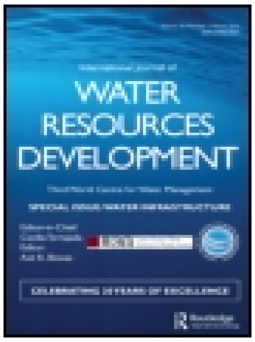

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Agricultural water and energy management in Tajikistan: a new opportunity

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ABSTRACT
Agricultural water use in Tajikistan is largely based on mechanized irrigation pumps. The farming community cannot afford the cost of the energy used for pumping, resulting in large debts to the service provider. We propose limiting pumping facilities for five years in exchange for energy export to neighbouring countries. The energy export could cover the annual pumping expenditures, pay off agricultural debt and partly rehabilitate the irrigation network. We suggest three scenarios with different pumping energy reductions, and the relevant technical parameters of the set-aside scheme are assessed.

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Water-energy nexus; hydropower; agriculture; irrigation pumping; Central Asia

Introduction

Tajikistan is a landlocked, mountainous and largely agrarian country; half of the territory is above 3000 metres in altitude. It is considered the poorest country in Central Asia, with 49% of the rural population living below the poverty line. Approximately 73% of the population of 9 million reside in rural areas, where paid jobs are scarce (Government of Tajikistan, 2016a). The rural sector is heavily occupied in farming: 46% of the population is employed in the agricultural sector, which contributes 21% of the national GDP (USAID, 2014; World Bank, 2013). Extensive agriculture is mostly practised in lowland areas, although in the mountainous regions subsistence farming plays a major role in the livelihoods of local communities.

Agriculture in Tajikistan was modernized in the Soviet period and continues to be one of the most important sectors in the country. During the Soviet era, Central Asia was transformed into an agricultural supplier for the whole Soviet Union, mainly of wheat and cotton. Through massive modernization, agricultural output in Tajikistan tripled between 1960 and 1988 (Rahaman, 2012). After independence, liberalization of the agricultural sector and a devastating civil war slowed agricultural output, dropping productivity by 55% between 1991 and 1997. But many agricultural reforms have attempted to revamp the sector and underpin subsistence farming, with considerable success (Government of Tajikistan, 2006, 2012).

Due to differences in climatic conditions, agriculture in Tajikistan is dependent on irrigation, which in some regions is highly energy-intensive as a result of mechanical irrigation pumps. The agricultural sector is the third-largest energy consumer, accounting

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for 20.5% of Tajikistan's summer electricity demand, according to the national integrated power company of Tajikistan, Barqi Tojik (World Bank, 2017). Electricity for irrigation pumping is heavily subsidized by the government of Tajikistan, and the irrigation fees are among the lowest in the world (World Bank, 2013). The fees cannot fully compensate Barqi Tojik for the energy provided to agriculture, creates major debts, as will be discussed in the following section (Barqi Tojik, 2018).

The need to constantly maintain the outdated network, the high subsidies, and the limited fee collection place a heavy burden on the country's national budget. Recognizing this problem, the government has made significant investments to rehabilitate parts of the irrigation network. Also, major reforms are currently underway to adjust the agricultural water fees so that they better reflect the maintenance and operational expenditures of the irrigation network. However, as the funds for major rehabilitation are limited, other financial, technical and organizational solutions are needed to make the agricultural sector economically sustainable in the long run. At the same time, Tajikistan is heavily investing in new hydroelectric and thermoelectric power stations to become energy sufficient and a net exporter of electricity, supplying growing economies in Afghanistan and Pakistan.

For instance, the huge Rogun embankment dam under construction in south Tajikistan will nearly double the country's installed energy capacity to about 9000 MW when completed. The reservoir is an overall USD 3.9 billion project, with a height of 335m and estimated capacity of 3600 MW (Impregilo, n.d.). The first turbine, of 600 MW, was commissioned in 2018, and the capacity will be gradually increased as the reservoir is filled. The Rogun dam and the other installed energy stations will ensure energy security in Tajikistan and bring major economic benefits by exporting excess electricity to neighbouring countries (Rahmon, 2018). The energy surplus is created in summer thanks to melting snow and ice in the mountainous parts of the country.

Such energy exporting was in place through barter exchanges with neighbouring Central Asian republics during the Soviet era, and continued after independence. It was suspended in 2009, when Uzbekistan unilaterally withdrew from the Central Asia Power System, a network for energy exchange (Laldjebaev, Morreale, Sovacool, & Kassam, 2018). A regional collaboration was relaunched in 2018, and Tajikistan resumed energy trade with Uzbekistan, with plans to increase it further (IEU, 2018). Energy export to Afghanistan began in 2012, with financial assistance from the Asian Development Bank to construct transmission lines and related infrastructure (ADB, 2014), and has reached 1 billion kWh per year (Aliyeva, 2018).

The inauguration of the Central Asia-South Asia Electricity Transmission and Trade Project (CASA-1000) in May 2016 is expected to further increase exports to South Asia. This USD 1.2 billion project connects Tajikistan, Kyrgyzstan, Afghanistan and Pakistan through massive transmission lines, enabling large power flows from north to south (CASA-1000, 2018). Tajikistan and Kyrgyzstan are expected to annually supply up to 5 billion kWh of summer electricity to Afghanistan and Pakistan via this power transmission line (SNC-Lavalin, 2011; Barqi Tojik, 2016a). In September 2018, the first contracts were signed for the construction of converter stations in Tajikistan and Pakistan; the energy exchange is to reach its full capacity by the summer of 2021 (World Bank, 2018). The very lucrative energy trade could provide significant revenues to Tajikistan's economy and contribute to rehabilitating vulnerable energy systems, including irrigation pumping.

We have developed a scenario analysis to assess the potential of a reduction in energy consumption in the agricultural sector in exchange for coverage of annual pumping expenditures, paying off of agricultural debt, and substantial investments in infrastructural assets. We assume that the energy currently consumed in irrigation pumping is initially shifted to export to generate higher revenues. The profits from the energy exporting are channelled back to the agricultural sector to rehabilitate the supply network.

We develop three different energy policy scenarios to estimate various options of national energy capacity, agricultural energy shifting to the national grid, and export to neighbouring countries. We calculate the potential effects of the energy shifting to agricultural water supply and the anticipated benefits from the exporting revenues. The challenges faced in the energy policy scenarios in compromising between the lucrative export trading and the sustainability of agricultural sector are indicated, and relevant implementation measures are recommended.

This study goes a step further than merely proposing political solutions or hypothetical exercises for the improvement of the agricultural sector in Tajikistan. We employ technically feasible options based on real case data and practical policy dimensions that could alleviate the burdensome situation of agriculture in the country. The overall improvement of the agricultural sector in Tajikistan is a long-term objective that needs to include an array of technical, economic, social and institutional factors in an integrated approach. But the adopted scenarios indicate that the water and energy trade-off could offer a major opportunity for agricultural sustainability in Tajikistan, grounded on socio-economic realities.

Agricultural water use in Tajikistan

The irrigation network in Tajikistan was heavily expanded and mechanized in the Soviet period, mainly emphasizing cotton, and secondly wheat. In the Soviet era, all the costs of maintaining large canals and drainage systems were covered by the state, and educated personnel were given some technical capacity (Granit et al., 2012) Before independence in 1991, the main land owners were around 600 collective and state farms. However, land reforms after independence, especially intensified in the late 1990s, reshaped the ownership status of farmlands towards a more privatized profile. According to the Land Code of Tajikistan, the land use rights were gradually moved to private (*dehkan*) farms and associations through long-term lease agreements (Government of Tajikistan, 1996).

Little effort has been made to explain to the new landholders their rights and roles in the agricultural sector. In particular, little attention was given to irrigation and drainage management, and maintenance and operation of existing systems was overlooked. On-farm irrigation and drainage infrastructure, formerly operated by collective farms, was gradually abandoned, without clear delegation of a new management body. The lack of funding from the state and the modest revenues from farmers' water fees could not support the rehabilitation of irrigation and drainage systems. Thus, the agricultural sector deteriorated, and measures like water use efficiency decreased, resulting in lower crop productivity and land degradation.

Since the beginning of the twenty-first century, agricultural production has shown remarkable recovery and has surpassed the level of 1991 once again. This is due partly to constant efforts to rehabilitate the irrigation network, but also to a major effort to shift

Table 1. Pump irrigation areas (in hectares) by height of water lifting, as of 2015.

Location	Up to 100 m	100–150 m	150–200 m	200–250 m	250–300 m	Total
Sughd	109,051	24,415	26,040	1,627	1,627	162,760
Khatlon	90,562	11,320	1,029	–	–	102,911
RRS	7,995	2,112	3,922	754	302	15,085
Badakhshan	92	–	–	–	–	92
National	207,700	37,847	30,991	2,381	1,929	280,850

Source: World Bank (2017).

from cotton monoculture to other crops like potatoes, fruits, onions and cotton (USAID, 2014). Currently, agricultural land in Tajikistan covers about 4.6 M hectares (ha), with a potential irrigable area of 1.57 M ha (Government of Tajikistan, 2001). However, only 753,083 ha of irrigated land and 201,370 ha of rainfed arable land is cultivated, due to technical and economic constraints (Government of Tajikistan, 2016b). The average amount of arable land held per person was estimated at 0.08 hectares in 2016 (Shenhav, Xenarios, & Domullodzhanov, 2019).

The total volume of water abstracted from all sources for irrigation is on average 8.0–10.0 km^3 per year. Irrigation water is often diverted from rivers by gravitation canals. But in many cases the river water is at a lower elevation than the agricultural land, which makes it necessary for water to be lifted into main canals by large pumping stations (Table 1). There are also many boreholes drilled into deep aquifers.

The actual mix between pumped and gravity irrigation is unknown. Out of around 36 large, 450 inter-farm and 1807 on-farm pumps, only 21 large, 286 inter-farm and 900 on-farm pumps are presently operational. The current operational status of pumping infrastructure is roughly estimated to irrigate only 280,000 ha, representing 37% of the overall irrigated lands, and there is great variety in the pumped irrigation across the country, as shown in Table 1. In areas of eastern Tajikistan, for instance, pumps supply 21% of the land, while northern areas rely up to 85% on pumped irrigation. The overall irrigation efficiency in Tajikistan is estimated at about 30% (i.e., only 30% of the withdrawn water reaches the plant roots), and the average annual abstraction for irrigation is over 15,000 m^3 per hectare (World Bank, 2017). Nevertheless, the irrigation is crucial, as the yield of irrigated crops is significantly greater than rainfed cultivation: for instance, wheat yields are on average four to six times greater. As a result, almost 80% of the agricultural output in Tajikistan is cultivated in irrigated areas (Shenhav, Xenarios, & Domullodzhanov, 2019).

Agricultural energy consumption

Energy for agriculture should be viewed in the context of overall energy supply and demand in Tajikistan. Electricity production in Tajikistan is based mainly (over 90%) on hydropower, of which the Nurek hydroelectric power plant (HPP) contributes over 75% (2700 MW installed capacity). Other notable HPPs are the Sangtuda-1 (670 MW), Baipaza (600 MW), Sarband (240 MW) and Sangtuda-2 (220 MW) (Barqi Tojik, 2018).

The Rogun HPP (3600 MW), the tallest dam in the world, has recently started to produce electricity after several decades of construction (see the introduction). The large percentage of hydro in electricity generation in Tajikistan is facilitated by water resources (glacier-fed rivers) and the steep gradients of the mountainous terrain. The rest of the electricity is supplied by thermal power plants and small and medium-size HPPs.

Agriculture and energy are intimately connected in Tajikistan. According to the first large-scale, one-off sample survey on energy facilities and efficiency of use, conducted in 2016 by the Statistical Agency (2018), the agricultural sector was the largest consumer among individual entrepreneurships. In particular, agriculture accounted for 42.4% of the 658.3 million kWh of electricity consumed by individual entrepreneurships in 2016 (trade and service, 38.2%; transport and communications, 15.1%; processing industry, 3.9%; construction industry, 0.4%). In the same survey, individual entrepreneurships in agriculture also consumed a large part of other energy sources: coal, 11.6% of 11.2 thousand tonnes; liquefied gas, 15.2% of 17.1 thousand tonnes; oil products, 44.2% of 239.8 thousand tonnes; and fuel wood, 65.1% of 138,100 m^3.

Overall, the agricultural sector in Tajikistan holds a significant proportion of the total national electricity bill, and in 2015 it was the third-largest energy consumer in the country, accounting for 13% of the total energy consumption (Table 2). Total agricultural energy consumption rose from 10% in 2005 to 13% in 2015. However, the share of irrigation pumping slowly decreased over the same decade, from 10–11% to 8–9%, with electricity consumption falling from 1,546 million kWh in 2005 to 1,246 million kWh in 2015. This decrease could be partly due to the deteriorating power network that supplies the agricultural sector with electricity. The share of irrigation pumping is higher during the summer months and varies annually depending on climatic conditions (ADB, 2011). In Figure 1, the mean monthly electricity consumption in agriculture is estimated for 2012–2016 as part of the total energy produced.

Due to the deteriorating power grid that connects HPPs to pump stations, many pumps shut down erratically. These interruptions create severe operation problems for both pump station operators and farmers and significantly impact crop production. The Energy Charter Secretariat (2013) estimated the average annual loss of agricultural products caused by energy supply limitations at 30% per year. In 2011, summing up newer machinery, efficient water use and introduction of better crop patterns, at least 50% of the electricity consumption in agriculture could have been saved (ADB, 2011). Industrial electricity consumption has decreased since 2005. This is largely due to the falling productivity of Tajikistan's largest aluminium plant, the Tajik Aluminium Company, which used to account for around 40% of Tajikistan's energy consumption (ADB, 2011).

Agricultural energy tariffs

The electricity for the agricultural sector is subsidized for farmers. The subsidy rate may vary between agricultural activities (Table 3). For instance, the tariff for pumping systems is still much lower than for all other sectors. Tariffs for pumping systems are different in winter and summer, to discourage electricity consumption in winter, when there are power shortages. In practice, in 2016 the tariff on irrigation pumping was 0.0028 US$/kWh in April through September and 0.12 USD/kWh in October through March, to the average was 0.0030 USD/kWh for the whole year.

The tariffs presented in Table 3 and Figure 2 demonstrate the charges per kWh as defined by Barqi Tojik. Tariffs for all types of agricultural use have fluctuated in the last decade. But while costs for offices, farmhouses and livestock farms have been steadily increased since 2006, the costs for irrigation pumps and rural drinking water pumps remain low. Irrigation pumping tariffs increased by 16.2% in 2017, and again by 15% in November 2018, but generally they remain distinctively low (Chorshanbiev, 2018).

Table 2. Consumption of electricity per sector, 2005–2015 (in million kWh).

YEARS		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
1. Industry	**kWh**	7,187	8,113	8,109	7,729	6,804	7,435	6,565	6,421	5,592	4,421	4,610
	%	48%	52%	47%	48%	42%	46%	40%	39%	34%	31%	30%
	kWh	3,941	3,352	3,045	2,818	3,618	3,967	3,881	3,611	4,369	4,447	4,914
2. Residences	**%**	26%	21%	18%	18%	22%	24%	24%	22%	27%	31%	32%
3. Agriculture	**kWh**	1,546	1,677	2,222	1,967	1,962	1,757	2,189	2,266	2,167	1,832	1,977
	%	10%	11%	13%	12%	12%	11%	13%	14%	13%	13%	13%
Irrigation pumps	**kWh**	1,546	1,677	1,648	1,512	1,497	1,307	1,676	1,585	1,434	1,227	1,246
	%	10%	11%	10%	9%	9%	8%	10%	10%	9%	9%	8%
Farm-houses, offices	**kWh**	0	0	31	23	10	8	7	4	4	3	3
	%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Livestock	**kWh**	0	0	5	5	6	7	11	13	11	10	7
farms	**%**	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Drinking water pumps	**kWh**	0	0	538	427	449	435	495	664	718	592	721
	%	0%	0%	3%	3%	3%	3%	3%	4%	4%	4%	5%
4. Other	**kWh**	438	423	1,179	1,141	1,453	992	1,119	1,573	1,536	1,423	1,481
	%	3%	3%	7%	7%	9%	6%	7%	9%	9%	10%	10%
5. Public sector	**kWh**	426	410	478	480	420	308	360	422	410	457	556
	%	3%	3%	3%	3%	3%	2%	2%	3%	3%	3%	4%
TOTAL	**kWh**	**15,084**	**15,652**	**17,255**	**16,102**	**16,219**	**16,216**	**16,303**	**16,559**	**16,241**	**14,412**	**15,515**

Source: Government of Tajikistan (2011), Barqi Tojik (2016a).

Table 3. Electricity tariffs for the agricultural sector, 2006–2016 (US cents and TJS diram per kWh).

		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Offices and farmhouses	USD	0.0018	0.0162	0.0288	0.0367	0.0484	0.0058	0.0620	0.0647	0.0673	0.0583	0.0461
	TJS	0.6	5.58	9.87	15.26	21.2	2.68	29.51	30.81	33.27	36.11	36.2
Livestock farming	USD	0.0081	0.0114	0.0237	0.0356	0.0486	0.0544	0.0616	0.0659	0.0679	0.0583	0.0461
	TJS	2.66	3.91	8.12	14.8	21.29	25.12	29.33	31.41	33.59	36.11	36.15
Irrigation pumping	USD	0.0016	0.0023	0.0083	0.0082	0.0040	0.0040	0.0048	0.0048	0.0046	0.0054	0.0030
	TJS	0.54	0.8	2.84	3.42	1.75	1.87	2.31	2.29	2.25	3.33	2.34
Drinking water pumping	USD	0.0020	0.0028	0.0081	0.0082	0.0059	0.0064	0.0067	0.0071	0.0063	0.0038	0.0041
	TJS	0.65	0.95	2.77	3.43	2.58	2.96	3.19	3.4	3.1	2.38	3.19

Source: Barqi Tojik (2016b). Note: In 2006, USD 1 was valued TJS 3.302; in 2007, TJS 3.443; in 2008, TJS 3.428; in 2009, TJS 4.159; in 2010, TJS 4.379; in 2011, TJS 4.618; in 2012, TJS 4.763; in 2013, TJS 4.764; in 2014, TJS 4.943 for 2014; in 2015, TJS 6.193; and in 2016, TJS 7.849 (Deutsche Bundesbank, https://www.bundesbank.de/dynamic/action/en/statistics/time-series-databases/time-series-databases/745582/745582?nsc=true&https=1&https=1&https=1&https=1&tsId=BBEX3.A.TJS.USD.CA.AC.A04).

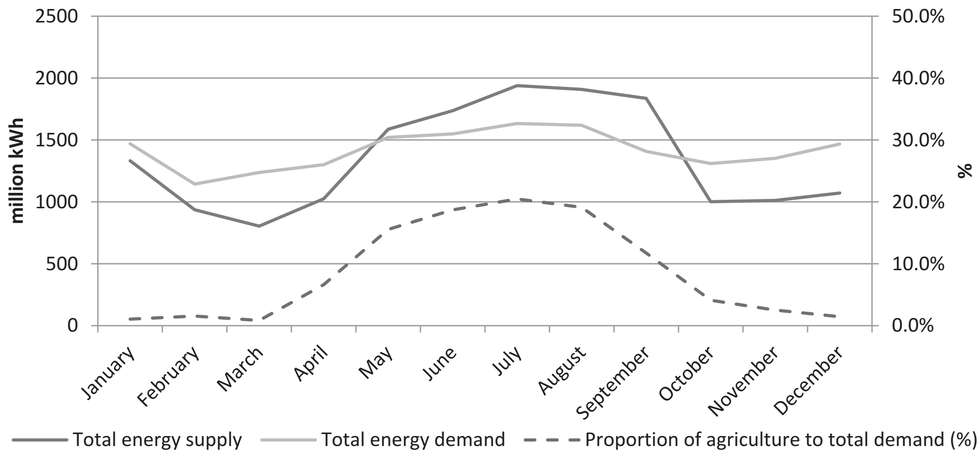

Figure 1. Mean monthly agricultural electricity consumption in 2012–2016, in million kWh (World Bank, 2017).

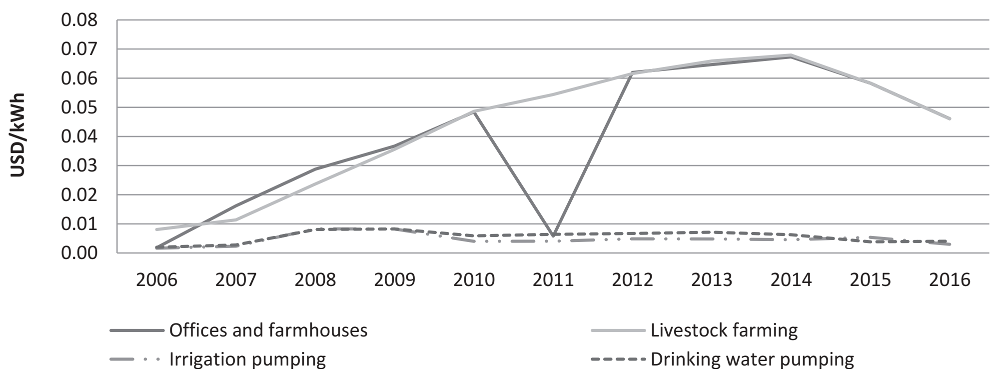

Figure 2. Agricultural tariffs, 2006–2016 (USD per kWh).

Electricity tariffs for agriculture have been very favourable; but the sector has incurred massive debts. Assuming no change in consumption compared to 2015 (1.97 million kWh), and taking into account electricity tariffs for pumping stations in agriculture at USD 0.0063 per kWh (Avesta, 2017), the sector is estimated to cost the state over USD 12.45 million annually.[1] The agriculture sector (that is, the Agency for Land Reclamation and Irrigation) has had trouble paying for electricity due to the limited income from farmers and the poor supply services. Over the years the accumulated debt has reached about USD 43 million (AsiaPlus, 2017a), or 26% (AsiaPlus, 2017b) of the total debt of Barqi Tojik (USD 164 million). According to Barqi Tojik's financial disclosure statement, the annual debts of Agency for Land Reclamation and Irrigation in 2015 and 2016 were USD 8.7 million and USD 6.6 million, respectively (Barqi Tojik, 2017).

Agriculture and energy scenarios

Because the agricultural sector is a large consumer of electricity but largely fails to cover its own expenses (despite very low tariffs), a vicious circle is set in motion, whereby both agriculture and energy sectors suffer. As a result, the national budget, and by extension ordinary citizens (taxpayers), suffer most when debts in either sector are written off. To turn this circle into a virtuous one, the agricultural sector must be economically sustainable to afford the heavy burden of electricity costs in irrigation pumping (Figure 3). Nowadays this looks unfeasible given the overall low efficiency of water supply and the deep subsidization of water tariffs.

But the situation might be reversed by heavy financing of the irrigation network, and particularly the pumping facilities, for more efficient delivery of agricultural water. Better and more reliable water supply might persuade farmers to fully compensate water services. As better infrastructure and water management improves agricultural output and efficiency, both farmers' livelihoods and national finances could be improved.

A source of funding for the reinvigoration of the irrigation sector could be found in reducing electricity use in agriculture and exporting electricity to neighbouring countries. Tajikistan has recently signed electricity trading agreements with Kyrgyzstan and Afghanistan to export its large hydropower surpluses in summer at lucrative pricing. The energy trading revenues could be reinvested in the agricultural sector for to rehabilitate pumps and improve water supply efficiency while also covering annual irrigation costs and paying off the debt.

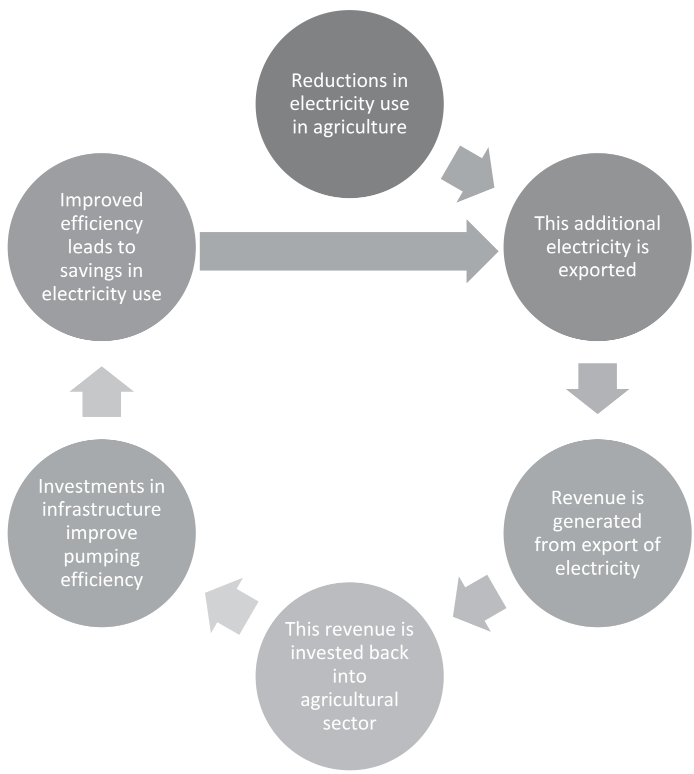

Figure 3. Creating a virtuous circle in the agriculture–energy nexus.

Better efficiency would save electricity, and better water supply would encourage end users (farmers) to cover the operational and maintenance costs of the network. Exporting electricity could bring major benefits to support investments in the irrigation sector and minimize the threat of food shortages.

To design the scenarios, we initially assume that agricultural electricity will be limited in the first five years of 2020–2024. We suggest that the Agency for Land Reclamation and Irrigation, as the main irrigation authority, implement a pilot five-year set-aside of the pumping systems. We then develop three different scenarios based on the amount of reduction of electricity use in the agricultural sector: the modest scenario, with a 10% cut; the moderate scenario, with 15% reduction; and the ambitious one, with a 20% decrease. The reduction would come from shutting off selected pumping stations, which are the largest energy consumers in the agricultural sector.

The electricity savings from the reduction are directed to exports. In other words, Barqi Tojik, as the main electricity provider, shifts the corresponding amount of electricity to exports in Afghanistan, for higher earnings. These revenues are then invested in the agricultural sector to cover the running costs of annual energy expenditures, pay down debt, and invest in the rehabilitation of irrigation networks.

Currently, there is little trust or confidence in the government or state authorities to reinvest export profits in the rehabilitation of agriculture. To ensure transparency and transfer of funds from the energy to the agricultural sector, we propose that an independent body be established in cooperation with the Tajik government, and appointed by development partners that currently heavily invest in hydropower and agriculture in Tajikistan. All our scenarios consider 2019 as the baseline year for the preparation of the scheme in the five-year period of 2020–2024.[2] The ending year varies between 2030 and 2032 depending on the payback period needed for the agricultural debt.

Table 4 gives an explanatory list of all the components considered for the development of the scenarios and the relevant calculations.

Scenario 1: modest 10% reduction

In the modest scenario, we propose an initial energy reduction of 0.5% in 2020 which increments to 1% in 2021 and 2%, 3% and 3.5% from 2022 to 2024, respectively, while keeping other items constant (Table 5). The electricity savings from the reduction are diverted to exporting, which is increased from 6.23 M kWh in 2020 to 120.10 M kWh in 2024.

From 2021, a fraction of the revenues earned from exporting is targeted to cover annual pumping expenditures (Item 7). In particular in 2021, 10% of the export revenues are shifted to pumping expenditures, while the percentage is increased to 30%, 67% and 90% in subsequent years, until 2025, when the full pumping expenditures (100%) are covered. From 2025 onwards, all the pumping expenditures can be covered by export revenues.

In addition to the annual pumping costs, the export revenues are also compensating for the agricultural debt (Item 8). An initial amount of 2.2% can be compensated from 2024, while a gradually increased payoff (4%, 6.3%, 9.5%, 14%, 21%, 33.7% and 63.3%) is offered for every year from 2025 to 2031. The debt could be fully paid by 2032.

Besides the reimbursement of the agricultural debt and full coverage of pumping expenditures, the remaining export revenue allows continued annual investments in

Table 4. Item descriptions for the development of the three scenarios.

#	Item	Explanation and reasoning
1	**Total electricity production (million kWh)**	Volume of electricity production is the total annual electricity generation in the country, which is expected to increase with the staged operation of the Rogun HPP. As noted earlier, one turbine of Rogun has started operation, which provides high confidence for subsequent increase in electricity generation within the estimated period.
2	**Electricity consumption in agriculture (million kWh)**	Total annual consumption of electricity in the agricultural sector. In 2019 it is stable, while in 2020 to 2024 a reduction takes place.
3	**Electricity consumption in agriculture as a percentage of total**	Percentage of electricity consumption in agriculture is the total annual consumption of electricity in agricultural sector out of the total annual volume of electricity production. Electricity consumption in this sector is assumed to be stable overall, except for the five years (2020–2024) when reduction is implemented, and onwards keeping the reduction stable.
4	**Electricity consumption in irrigation pumps (million kWh)**	Volume of electricity consumption in irrigation pumps is provided separately because the reduction of electricity consumption is heavily dependent on the energy pumping reduction. Consumption is also assumed to be stable overall except for the five years (2020–2024) when reduction is proposed, and onwards keeping the reduction stable.
5	**Tariff for pumping stations (USD/kWh)**	Tariff for pumping stations takes into account only summer tariff, when the bulk of water demand is noticed and the exporting of energy to Afghanistan occurs. In November 2018 a 15% tariff increase took place, and a mean 3% annual increase is further estimated, according to government plans for cost recovery in agricultural water supply. But the tariff shows a decreasing trend; this is because the tariff increases in the local currency (TJS) but it is devaluated due to depreciation against the US dollar.
6	**Change in tariff for pumping stations (%)**	This shows the percentage change per year to indicate magnitude on annual basis.
7	**Cost of electricity consumption by irrigation pumps (USD millions)**	Cost of electricity consumption by irrigation pumps is calculated by multiplying the volume of consumption (Item 4) by the tariff (Item 5). This is a straightforward calculation and assumes that all electricity is consumed in the summer; hence, using summer tariff. A more complex analysis would require disaggregated information on electricity consumption over the year, with tariffs changing by season. But the current assumption is reasonable because most irrigation pumping is done in summer, and therefore the difference from reality is considered nominal.
8	**Total agricultural electricity debts (USD millions)**	Agriculture electricity 'debts' are not loans but non-payments for electricity used by the agricultural sector over years. The agricultural sector fails to pay for electricity provided by Barqi Tojik every year, and as a result debt is accumulated. The proposed reduction of electricity use by the agricultural sector helps pay off the debts in subsequent years.
9	**Total electricity exports (million kWh)**	The total volume of electricity exported by Barqi Tojik. The assumption accounts for an existing agreement between Tajikistan and Afghanistan on electricity trade until 2029, which may be extended. The agreement stipulates an annual increase of 3% energy export, given the gradually increasing capacity of the Rogun HPP. It also aligns with the plans of CASA-1000 project for increasing export volume between Tajikistan and Afghanistan.
10	**Export tariff (USD/kWh)**	Export tariff is the price applied for exports of electricity to Afghanistan, which is paid in US dollars. According to an agreement between the two countries (see Item 9), the tariff increases 3% every year.
11	**Reduction of electricity consumption by irrigation pumps (%)**	Voluntary reduction of electricity consumption by irrigation pumps is the key proposed measure. The agricultural sector will forgo consumption of electricity by suspending operation of some pumping stations. The reduction is staged as 10%, 15% and 20%, staggered over five years between 2020 and 2024.
12	**Electricity export contributed by agriculture reduction (million kWh)**	The volume of electricity diverted from pumping stations to exports on annual basis.

(*Continued*)

Table 4. (Continued).

#	Item	Explanation and reasoning
13	**Share of export volume contributed by agriculture reduction (%)**	The percentage of electricity that the agricultural sector will contribute to total electricity exports.
14	**Revenue from export resulting from reductions (USD millions)**	Revenue from export of electricity is the product of export volume (Item 12) and associated tariff (Item 10). This is the revenue the agricultural sector should generate by exporting electricity that it diverts from pumping stations, via Barqi Tojik, to Afghanistan.
15	**Net revenues for agricultural rehabilitation (USD millions)**	The net revenue generated by the agricultural sector after the coverage of the annual energy costs in agriculture and the payment of the accumulated debts. Ultimately, this is where the opportunity lies to improve the situation in the agricultural sector.
16	**Exchange rate, USD to TJS**	The exchange rate was based on the trend of the past 10 years according to Deutsche Bundesbank (2019). From 2019 onwards an annual depreciation of 12% is assumed based on historical data.

Table 5. Scenario 1: Modest 10% Reduction.

#	Item description	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
1	Electricity production (million kWh)	20,162	20,162	23,162	23,162	26,162	26,162	26,162	26,162	26,162	26,162	26,162	26,162	26,162	26,162
2	Electricity consumption in agriculture (million kWh)	1,977	1,971	1,958	1,934	1,898	1,857	1,857	1,857	1,857	1,857	1,857	1,857	1,857	1,857
3	Percentage of electricity consumption in agriculture, out of total volume (%)	10%	10%	8%	8%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%
4	Electricity consumption by irrigation pumps (million kWh)	1,246	1,239	1,227	1,202	1,166	1,125	1,125	1,125	1,125	1,125	1,125	1,125	1,125	1,125
5	Tariff for pumped stations, summer (USD/kWh)	0.0068	0.0062	0.0057	0.0053	0.0048	0.0044	0.0041	0.0038	0.0035	0.0032	0.0029	0.0027	0.0025	0.0023
6	Change in tariff for pumped stations (%)	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
7	Cost of electricity consumption by irrigation pumps (USD millions)	8.42	7.70	7.01	6.32	5.64	5.00	4.60	4.23	3.89	3.58	3.29	3.03	2.78	2.56
8	Agriculture electricity debts, total (USD millions)	54.71	56.55	56.80	55.14	51.09	45.11	38.67	32.35	26.14	20.07	14.16	8.38	2.75	0.00
9	Totalelectricity exports (million kWh)	1,545	1,591	1,639	1,688	1,738	1,791	1,844	1,900	1,957	2,015	2,076	2,138	2,202	2,268
10	Export tariff (USD/kWh)	0.0444	0.0457	0.0471	0.0485	0.0499	0.0514	0.0530	0.0545	0.0562	0.0579	0.0596	0.0614	0.0632	0.0651
11	Reduction of electricity consumption by irrigation pumps (%)	0.00	0.005	0.01	0.02	0.03	0.035	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	Volume of electricity export contributed by agriculture, reduction (million kWh)	0.00	6.23	18.63	43.18	79.26	120.10	120.10	120.10	120.10	120.10	120.10	120.10	120.10	120.10
13	Share of export volume contributed by agriculture,reduction (%)	0.00	0.004	0.011	0.026	0.046	0.067	0.07	0.06	0.06	0.06	0.06	0.06	0.05	0.05
14	Revenue from export resulting from reductions (USD millions)	0.00	0.28	0.88	2.09	3.96	6.18	6.36	6.55	6.75	6.95	7.16	7.37	7.59	7.82
15	Net revenues for agricultural rehabilitation (USD millions)	0.00	0.28	0.18	0.20	0.18	0.17	0.15	0.15	0.11	0.10	0.10	0.09	0.07	2.81
16	Exchange rate, USD to TJS	10.263	11.494	12.874	14.419	16.149	18.087	20.258	22.689	25.411	28.461	31.876	35.701	39.985	44.789

infrastructure (Item 15). The revenue for infrastructure is traced early on, from 2020 (USD 0.28 million), when the first energy reductions occur. They are distinctively maintained between USD 0.18 and USD 0.20 million during the reduction scheme (2020–2024) to allow investments in agriculture. From 2025 to 2031 revenue is smaller due to increased paying down of the debt. In 2032 the net revenue increases to USD 2.81 million because the agricultural debt has been fully reimbursed.

Overall, 10% electricity pumping reduction in 2020–2032 can provide 1,228 million kWh of exported energy, for total revenue of USD 69.94 million.

Scenario 2: moderate 15% reduction

The moderate scenario also describes energy reduction starting in 2020, with higher rates than the modest scenario (Table 6). The decrease for 2020 is 1% (Item 11), or 12.46 million kWh (Item 12), which is exported and fetches USD 0.57 million (Item 14). Similar to the modest scenario, a gradual but more robust decrease follows of 2%, 3%, 4% and 5% for 2021–2024.

In the same pattern as the modest scenario, some amount is diverted to annual pumping expenditures. The amount of 10% is assigned for 2021, while 30%, 67% and 90% of the amount is allocated in subsequent years until the annual electricity consumption expenses for pumping are fully paid for by 2025. The difference with the modest scenario is that the pumping expenditures are lower than currently, due to the greater reduction. Conversely, the exporting volume becomes more prominent by making easier the coverage of yearly pumping expenditures. Similar to the modest scenario, all pumping costs are paid through export revenues for 2025–2030.

The reduction of agricultural debt (Item 8) is also served through the export revenues from 2024 onwards. A similar pattern is followed as the modest scenario, but the years and the amounts of compensation differ. The reason is that the profits from the exported energy can pay off the debt sooner than in the modest scenario. In particular, an increasing payment rate of 7%, 10%, 15%, 22%, 35% and 67% in 2023, 2024, 2025, 2026, 2027 and 2028 can eliminate the debt by 2030, two years sooner than in the modest scenario.

An infrastructural investment (Item 15) is also possible, and more substantial than in the modest scenario. In the modest scenario on average USD 0.14 million is left annually after paying the annual cost of electricity and servicing the debt from 2021 to 2031, while in the moderate scenario an average of USD 1.34 million remains from 2021 to 2029, which is about 9.6 times a great and two years sooner. Moreover, the revenues are maintained at around USD 1 million annually, which allows significant investments in agricultural infrastructure. Full payback of the agricultural debt comes earlier, in 2030, when the revenues are mounting to USD 5.2 million, almost twice as much as in the modest scenario (USD 2.81 million).

In total, USD 81.45 million can be generated over 11 years through reduction of 15%, or 1479 million kWh of electricity.

Scenario 3: ambitious 20% reduction

A more ambitious scenario brings forward an overall energy reduction of 20% within the same period (2020–2024). The reduction rates follow an increment of 2%, 3%, 4%, 5% and 6% from 2020 to 2024 (Table 7). The greater reduction induces greater energy savings and more revenue from the first implementation year, 2020 (USD 1.14 million).

Table 6. Scenario 2: Moderate 15% Reduction.

#	Item description	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
1	Electricity production (million kWh)	20,162	20,162	23,162	23,162	26,162	26,162	26,162	26,162	26,162	26,162	26,162	26,162
2	Electricity consumption in agriculture (million kWh)	1,977	1,965	1,940	1,904	1,857	1,800	1,800	1,800	1,800	1,800	1,800	1,800
3	Percentage of electricity consumption in agriculture, out of total volume (%)	10%	10%	8%	8%	7%	7%	7%	7%	7%	7%	7%	7%
4	Electricity consumption by irrigation pumps (million kWh)	1,246	1,233	1,208	1,172	1,125	1,069	1,069	1,069	1,069	1,069	1,069	1,069
5	Tariff for pumped stations, summer (USD/kWh)	0.0068	0.0062	0.005	0.0053	0.0048	0.0044	0.0041	0.0038	0.0035	0.0032	0.0029	0.0027
6	Change in tariff for pumped stations (%)	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
7	Cost of electricity consumption by irrigation pumps (USD millions)	8.42	7.66	6.91	6.16	5.44	4.75	4.37	4.02	3.70	3.40	3.13	2.87
8	Agriculture electricity debts, total (USD millions)	54.71	56.51	56.67	54.91	50.82	42.68	34.29	26.03	18.13	10.52	3.10	0.00
9	Totalelectricity exports (million kWh)	1,545	1,591	1,639	1,688	1,738	1,791	1,844	1,900	1,957	2,015	2,076	2,138
10	Export tariff (USD/kWh)	0.0444	0.0457	0.0471	0.0485	0.0499	0.0514	0.0530	0.0545	0.0562	0.0579	0.0596	0.0614
11	Reduction of electricity consumption by irrigation pumps (%)	0.00	0.01	0.02	0.03	0.04	0.05	0.00	0.00	0.00	0.00	0.00	0.00
12	Volume of electricity export contributed by agriculture, reduction (million kWh)	0.00	12.46	37.13	73.40	120.30	176.59	176.59	176.59	176.59	176.59	176.59	176.59
13	Share of export volume contributed by agriculture, reduction (%)	0.00	0.008	0.023	0.043	0.069	0.099	0.10	0.09	0.09	0.09	0.09	0.08
14	Revenue from export resulting from reductions (USD millions)	0.00	0.57	1.75	3.56	6.01	9.08	9.35	9.63	9.92	10.22	10.53	10.84
15	Net revenues for agricultural rehabilitation (USD millions)	0.00	0.57	1.06	1.71	2.36	1.15	1.17	1.02	1.11	1.16	1.11	5.20
16	Exchange rate, USD to TJS	10.263	11.494	12.874	14.419	16.149	18.087	20.258	22.689	25.411	28.461	31.876	35.701

Table 7. Scenario 3: Ambitious 20% Reduction.

#	Item description	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
1	Electricity production (million kWh)	20,162	20,162	23,162	23,162	26,162	26,162	26,162	26,162	26,162	26,162	26,162	26,162
2	Electricity consumption in agriculture (million kWh)	1,977	1,952	1,915	1,868	1,811	1,746	1,746	1,746	1,746	1,746	1,746	1,746
3	Percentage of electricity consumption in agriculture, out of total volume (%)	10%	10%	8%	8%	7%	7%	7%	7%	7%	7%	7%	7%
4	Electricity consumption by irrigation pumps (million kWh)	1,246	1,221	1,184	1,137	1,080	1,015	1,015	1,015	1,015	1,015	1,015	1,015
5	Tariff for pumped stations, summer (USD/kWh)	0.0068	0.0062	0.0057	0.0053	0.0048	0.0044	0.0041	0.0038	0.0035	0.0032	0.0029	0.0027
6	Change in tariff for pumped stations (%)	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
7	Cost of electricity consumption by irrigation pumps (USD millions)	8.42	7.58	6.77	5.97	5.22	4.51	4.15	3.82	3.51	3.23	2.97	2.73
8	Agriculture electricity debts, total (USD millions)	54.71	56.43.	5648	54.61	50.48	39.66	28.68	17.93	8.00	0.00	0.00	0.00
9	Totalelectricity exports (million kWh)	1,545	1,591	1,639	1,688	1,738	1,791	1,844	1,900	1,957	2,015	2,076	2,138
10	Export tariff (USD/kWh)	0.0444	0.0457	0.0471	0.0485	0.0499	0.0514	0.0530	0.0545	0.0562	0.0579	0.0596	0.0614
11	Reduction of electricity consumption by irrigation pumps (%)	0.00	0.02	0.03	0.04	0.05	0.06	0.00	0.00	0.00	0.00	0.00	0.00
12	Volume of electricity export contributed by agriculture, reduction (million kWh)	0.00	24.92	61.55	108.93	165.78	230.60	230.60	230.60	230.60	230.60	230.60	230.60
13	Share of export volume contributed by agriculture, reduction (%)	0.00	0.016	0.038	0.065	0.095	0.13	0.12	0.12	0.12	0.11	0.11	0.11
14	Revenue from export resulting from reductions (USD millions)	0.00	1.14	2.90	5.28	8.28	11.86	12.21	12.58	12.96	13.35	13.75	14.16
15	Net revenues for agricultural rehabilitation (USD millions)	0.00	1.14	2.22	3.49	1.59	1.49	1.34	1.08	1.44	2.97	10.78	11.43
16	Exchange rate, USD to TJS	10.263	11.494	12.874	14.419	16.149	18.087	20.258	22.689	25.411	28.461	31.876	35.701

The payment for the annual cost of electricity consumption in agriculture can be launched in the year 2021, similar to both modest and moderate scenarios in terms of percentages, namely, 10%, 30%, 67% and 90% from 2021 to 2014, with full coverage in 2025. The difference is that instalments for agricultural debt can be arranged from the year 2022, one and two years earlier than the modest and moderate scenarios, respectively, with incremental rates of 3%, 13%, 19%, 30%, 50% and 100% until 2027. The debt could be completely phased out by 2028, two and four years earlier than the moderate and modest scenarios.

The annual revenues assigned to the rehabilitation of infrastructure (Item 15) in 2020–2030 are consistently higher, except 2023, than in the moderate scenario. Between 2021 and 2027, after paying for annual electricity consumption and debt servicing, the ambitious scenario generates on average USD 1.81 million annually, compared to USD 1.32 million retained from 2021 to 2029 in the moderate scenario. Notably, the ambitious scenario outperforms the moderate with a larger amount in a period shorter by two years. Moreover, the ambitious 20% cut allows the payback of agricultural debt by 2028, creating substantial revenues of USD 10.78 million and USD 11.43 million for rehabilitation in the last two years, 2029 and 2030.

The ambitious scenario could encourage electricity exports of 1,975 million kWh (Item 12) in 2020–2030 for total revenue of USD 108.44 million, which, remarkably, could support rehabilitation of the entire agricultural sector

Recommendations and concluding remarks

Tajikistan was endowed with extensive mechanized irrigation facilities in the Soviet era which nowadays are underperforming due to the excessive use and poor maintenance over the years (Stucki & Sojamo, 2012). In its current state, the agricultural sector cannot economically sustain the irrigation network or most of the electricity cost for the pumping stations.

Reducing agricultural electricity for export purposes could be the most viable way for the sector to rehabilitate the irrigation network and operate without losses. We developed three different scenarios to estimate how electricity export revenues could cover annual pumping costs, pay back the agricultural debt and rehabilitate irrigation systems. The scenarios were distinguished as modest (10%), moderate (15%) and ambitious (20%) to emphasize the effects of energy reduction in different conditions. An overview of the three scenarios is presented in Table 8.

Table 8. Performance overview of the three different reduction scenarios.

Parameters	Scenario 1: Modest	Scenario 2: Moderate	Scenario 3: Ambitious
Base year	2019	2019	2019
Time horizon	2020–2032	2020–2030	2020–2030
Aggregate percentage of reduction	10%	15%	20%
Total electricity reduction	1,228 million kWh	1,479 million kWh	1,975 million kWh
Total revenue from exports	USD 69.94 million	USD 81.45 million	USD 108.44 million
Annual electricity costs paid fully	2025	2025	2025
Long-term debt paid fully	2032	2030	2028

The greater the electricity reduction, the greater the revenues from export and the quicker the compensation of the agricultural-related expenditures. The selection of the most suitable scenario for the economic viability of the agricultural sector is subject to different factors. A vigorous energy reduction of 20% could substantially support the agricultural sector in the near future, but might also have considerable repercussions.

A 20% reduction would mean that an almost equivalent amount of agricultural land would cease to be irrigated by the existent network. Subsistence farming communities, which are strongly dependent on low-tariff water pumping, would be unable to seek alternative water sources and could barely make ends meet. There would be hardly any alternative professions for poor farmers other than emigration for better income options, as mostly occurs in rural Tajikistan.

There are counterarguments, however, mentioning that the irrigated land with pumping stations mostly belongs to wealthy farmers, while the poorer communities cultivate marginal and rainfed plots (Xenarios et al., 2019). Also, it is questionable whether the preservation of all the pumping facilities could even support a sustainable agricultural sector. The low productivity and revenues of rural farming in Tajikistan are attributable to many factors; water supply is only one of them. Marginal land, poor agricultural inputs (pesticides, herbicides, seeds, machinery, etc.) and low awareness in the farming community of more efficient cultivation practices are some of the elements that could be hardly improved, even with better water supply (Pak, Wegerich, & Kazbekov, 2013).

Also, the impact of the energy reduction scheme on agriculture would largely depend on the region and the types of pumping stations to be set aside. The most probable assumption is the suspension of pumps mainly in the Sughd and Khatlon regions of northern and southern Tajikistan, where pumping stations are more frequent. Still, however, identifying the particular pumping stations to turn off would be an arduous task, due to the different farming cases dependent on lifted water. The impact on grain crops, for instance, will be smaller than on rice farming, due to the lower demands on water volume. Also, poorer farming communities will struggle to replace pumped water with other sources, while wealthier farmers may drill their own wells. Acknowledging these limitations, an ex ante impact evaluation study should precede the energy reduction scheme for a better assessment of the effects on the farming community. The impact evaluation should carefully assess the capacity, status and efficiency of each pumping station and its contribution to the irrigation network. Further, an economic analysis should estimate the opportunity cost of setting aside selected pumps and the associated impacts on dependent farming communities. The evaluation should be also accompanied by the use of geographic information systems to identify the areas with low, medium and high water demand, associated agricultural productivity and farmers' livelihoods, and then make a selection based on cost minimization to avoid severe repercussions, as highlighted above.

We have not considered the transaction costs of shifting electricity from agriculture use to export and then back to agriculture. We recognize that substantial expenses may derive from this energy swapping between the sectors due to technical limitations like energy loss because of poor infrastructure in transmission lines. Institutional constraints emerging from the involvement of different agencies and stakeholders could make transaction costs prohibitive. A more detailed analysis could better investigate the exact amount to be allocated to these transaction costs.

We do acknowledge the potential repercussions for farmer's livelihoods from reducing energy consumption in the short term. Measures should be taken to assure that vulnerable groups are protected from such repercussions. On the national level, we see evidence in the supporting literature that the current situation has put the electricity utility provider in grave position, which remains on the brink of bankruptcy, mainly due to unpaid irrigation debts. Also, the agricultural sector is likely to shrink in the coming years, due to marginal revenues, unless some robust rehabilitation takes place.

The viability of agriculture in Tajikistan in its current form seems to be threatened due to the heavy economic burden of extensive electricity use by pumping stations. The current study is the first attempt to show at least one way to help salvage the agricultural sector and is purposefully lodged in the technical domain to first solidify the suggested solutions through some well-grounded arguments. The proposed scenarios could be convincing to policy makers by offering a beneficial situation for agriculture and energy export so that a dialogue with the relevant authorities can be launched.

Considering pumping for agriculture as an important aspect of the economy, and that the authorities have already significantly invested in this sector (and are currently implementing water sector reforms), the authorities must be seeking effective solutions in this field as well. The measures suggested here would be beneficial to the national authorities by alleviating pressure on the national budget and expanding revenue sources. The study could offer the basis for discussion with government agencies to consider the social, political and other relevant dimensions prior to any implementation of any of the scenarios or some permutations of such. The temporary set-aside of pumping facilities in exchange for electricity export could provide crucial economic aid to agriculture and trigger the needful restructuring of the entire sector in Tajikistan.

Notes

1. USD 1 = TJS 9.1637 as of 2018 (Deutsche Bundesbank, 2019).
2. The year 2019 is not part of the scenarios because the year has already started, but electricity consumption and its associated costs during the year are considered, e.g. by adding the cost to agricultural debt.

Disclosure statement

No potential conflict of interest was reported by the authors.

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