soil carbon pool of the area has 76 percent of total carbon holding capacity.

8 billion of carbon sink is stored in aboveground biomass pools due to the limited vegetation cover with sparse and uneven distribution over Kashkadarya River basin. Other 2 billion Mg of carbon sequestration comes to belowground and deadwood carbon pools consequently.

Source: IWMI, 2017
Sediment yield growth is observed in many parts of the world which consequently affects water quality and dam management (Walling, 2009). Sediment yields are strongly related to the climate, topography and land use which produce mutual non-linear relationship (Allan, 2004; Gergel et al., 2002). The sediment delivery is natural process but human activities like agriculture alter the process which in turn increases the load of sediment and brings consequences such as: reduced soil fertility which decreases water and nutrient holding capacity; increase in treatment costs for drinking water supply; reduced lake clarity diminishing the value of recreation; increase in total suspended solids impacting health and distribution of aquatic populations; increase in reservoir sedimentation diminishing reservoir performance or increasing sediment control costs; and, increase in harbor sedimentation requiring dredging to preserve harbor function.

In order to understand the complex relationship, different theoretical, empirical and physics-based models have been developed as clear information about sediment retention helps to design strategies, to reduce the sediment loads, preserve areas with high retention capacity and also target low impact areas for agricultural activities. InVEST is among those models which help to quantitatively understand the natural and human induced processes combination in sediment delivery.

The outputs of InVEST Sediment Retention model are the sediment load delivered to the stream at a yearly basis, and also the total eroded sediment in the catchment and retained by vegetation and topographic features.

According to the InVEST Sediment Retention model, the total potential soil loss is calculated using the USLE equation. The amount of estimated sediment loss is given in tons per pixel in the map. The range of maximum sediment exportation for each cell which has size of 30 meters has increased considerably to 20 tons in two study years. Nevertheless, total soil loss is increased insignificantly from 29 to 32 billion tons between 1987 and 2016 respectively. The increase of soil loss is due to the increased residential area and agricultural area modification from natural land use types.

Moreover, the model estimated the soil loss for bare soil which means erosion potential for no vegetated cover as a separate output, and it showed that up to 336 tons of soil annually could be exported if land use type is changed or biomass is removed. This means vegetation cover of Kashkadarya River Basin is a function of decreasing erosion process by about 3 times (dividing bare soil annual soil loss, 336 tons, by current annual soil loss, 107 tons).

Source: IWMI, 2017
The figure shows information about soil load and movement in Kashkadarya River Basin at watershed level. Sediment exported map provides information about the quantity of total exported sediment in each watershed. Whereas, sediment retained map illustrates the difference of soil loss between suppositional watershed with no vegetation cover and current watershed sediment load delivery. According to this figure, north-eastern part of the basin watersheds holds biggest capacity to retain soil by reducing soil erosion up to 10 times.

The overall amount of sediment exported from each pixel that reaches the stream was 30 and 31 tons for years 1987 and 2016 respectively, correspondingly showing little change in the thirty-year period.

Source: IWMI, 2017
Nutrient retention model estimated a possible retained amount of phosphorus and identified the location of retained nutrient in the area. Grasslands and croplands have significant pattern of phosphorus retention in the study area.

The pixel level maps of phosphorus present how much load from each pixel ultimately reaches the stream. In total, 37 tons of phosphorus in 1987 and 57 tons in 2016 were exported. The rocketed quantity of nitrogen exported to the stream are due to the declined grasslands in the area.
Nutrient retention model estimated a possible retained amount of nitrogen and identified the location of retained nutrient in the area. Grasslands and croplands have significant pattern of nitrogen retention in the study area.

The pixel level maps of nitrogen present how much load from each pixel ultimately reaches the stream. In total, 286 tons in 1987 and 341 tons in 2016 of nitrogen were exported. The rocketed quantity of nitrogen exported to the stream are due to the declined grasslands in the area.
The amount of retained nutrient load for each watershed and volume of sediment exported to the stream per watershed.

The maps above provide information about nitrogen retention capacity of the area and exported nutrient amount at watershed level. Nutrient retention is highest in eastern part of the Kashkadarya River Basin as this part has the highest elevation covered with grasslands and shrublands.
Crop type change in Karshi steppe

<table>
<thead>
<tr>
<th>Class Names</th>
<th>1987 Area (ha)</th>
<th>1987 Percentage (%)</th>
<th>2010 Area (ha)</th>
<th>2010 Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Irrigated area</td>
<td>No irrigated</td>
<td>Irrigated area</td>
<td>No irrigated</td>
</tr>
<tr>
<td>Wheat</td>
<td>41745</td>
<td>3.5</td>
<td>91486.4</td>
<td>7.64</td>
</tr>
<tr>
<td>Cotton</td>
<td>222876.2</td>
<td>18.6</td>
<td>136687</td>
<td>11.41</td>
</tr>
<tr>
<td>Orchard</td>
<td>23140</td>
<td>1.9</td>
<td>19323</td>
<td>1.61</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>79292</td>
<td>6.6</td>
<td>19829.1</td>
<td>1.66</td>
</tr>
<tr>
<td>Settlement</td>
<td>58651</td>
<td>4.9</td>
<td>65171.43</td>
<td>5.44</td>
</tr>
<tr>
<td>Total irrigated</td>
<td>425704.2</td>
<td>35.5</td>
<td>332498.9</td>
<td>27.76</td>
</tr>
</tbody>
</table>

Vegetation indices (NDVI) of agricultural crops in Karshi Steppe

Source: IWMI, 2012
Irrigated land change in Karshi steppe

Source: IWMI, 2012
International Water Management Institute
Headquarters and South Asia Regional Office
127 Sunil Mawatha, Pelawatta, Battaramulla, Sri Lanka
Mailing address: P. O. Box 2075, Colombo, Sri Lanka
Tel: +94 11 2880000, 2784080
Fax: +94 11 2786854
Email: iwmi@cgiar.org

Central Asia Office
Office 118, Building 6, Osiyo Street,
Tashkent 100000, Uzbekistan
Tel: +998 71 2370445
Fax: +998 71 2370317
Email: iwmi-ca@cgiar.org

Website: www.iwmi.org