Water Management Practices of Irrigated Rice in Kzyl Orda, Kazakhstan

Location	Syr Darya basin, Kazakhstan
Contractor	EU
Period	2005

Scope of the project

Desiccation of the Aral Sea presented one of the major ecological catastrophes of the 20th century. Even-increasing water withdrawal from the two inflowing rivers – the Syr Darya and the Amu Darya – has resulted in the dramatic decline of level, area and volume of the Aral Sea.

The EU-funded "Environmentally-friendly development in Kzyl Orda oblast" (EDIKO) project aims at arresting desertification in the North Aral Sea region. In this context, WaterWatch was contracted to make an analysis of the water conditions of irrigated rice with advanced remote sensing technologies.

The Kzyl Orda oblast is located in the downstream end and delta of the Syr Darya. Kzyl Orda is characterized by a continental climate with dry hot summers and windy cold winters. Most of the territory is represented by steppes and deserts. Average annual rainfall in this arid landscape is 157 mm.

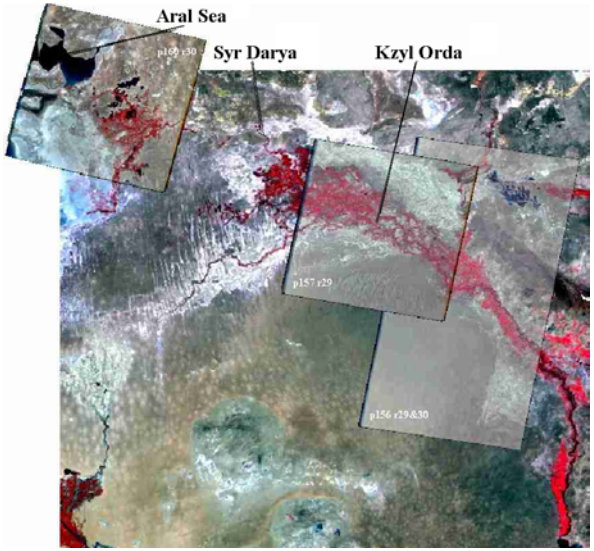

Fig 1 MODIS image with Landsat superimposed

In 2004, 160,000 ha of land was irrigated from Syr Darya water resources. Although insignificant elsewhere in the basin, rice dominates Kzyl Orda (70,000 ha), sometimes in rotation with winter wheat. Rice is sown in May and harvested in August/September.

Basin irrigation is the traditional way of land irrigation, and basic water allocation principles are the same as those during the Soviet era. Total river diversion in 2003 was estimated to be 3.27 km^3 across an irrigated area of 160,000 ha, which will yield an average water diversion of 2044 mm/year. This shows that rice and other crops are assumed to have a very high water consumption and that conveyance and distribution of losses are significant.

Study approach

The Surface Energy Balance Algorithm for Land (SEBAL) has been applied in conjunction with Moderate Resolution Imaging Spectrometer (MODIS) data aboard the Aqua satellite and Landsat data (see fig 1) to prepare an analysis of the water depletion and rice productivity in Kzyl Orda oblast.

9 two-monthly MODIS images were used to quantify hydrological variables such as the actual evapotranspiration (ET_{act}), potential ET (ET_{pot}), soil moisture (θ/θ_{sat}) and biomass production (kg/ha) during the rice season. MODIS imagery has a resolution of 250 m (biomass) and 1000 m^2 (ET).

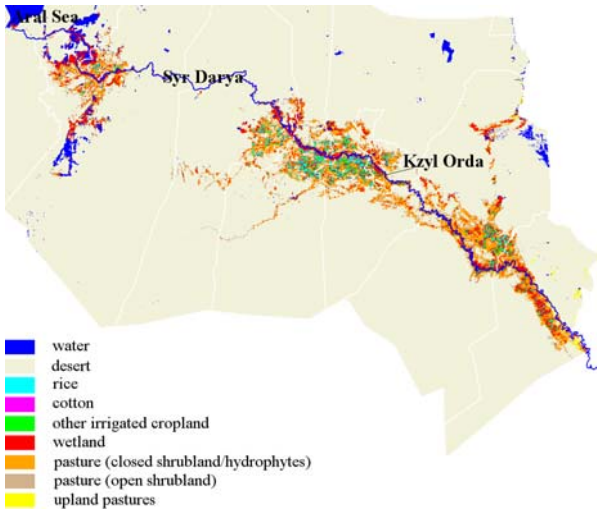

Fig 2 MODIS land use classification of Kzyl Orda

To provide more detailed spatial patterns, such as for individual fields, SEBAL was also applied on 4 high resolution (30 m) Landsat ETM-7 images, resulting in maps of 24h actual ET and biomass production in August 2004.

Sequential unsupervised classification on MODIS NDVI images resulted in the land use map shown in fig 2. A rice map was made similarly. For Kzyl Orda oblast, 71.913 ha has been classified as rice, which is almost equal to the official number of 69.998 ha. Table 1 shows the MODIS-based land use classification for 2003. A small part of Kzyl Orda oblast falls outside the MODIS image. Most of this area however is covered by desert and the amount of irrigated cropland excluded can be neglected.

Table 1 Land use statistics of Kzyl Orda based on MODIS

Land use	**area (ha)**
water	305,181
desert	15,246,550
irrigated cropland	169,320
wetlands	398,225
pasture (closed shrubland / hydrophytes)	674,506
pasture (open shrubland)	232,006
upland pastures	18,388
Total (covered by MODIS)	**17,041,175**
Not covered by MODIS	**5,571,044**
Total (whole Kzyl Orda oblast)	**22,612,219**

Results

Fig 3 and 4 show the total water consumption and biomass production in Kzyl Orda oblast for the rice season of 2003.

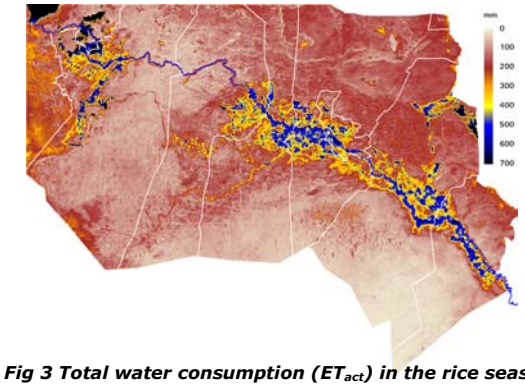

Fig 3 Total water consumption (ET_{act}) in the rice season

Highest water consumption takes place in the vicinity of the river, reaching values above 600 mm. Water consumption in the desert ranges between 0 up to 200 mm, which is in good agreement with the rainfall.

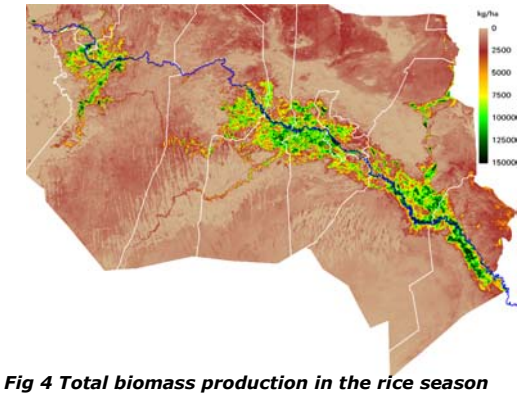

Fig 4 Total biomass production in the rice season

Like water consumption, also biomass production is highest close to the river. Areas with high ET and high biomass production have good correspondence. Most of the basin does not have problems with water shortage during the rice season since ET deficit is lower than 120 mm in the valley of the Syr Darya.

Rice yield and water productivity were calculated for assessing the benefits of river diversions using the MODIS and Landsat results. Rice yield was estimated using a Harvest Index of 0.4 (yield = harvest index * biomass production). Water productivity is the yield divided by the water consumption (yield/ET_{act}).

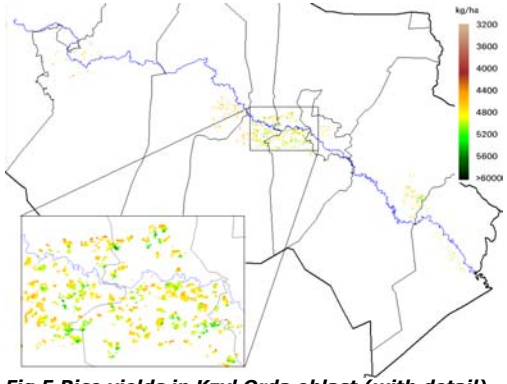

Fig 5 Rice yields in Kzyl Orda oblast (with detail)

Fig 5 shows the rice yield in 2003. Crop yields reduce towards the tail end of the irrigation system in Jalagash and in Kazalinsk (see table 2). Mean rice yield is 3739 kg/ha, which is moderately low.

Table 2 Rice yields in 2003 based on MODIS analysis

Rayon no.	Rayon name	Mean [kg/ha]	StDev [kg/ha]
166	Kazalinsk	2682	948
168	Karmakchi	3421	462
112	Jalagash	3779	572
171	Syr Darya	3912	561
169	Kzyl Orda	3372	438
170	Chiili-1	4062	572
113	Janakurgar	4008	540
Average		**3739**	**589**

downstream

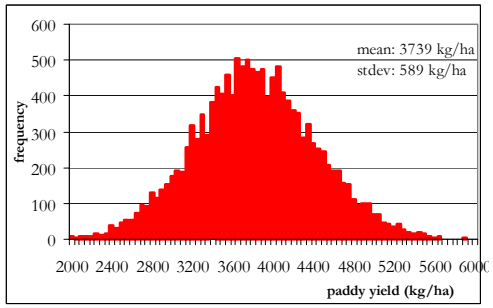

Fig 6 Frequency distribution of rice yield

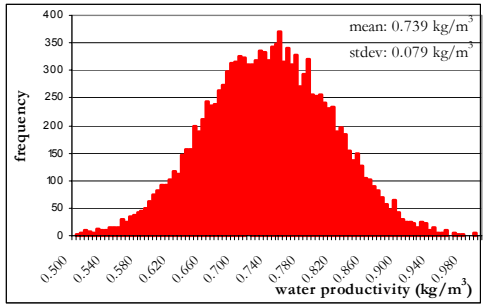

Fig 7 Frequency distribution of rice water productivity

Fig 6 and 7 show the frequency distribution of rice yield and rice water productivity. According to FAO33 rice water productivity ranges between 0.7 and 1.1 kg/m^3. Zwart and Bastiaanssen (2004) found that rice water productivity in field experiments ranges between 0.6 and 1.6 kg/m^3. The mean crop water productivity of 0.74 kg/m^3 is below the world average of 1.1 kg/m^3.

Maintenance of irrigation works has been neglected over the last 15 years, resulting in excessive system losses and abandoning of irrigated land. Table 3 shows the average water diversion and water depletion (ET_{act}) per rayon. According to these data, irrigation efficiencies (depletion / diversion) are very low, around 15%.

Table 3 Water allocation for rice at the point of river diversion for rice cultivation in 2003

Rayon no.	Rayon	Water diversion [mm]	Water depletion [mm]	Irrigation efficiency [%]
166	Kasalinsk	3375	458	13.6
168	Karmakchi	3758	487	13.0
112	Jalagash	3201	512	16.0
171	Syr Darya	3357	530	15.8
169	Kzyl Orda	3437	516	15.0
170	Chiili	3318	531	16.0
113	Janakurgan	3599	514	14.3
Average		**3397**	**514**	**15.1**

Furthermore, accumulated ET_{act} is around 600 mm per season, while the ET_{pot} is 650 mm, which implies the irrigation norms at the farm gate of more than 1000 mm per season are grossly over-estimated and can be strongly reduced, even in areas with soil salinity.

Conclusions

Average rice yields are moderately low, which is believed to be related to the long stems of the rice plants and prevailing arid conditions. There is no overall shortage of water resources, but lowest yields are found at the tail end of the irrigation system, suggesting that irrigation water does not always reach the final destination. Taking in account the very low irrigation efficiencies, this really catches the attention.

The main problem in Kzyl Orda is improper management of irrigation systems. Both systematic over-irrigation and excessive system losses, has resulted in excess water withdrawals from the Syr Darya, far above the level to meet food production targets. Diversions could be strongly reduced, leaving more water resources in the Syr Darya river, thus yielding more inflow into the Aral Sea.

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