The challenge of water, energy, and food issues in the Ili River-Lake Balkhash ecosystem

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Background and Previous MSU Work in Central Eurasia - Personnel

- Substantial group of faculty engaged in social science and regional studies of Central Asia and Caucasus (history; politics; economics; geography ; Slavic, Turkic, and Persian languages and Cultures; e.g., Martha Olcott, Sherman Garnett, Norm Graham, Kyle Evered, Emine Evered, Eric Freedman, Jason Merrill, Timur Kocaoglu, Susan Linz, Matthew Pauly, Jiaguo Qi, Matthew Zierler)
- Substantial group of STEM and Agriculture/Natural Resources faculty engaged in technical assistance and remote sensing and modeling of agricultural development challenges with a growing emphasis on Land Use trends and policy and the Water-Energy-Food Nexus (e.g., George Bird, Karim Maredia, Steve Pueppke, Jiquan Chen, David Hyndman, Geoffrey Henebry, Kevin Mackey, Yadu Pokrel, Volodymyr Tarabara)

Background and Previous MSU Work in Central Eurasia – Past Project Highlights

- Integrated Pest Management for Wheat, Potatoes, Rice in Kyrgyzstan, Tajikistan, Uzbekistan (5 year technical assistance, capacity building, PhD education and training effort sponsored by USAID)
- Research on the Inland Fisheries Collapse in Central Asia after the Dissolution of the USSR (several published papers in collaboration with Faculty of Biodiversity and Bioresources at Al-Farabi Kazakh National University; contribution to FAO/MSU Global Conference of Inland Fisheries-2016)
- Environmental Challenges in Central Asia with Focus on Adaptation to Climate Change (Qi and Evered edited volume from NATO Science Conference

Pending MSU Work in Central Eurasia

- Rangeland Assessment in Akmola Region of Kazakhstan with USDA (pending project with USDA and AgroTech Hub of Kazakh National Agrarian University with funding expected by Asian Development Bank)
- Modeling and Managing Ili River/Lake Balkhash Ecosystem of Xinjiang, China and Kazakhstan (pending project with Xinjiang Institute of Ecology and Geography with funding expected by NSF and NSF/China joint submission)
- Support of development of 44 station extension network (for training and problem solving in agriculture, veterinarian and aquaculture capacity in Uzbekistan in collaboration with Tashkent State Agricultural University and the Uzbek Ministry of Agriculture with expected funding from the EU in Tashkent.

The Caucasus and Central Asia

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water

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Article

The Current Status and Future of Central Asia's Fish and Fisheries: Confronting a Wicked Problem

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Abstract: Central Asia's arid lowland ecosystems are dependent on water that originates in nearby mountains and is carried by rivers to terminal lakes and freshwater seas with no outlets to the ocean. Fish traditionally thrived in these waterways, but they have become increasingly jeopardized by water impoundment and diversion for energy and crop production. Fish capture in the five new Central Asia republics consequently entered a period of long decline, a trend that was accelerated by removal of the centralized controls imposed by the former Soviet Union. Production levels have recovered during the past decade, but only in some countries. A similar trend is evident with aquaculture, which reached its lowest production levels in 2003-2008 but now is partially recovering. In both cases, progress is most evident in water-deficient Uzbekistan. Fish capture in Kazakhstan's Ili River ecosystem, including Kapchagay Reservoir and Lake Balkhash, is now dropping precipitously. Effects on the lake's fisheries have been magnified by the disproportionate rates of disappearance of valuable carp and zander. The interrelationships between water, energy, and food underlie these threats to Central Asia's fish and define a classic "wicked problem" that must be addressed regionally with explicit attention given to fish as important components of the ecosystem. Recent developments, although not all positive, give reason for cautious optimism that the region's fisheries and aquaculture industries can be stabilized.

Keywords: Central Asia; Lake Balkhash; Ili River; inland fisheries; Water-Energy-Food nexus; sustainable fisheries; aquaculture

1. Introduction

A landlocked region of dramatic landscape diversity, Central Asia is distant from the world's oceans. Encompassing about 4 million km² and home to more than 60 million people, it is bracketed by the Caspian Sea, desert, and treeless steppe on the west and north and the Hindukush, Pamir, and Tian Shan mountain ranges, which form an imposing arc-shaped barrier on the south and east. Elevation falls off rapidly from the external slopes of these mountains, giving rise to the vast expanses of semi-arid plains that grade into the deserts that define most of the region. The climate is sharply continental, with large annual temperature fluctuations that lead to hot summers and cold winters. Precipitation in Central Asia generally averages between 250 and 300 mm per year but is highly seasonal and varies significantly with location [1]. It is greater as elevation increases, ranging from as

water

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Review

Central Asia's Ili River ecosystem as a wicked problem: Unraveling complex interrelationships at the interface of water, energy, and food

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Abstract: The Ili River originates in the mountains of Xinjiang, China, and flows across an increasingly arid landscape before terminating in Kazakhstan's Lake Balkhash, which has no outlet to the ocean. The river has been extensively impounded and diverted over the past half century to produce hydroelectric power and food on irrigated land. Water withdrawals are increasing to the extent that they are beginning to threaten the ecosystem, just as it is becoming stressed by altered inflows as glaciers retreat and disappear. If the Ili River ecosystem is to be preserved, it is crucial that we thoroughly understand the spatial and temporal nuances of the interrelationships between water, energy, and food—and the vulnerability of these components to climate change. The ecosystem has all of the characteristics of a classically defined wicked problem, and so it warrants treatment as a complex and dynamic challenge subject to changing assumptions, unexpected consequences, and strong social and economic overtones. Research thus should focus, not just on new knowledge about the water, energy, *or* food component, but on advancing our understanding of the ecosystem as a whole. This will require the participation of interdisciplinary teams of researchers with both tacit and specialized knowledge.

Keywords: Ili River; Kapchagay dam and reservoir; Lake Balkhash; Central Asia; water-energy-food; wicked problems.

1. Introduction

Endorheic river basins are among the earth's most threatened features. Water in these closed hydrological systems has no pathway of egress to the sea, and so it flows into so-called terminal lakes that, as their name implies, lack outlets. These water bodies, the rivers that sustain them, and indeed, the fragile ecosystems surrounding them, can be easily disrupted by diversion of water for human uses. Such anthropogenic pressures are becoming acute in Central Asia, the region centered on the five former Soviet republics of Turkmenistan, Tajikistan, Kazakhstan, Kyrgyzstan, and Uzbekistan [1]. It is here, where the climate is arid, evaporation a significant factor, and the vast majority of all waterways fail to reach the sea, that large volumes of water are being redistributed to meet human

The Ili River Lake Balkhash Ecosystem

Fragile, complex, and unique
Threatened by diversion of water to produce energy and food
Further threatened by climate change

These challenges make the Ili attractive to researchers
As ecosystems go, this one is well defined and thus amenable to study
A model for WEF paradigm

Two Defining Characteristics of Water in Central Asia

1. the endorheic nature of the region; Rivers either enter terminal lakes that lack outlets, or they simply disappear before reaching any larger body of water

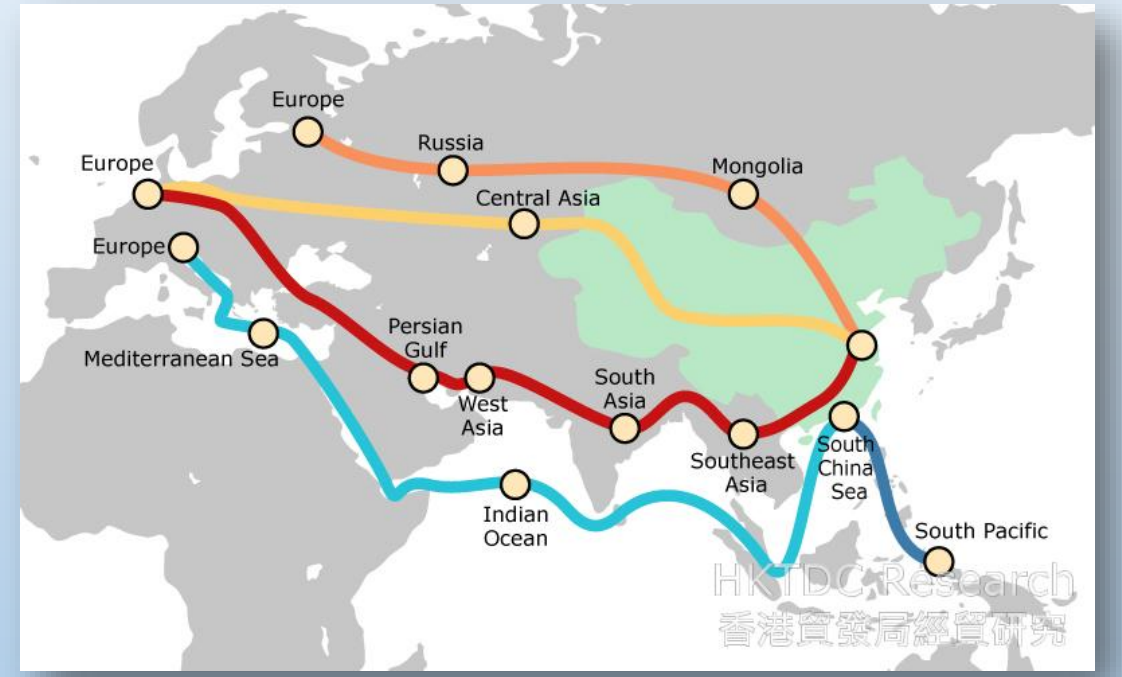
2. the region's unusual dependence on precipitation that falls at high elevations; some retained in glaciers, but much of it flows down to the arid, more heavily populated lower elevations

- Climate change, glacial retreat, dam construction, water use for irrigation, and infrastructure development have significantly altered hydrological processes in the region, imposing a major threat to food, energy, and water (WEF) security

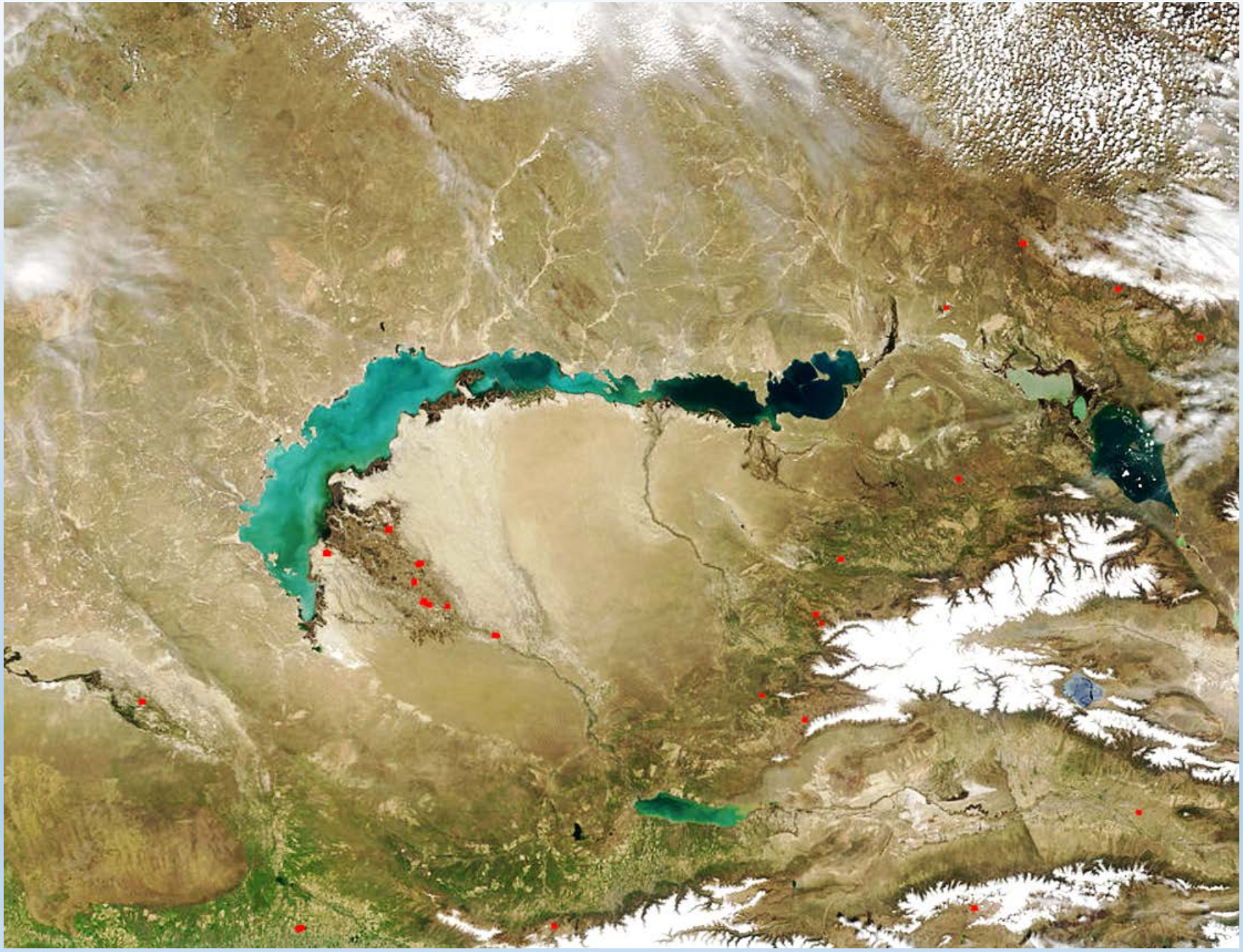
The river and the lake

- Arises from snow and glacier melt in the Tien Shan mountains of Xinjiang, China
- Flows across an increasingly arid landscape
- Forms a delta surrounded by desert
- Terminates in Lake Balkhash
- Nourishes a fragile ecosystem

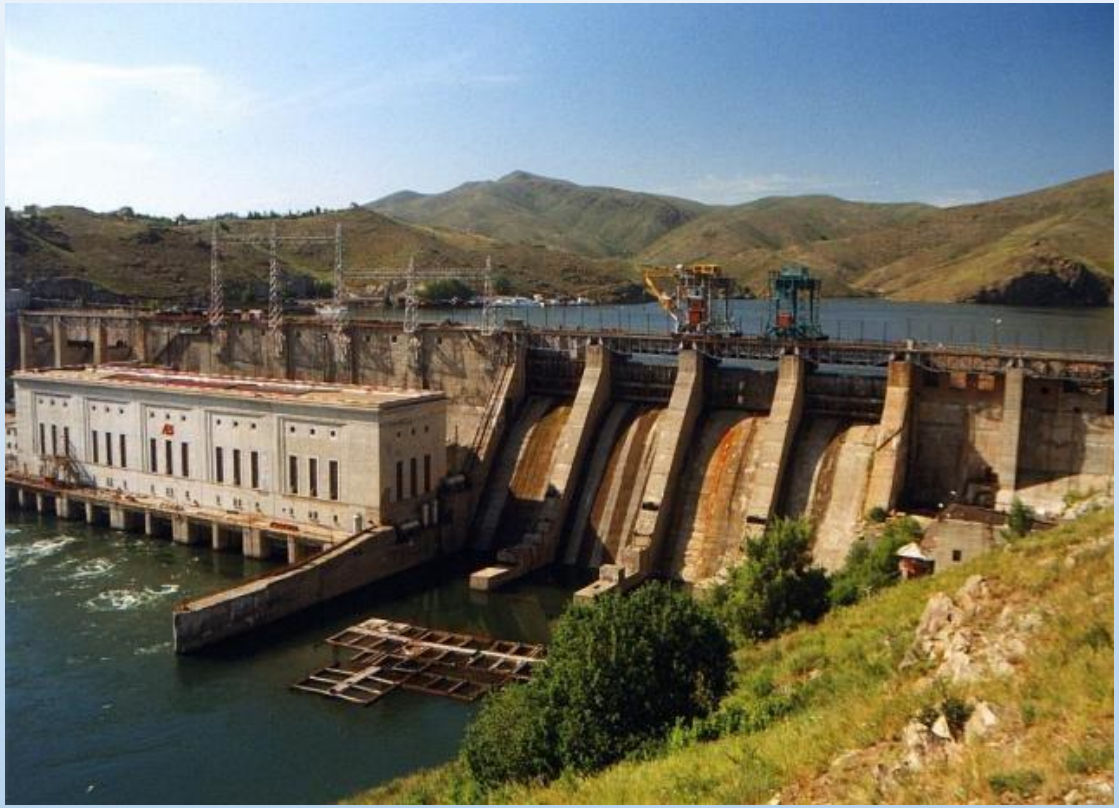
Fragile, complex, and unique



Fragile, complex, and unique



Human intervention: Water, energy, food



Turkmen Gas Exports

	To Russia	To China
2006	41	
2007	43.2	
2008	45	
2009	9	2.9
2010	12	6
2011		17

Source: Pirani, Simon. *Russian and CIS Gas Markets and Their Impact on Europe*. Oxford University Press, New York, New York, 2009

Table 5.2

Central Asia:
Annual Natural Gas Production and Exports

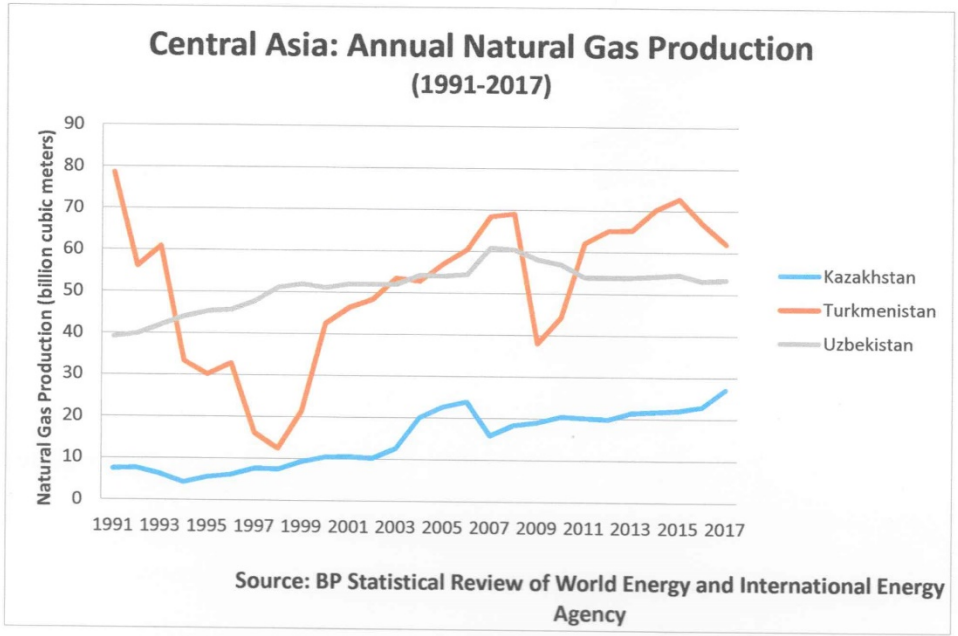
Unit = billion cubic meters

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Kazakhstan											
Production	15.8	18.3	19.0	20.4	20.1	19.8	21.4	21.7	22.0	22.9	27.1
Exports			10.3	11.95	11.5	11.3	11.8	11.4	11.3	16.6	13.2
to China			0	0	0	0	0.1	0.4	0.4	0.4	1.1
to Russia			9.82	11.95	11.4	11	11.5	10.9	10.9	16.1	12.1
Turkmenistan											
Production	68.4	69.1	38.0	44.3	62.1	65.1	65.2	70.2	72.8	66.9	62.0
Exports	6.1	6.5	16.73	19.73	34.6	41.1	40.1	41.6	38.1	37.3	33.6
to China	0	0	0	3.55	14.3	21.3	24.4	25.5	27.7	29.4	31.7
to Iran	6.1	6.5	5.77	6.5	10.2	9	4.7	6.5	7.2	6.7	1.7
to Russia	0	0	10.68	9.68	10.1	9.9	9.9	9.0	2.8		0
Uzbekistan											
Production	60.9	60.4	58.1	56.9	53.9	53.9	53.9	54.2	54.6	53.1	53.4
Exports			15.7	13.56				8.5	7.5	11.4	11.8
to China			0	0				2.4	1.5	4.3	3.4
to Iran			0	0				0	0	0	0
to Russia			11.86	10.32				4.1	3.3	5.6	6.7

Source: BP Statistical Review of World Energy 2002-2018; and

International Energy Agency

Figure 5.9



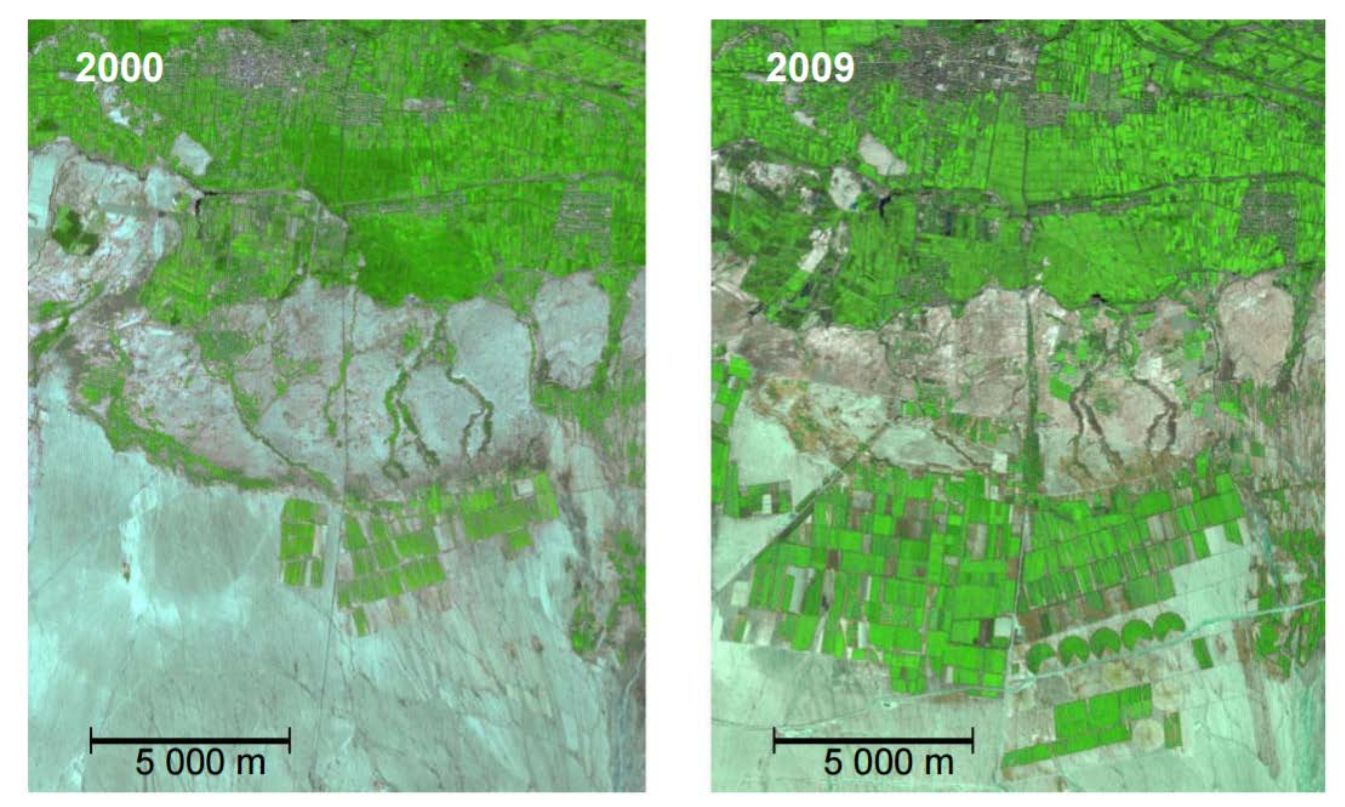
Source: BP Statistical Review of World Energy and International Energy Agency

More power
More crop-based food

More evaporation
Less fish-based food
Less forage for livestock

Human intervention

- Reservoirs and irrigation projects—mostly upstream
- Large power plants that burn coal and consume water for cooling
- Rapid pace of change
- One-off decisions
- Coupled impacts across time and space

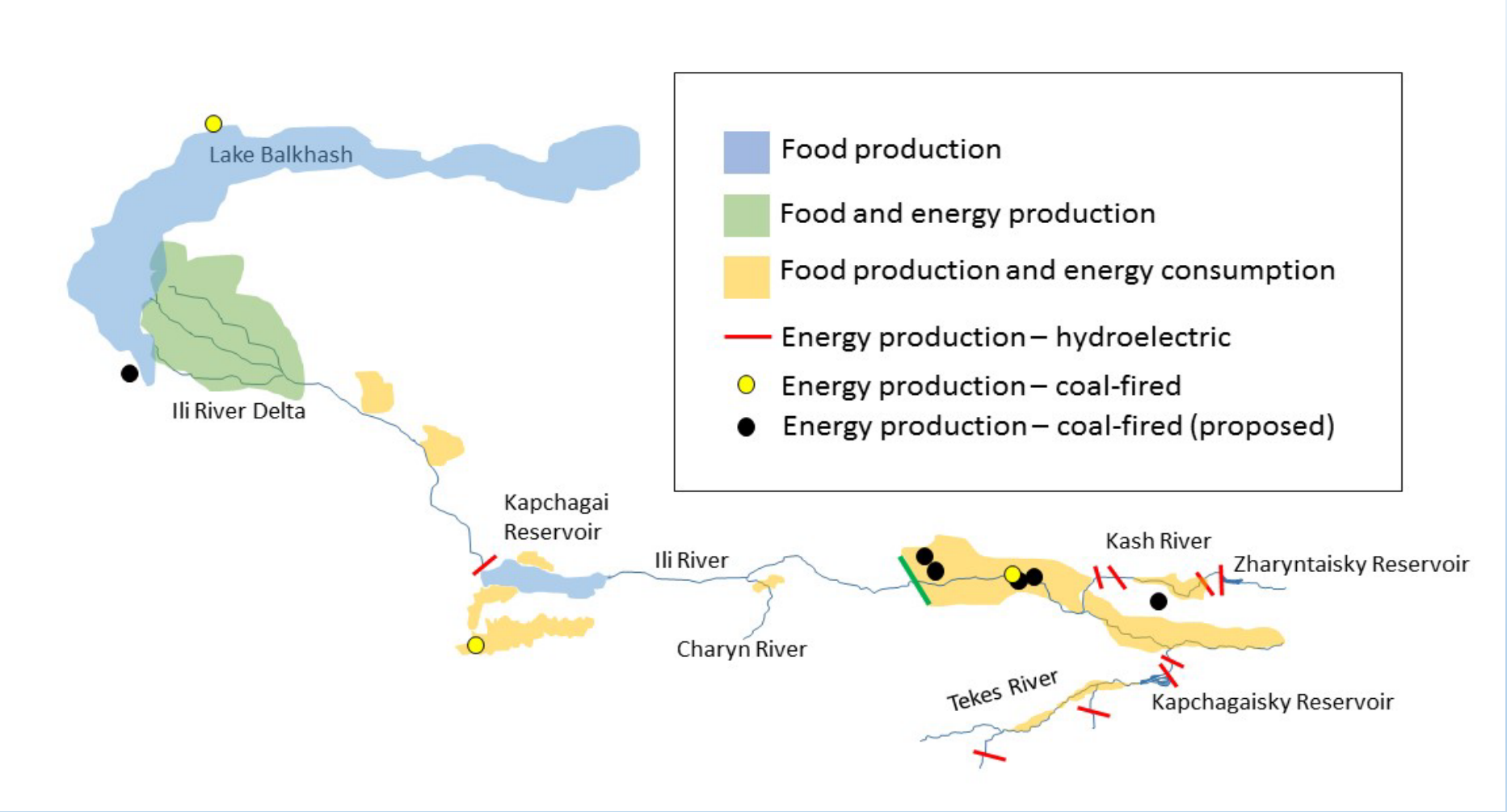


Launch of Balkhash thermal power plant might be postponed

samruk-energy.kz

--Images from A. Terekhov and S. Dolgikh, RSE Kazhydromet, KZ

Everything interconnected to everything else



The Challenges of Sustaining Inland Fisheries in Central Asia

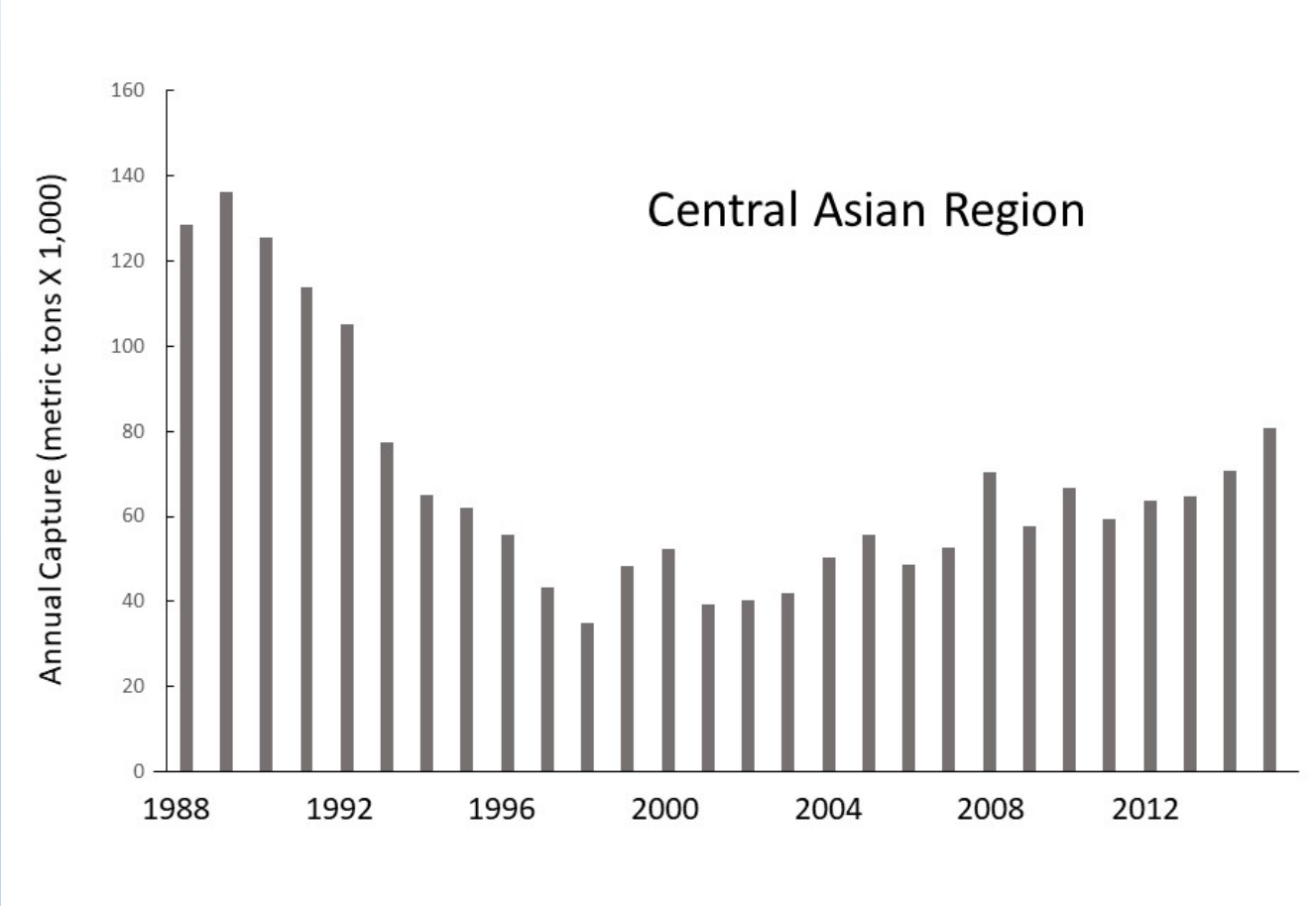
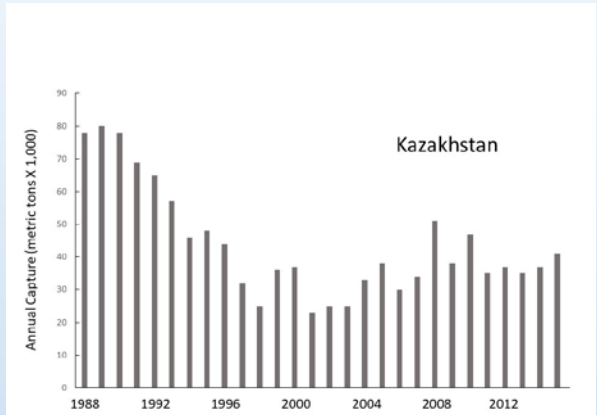
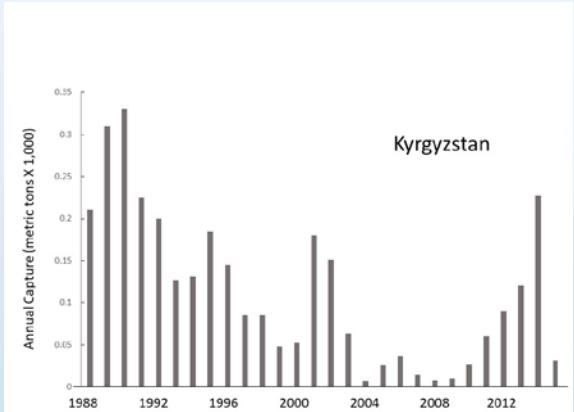
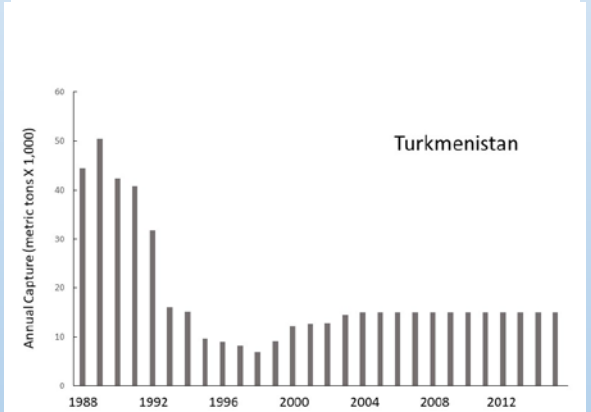


Figure 2. Estimated annual fish capture in Central Asia between 1988 and 2015 (Sources: www.fao.org and www.worldbank.org/indicator/ER.FSH.PROD.MT).







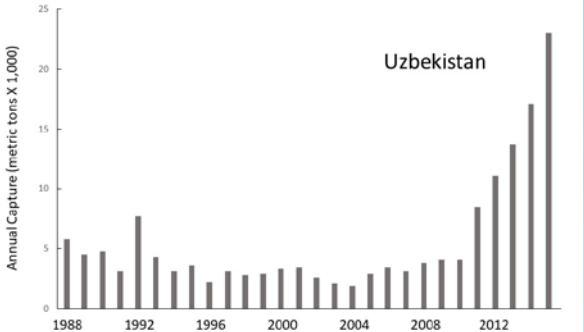


Table 3. Commercial catches and fishing operations on Balkhash Lake (1960-1966) (Source: Kazakh Research Institute of Fishery).

Commercial catches and fishing operations on Lake Balkhash (1960-1966)

Year	Fishers	Total catch (tons)	Average catch per fisher (tons)	Seines in use	Fishnets in use
1960	664	8,870	13.4	66	23,000
1961	574	8,850	15.4	55	28,000
1962	641	11,810	18.4	65	27,900
1963	724	13,450	18.6	72	30,100
1964	781	15,040	19.3	77	24,600
1965	787	16,170	20.6	77	31,500
1966	775	16,500	21.3	88	32,000

Commercial Fishing in Ili River-Lake Balkhash Ecosystem

- Clear decline in:
  - Total catch
  - Catch of most prized species,
  - Employment of fishers
  - Economic impact

  Prospects for Economic Diversification/Alternative Employment seem limited in the region

  Some Development of Aquaculture as an Alternative Food Supply Option

Commercial Fish Capture in Lake Balkhash (2010-2017)

Species	Commercial catch (tons)			
	2010	2011	2016	2017*
Asp (Aspius aspius)	290	320	296	324
Common carp (Cyprinus carpio)	910	1,060	483	482
Freshwater bream (Abramis brama)	5,040	5,047	4,801	4,604
Goldfish (Carassius auratus)	230	236	79	145
Pike-perch (Sander luciopera)	1,210	1,324	697	554
Roach (Rutilus rutilus)	300	315	303	312
Snakehead (Channa argus)	No data	No data	50	50
Volga pike-perch (Sander volgensis)	200	209	142	102
Wels catfish (Silurus glanis)	890	938	701	735
TOTAL CATCH	9,070	9,449	7,552	7,308

Fishing Employment and Fleet on Lake Balkhash (2010-2015)

Year	Fishing firms	Fishers	Self-propelled boats	Seines in use	Fishnets in use
2010	39	1090	433	89	12,275
2011	33	1122	192	68	11,795
2012	24	506	208	75	5,500
2013	28	459	191	53	5,180
2014	28	618	154	41	7,350
2015*	26	447	242	58	5,849

Commercial Catch in Ili River and Ili River Delta (2010-2017)

Species	Commercial catch (tons)							
	Ili River				Ili River delta			
	2010	2011	2016	2017*	2010	2011	2016	2017*
Asp (Aspius aspius)	31.8	32.1	7.3	7.3	52.5	54	22.8	22.6
Common carp (Cyprinus carpio)	88.5	80.0	15.2	15.2	120	119	15.1	15.1
Freshwater bream (Abramis brama)	23.8	22.9	2.9	4.8	34	32	5.3	5.3
Goldfish (Carassius auratus)	19.1	19.8	6.0	6.0	25	25	5.8	5.8
Grass carp (Ctenopharyngodon idella)	14.9	12.2	0.6	0.7	9.2	8	2.6	3.3
Pike-perch (Sander luciopera)	40.0	34.9	4.2	4.2	68.3	76	16.1	16.1
Roach (Rutilus rutilus)	24.2	22.8	6.0	6.0	25	27	18.8	18.7
Snakehead (Channa argus)	ND	ND	1.3	1.3	ND	ND	8.7	8.7
Volga pike-perch (Sander volgensis)	7.2	7.7	1.5	1.5	17	16	4.6	4.6
Wels catfish (Silurus glanis)	70.5	74.8	29.3	29.3	207	225	43.2	42.8
TOTAL CATCH	320.0	307.0	74.3	76.3	558	582	143	143

Aquaculture as an Option for Fish Production

- Significant declines in production in Kazakhstan, Tajikistan, Turkmenistan
- Substantial increase in production in Uzbekistan
- Modest increase in Kyrgyzstan

- Modernization of facilities in the Almaty region underway

Fish Production in Aquaculture: Central Asia, 1991-2015

Country	Aquaculture fish production			Lowest production	
	1991 (tons)	2015 (tons)	Change (%)	Year	Tons
Kazakhstan	13,382	730	-95	2005	123
Kyrgyzstan	974	1,068	+10	2003	12
Tajikistan	3,689	450	-88	2004-2008	26
Turkmenistan	2,248	30	-99	2004	16
Uzbekistan	24,316	36,898	+52	2004	3,093

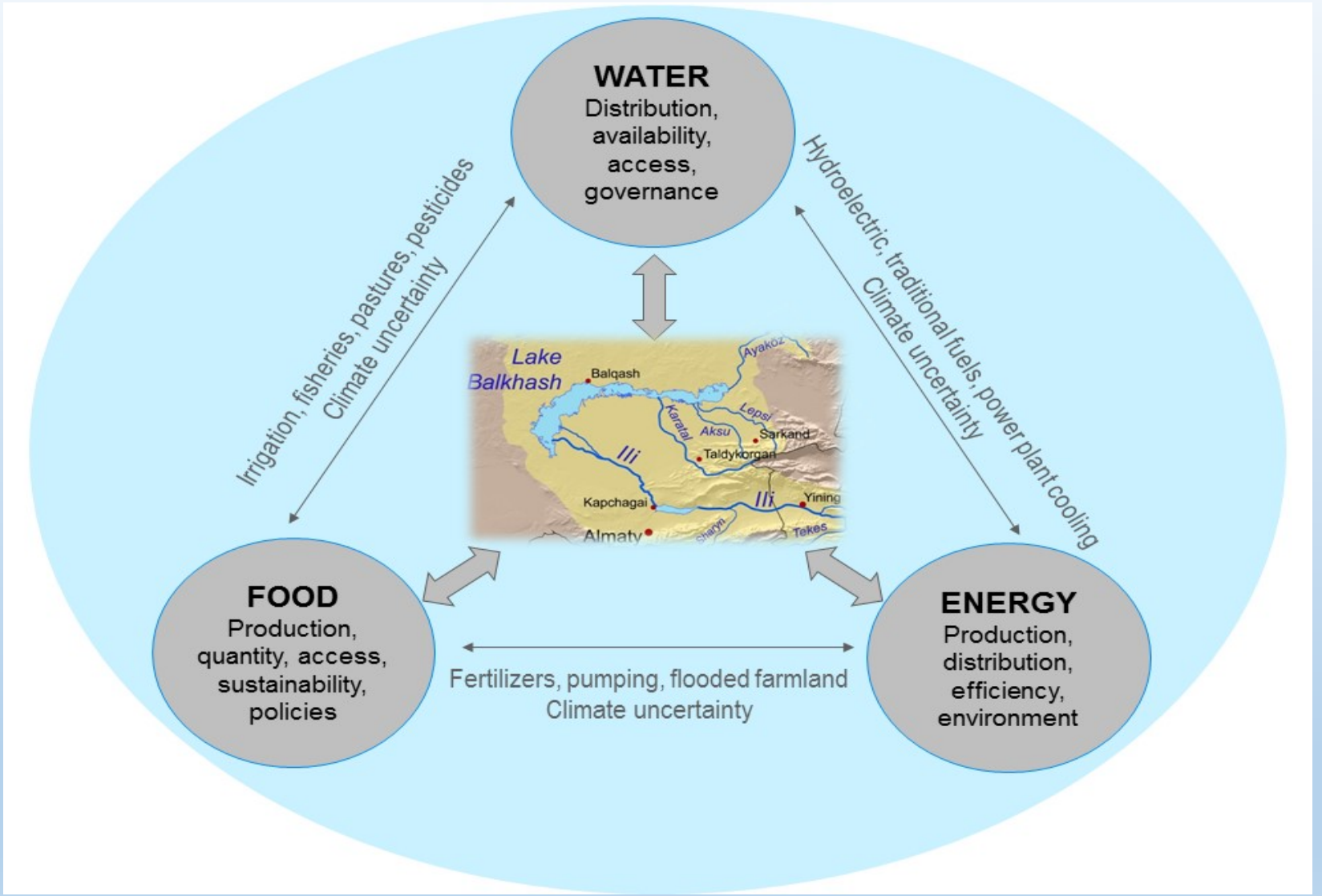

СХЕМА
РАСПОЛОЖЕНИЯ ПРУДОВ
ЧИЛИКСКОГО РЫБОКОМБИНАТА
Головной
НП-1
НП-2
НП-3
МВ-1
МВ-2
Н-1
пл. 9,5 га
Н-2
пл. 13,5 га
Н-3
пл. 13,2 га
Н-4
пл. 13,6 га
Н-5
пл. 12 га
Н-6
пл. 12 га
Н-7
пл. 20,5 га
Н-8
пл. 37,5 га
Н-15
пл. 87 га
Н-11
пл. 74 га
Н-12
пл. 74 га
Н-13
пл. 89 га
Н-14
пл. 75 га
Н-16
пл. 77 га
Н-17
пл. 22 га
Н-18
пл. 21 га
Н-10
пл. 72 га
Н-9
пл. 88 га
ЛМ-1
ЛМ-2
ЛМ-3
ПГ-1
ПГ-2
ПГ-3
отстойник
УСЛОВНЫЕ ОБОЗНАЧЕНИЯ
водопадающий канал
водосбросной канал
аварийный канал
проектируемые нак. пруды
автодороги

Modernization of Aquaculture in Uzbekistan

- Gradual recovery from post-Soviet collapse of Inland Fisheries
- Largest Aquaculture production in the region by far
- Dual use recreation facilities together with Sturgeon and Salmon production

The  approach:

- To the social scientist, it's about the collapse of the Soviet Union, transboundary issues, regional hegemons, and globalization
- To the hydrologist, it's about mass balance of water, stream flows, and melting glaciers
- To the agricultural scientist, it's about irrigated crops, forage for animals, and preservation of water resources for fish
- To the energy specialist, it's about maximizing hydroelectric potential or maybe preserving traditional fuels such as firewood


WATER
Distribution, availability, access, governance
Irrigation, fisheries, pastures, pesticides
Climate uncertainty
Hydroelectric, traditional fuels, power plant cooling
Climate uncertainty
Lake Balkhash
Balqash
Ayakoz
Lepsi
Karatal
Aksu
Sarkand
Taldykorgan
Ili
Kapchagai
Yining
Almaty
Sharyn
Tekes
FOOD
Production, quantity, access, sustainability, policies
ENERGY
Production, distribution, efficiency, environment
Fertilizers, pumping, flooded farmland
Climate uncertainty

How can we best develop sustainable pathways for Ili-Balkhash WEF systems in light of rapid climatological and differential socioeconomic changes? (NSF-NSF/China proposal)

- *Quantify historical climate and land use changes, associated socioeconomic drivers and demographic implications.*
- *Assess the effects of climate variability and land use change on water resources, productivity of crops, livestock, and fish, as well as energy infrastructures and utilities.*
- *Characterize and model the dynamic processes and interactions among the basin's WEF systems.*
- *Identify the tradeoffs and synergies across WEF systems to develop adaptation strategies and pathways toward basin-wide sustainability, including cross-border sharing and governance.*