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Intensive Fish Farming as a Contributor to the Depletion of Underground and Surface Water Resources in the Ararat Valley

Tatiana Trifonova

Executive Summary

The Ararat Valley is situated at an altitude of 800–950 meters above sea level. It stretches from northwest to southeast for 120 kilometers, it is 10–30 kilometers wide, and is a significant groundwater reservoir. Since the old days, the Ararat Valley has been regarded as a breadbasket of Armenia, and today it remains a major agricultural region in the country. Its climate is favorable for the cultivation of various crops, ranging from horticultural crops (peach, apricot, apple, pear, prune, cherry orchards) to cereals and root crops.

Currently, in the Ararat Valley, land uses are linked with the enhanced development of fish farming, which requires artesian water in great amounts. Monitoring data show that groundwater storage has dropped by almost 60 percent while the artesian water withdrawal rate increased from 34.7 cubic meters per second (m3 per sec) to 80 m3 per sec. As a result of unsustainable management of the natural resources, the water level of the artesian basin has declined by 8–15 meters, and the groundwater level has gone down by more than 3 meters. This has brought about a number of adverse processes: the drainage of agricultural soils, increased irrigation depth, losses of soil organic matter, and so on. It should be noted that the artesian basin of the valley is the main and strategically important storage of potable water for the City of Yerevan as well; and the groundwater resources are a major regulating factor for irrigated agriculture and also for soil humidity conditions, which define soil fertility. The change in the soil moisture regime has led to soil aridization in some areas of the Ararat Valley (as of today, over 30 communities are left without water for irrigation), and emerging waterlogging in other areas, which are exposed to water discharges from fish ponds at lower altitudes.

Thus the Ararat Valley faces a broad range of interrelated environmental challenges; and the most serious of these arise from poor water management.

Such a conflicting situation brings together several stakeholders. The first is government entities, alarmed with the tangible threat of the depletion of the artesian basin, which is a strategically important source of potable water for almost half of the country. The second stakeholder is comprised of arable farmers in the Ararat Valley: they adhere to ancestral traditions of vegetable, fruit, and grain growing, but now they are losing their fields and orchards as a result of their draining and impaired fertility. The third stakeholder group consists of fish farmers: the valley alone harbors over 300 operating fish farms. This is a fairly successful and profitable sector. Owing to the high quality of the fish they produce, it is in great demand in the Russian Federation and other countries; therefore, about 20–30 percent of the output is exported abroad. It is quite natural that fish farmers are keen to expand their operations. The fourth stakeholder group is nature conservation organizations, warning that the entire ecosystem, generated by nature and man, is entering a stage of degradation in the Ararat Valley, and unless this process is stopped, desertification will deprive the country of its once-abundant breadbasket and food security stronghold.

How to arrest the process and attain sustainability? There seems to be no one clear-cut solution, but rather a broad range of coherent actions. First, it is necessary to: (i) cause the water withdrawal from the artesian basin to be drastically reduced, (ii) forbid (at least temporarily) the drawing of water from artesian wells that are not flowing any longer (as a result of dropped internal pressure); (iii) revise the quotas and rates of respective financial taxes payable by fish farmers; (iv) equip fish farms with water purification systems as soon as possible in order to introduce closed or semi-closed water consumption cycles; (v) retrofit or upgrade the interception and drainage systems to prevent waterlogging; (vi) consider an opportunity to use discharged water for irrigation purposes; (vii) introduce up-to-date water-saving drip irrigation practices in crop farming; (viii) forbid landowners to use their fields and orchards for purposes other than those for which they are designated to avoid rapid soil fertility losses; (ix) explore whether it would be appropriate to revive the Soviet practice of quite effective alternate uses of the same land areas for crop cultivation and fish ponds (two to three years for each use); cause nature conservation groups to consider the opportunity of giving the Ararat Valley ecosystem a status that would enable regulation of its land uses in a more purposeful and strict manner; and (x) advise the country's government to develop and adopt a targeted government program aimed at optimizing the environmental and economic situation in the Ararat Valley.

The main objective of this case study is to highlight the problem of the underground water storage decline in the Ararat artesian basin, arising chiefly from the intensified fish farming; and use the available information to propose and analyze possible policy and economic options of addressing the problem in a fully participatory manner, in order to ensure food security.

Background

Environmental Conditions in the Ararat Valley

The Ararat Valley stretches from northwest to southeast for 120 kilometers, it is 10–30 kilometers wide, and is a sink for solid and liquid matter, flowing from the Ararat slopes surrounding the valley.

The valley is located at an altitude of 800–950 meters above sea level (Figures 1 and 2).

The flatland part of the Ararat Valley has a typically semi-desert landscape with its specific semi-desert soils. Its soils range from hummocky sands and alkaline and saline soils to water-logged soils. A significant part of the valley is managed; this part has irrigated meadow brown soils. The non-managed part is covered with xerophilous and halophilous vegetation and Artemisia (sage), whereas irrigated meadow brown soils bear fruit orchards, vineyards, and various agricultural plantations. The piedmont steppe soils had developed from volcanic lavas and large sediments from the left tributaries of the Aras River. The piedmont river torrents have produced canyons 50 to 60 meters deep or deeper with steep slopes. At relatively low elevations, irrigated meadow brown soils occur intermittently with alkaline and saline soils, but the prevailing soils of this area are brown semi-desert soils and the area of transition to the steppe zone is dominated by chestnut soils and black earth. The soils are covered with grass vegetation [1].

The Ararat Valley climate is characterized by an exceptionally long duration of sunshine: on the average, it has up to 2,600 hours of sunshine per year. The longest sunshine duration (in hours per day) is in summertime. Seasonal variations in the atmospheric circulation are a strong contributor into the development of the climatic specifics in this area; they are accounted for by its highly continental climate with great annual and diurnal variations in air temperature and humidity. In the Ararat Valley, the difference between winter and summer temperatures may exceed 31oC (it may be –6°C to –7°C in winter and +25°C to +26°C in summer). The aridity of the area is explained primarily by the closed area of the valley.

In the South Caucasus, one of the most arid areas is the Ararat Valley, especially its flatland area where total annual precipitation may be as low as 200 to 300 millimeters.

Figure 1: The Ararat Valley (Source: T. A. Trifonova, July 2014)

Figure 2: An Image of the Ararat Valley from Space, from 1970 (Google Earth, 1970)

The moisture deficit is very acute here: soil humidity drops to 8 percent in mid-summer.

The heat is mitigated by cool air descending from the mountains as well as night cooling. Evenings and nights may be cool in the Ararat Valley, which adds to the diurnal fluctuations in air temperature and relative humidity.

The Ararat Valley ecosystem has a fairly sophisticated pattern of soil and vegetation cover: fertile long-irrigated soils coexist with white alkali-saline soils and water-logged areas in lower river plains.

The Ararat Valley is a major agricultural region of the country. In 2006, the World Bank completed a study that identifies key challenges that need to be addressed in order to sustain its high GDP growth rate, improve life standards, and integrate the environment into agriculture and forestry [2].

The climatic conditions are favorable for cultivating various crops, ranging from horticultural crops to cereals and root crops. Agriculture draws on irrigated land in the lowland and piedmont part of the area. About one-third of the agricultural output comes from the Armavir and Ararat Provinces, both located in the Ararat Valley.

Plant crop farming's key subsectors are the cultivation of grain crops, viticulture, fruit growing, and the production of vegetables and tobacco.

The cultivation area is 332,700,000 hectares; since 1990, it has decreased by 20 percent (then, it was 417,000 hectares). Grain crops account for the greatest share of Armenia's cultivation area (56 percent). The share of forage crops is 23 percent; potato, melons, and gourds account for 19 percent; with technical (non-food) crops accounting for slightly over 1 percent. Compared with the pre-reform period, the breakdown of cultivated areas by crop has drastically changed. The area of forage crops shrank fourfold (in 1990 they accounted for 58 percent of the cultivation area). The total cultivation area decreased primarily because of the reduction in the forage crop area while the areas producing other crops increased.

Cereals have become most prevalent in the Aragatsotn Province (in the upper part of the Ararat Valley), which accounts for about 15 percent of the total grain crop area in the country. Almost all of the winter grain crop area consists of wheat (97 percent), and the most prevalent spring crop is barley (79 percent). The combined share of wheat and barley is 93 percent of the total area of grain fields.

Viticulture is one of the oldest agricultural activities in Armenia. There are over 150 local grape varieties generated through "native" breeding over many centuries. Armenian vine-growing is concentrated on irrigated land areas in the Ararat Valley (Ararat and Armavir)—they are home to 70 percent of the total vineyard area and produce the highest-yield varieties. Wine-grapes to make strong wines and brandies as well as table grapes are cultivated here.

Fruit production is well developed throughout the country, but the Ararat Valley, both its lowland and foothill (Aragatsotn) area is the most significant region in this respect. Here, three provinces harbor over half of the fruit and berry orchards in the country. The valley is also very important because the yield of its orchards significantly surpasses the country's average; therefore its share of the gross output is always greater. Lowland areas produce thermophilic drupes (mainly peaches and apricots) and the foothills and mountains are occupied with more cold-resistant pomes (apple, pear, and quince orchards).

The average revenue from each orchard is over 1 million Armenian drams (AMD), which is equivalent to about US$2,000–2,500 per hectare.

Soil Fertility Losses and Soil Degradation

In the Ararat Valley, white alkali-saline soils are widely spread; their area encompasses 29,500 hectares, including 5,500 hectares cultivated in 1970–88. In the 1970s and 1980s, Armenia introduced and widely implemented an integrated approach to cultivation on alkali-saline soils: this was a method for integrated chemical amelioration, based on the use of industrial wastes—black sulfuric acid, iron sulfate, chlorohydric acid, distiller's solubles, activated natural ameliorants, contactless electromelioration, and so on. As a result of such chemical amelioration, white alkali-saline soils acquire certain agronomical properties of high value and offer optimal conditions for plant cultivation. In the course of the agricultural use of such soils, the biological production of plant biomass is growing, and qualitative and quantitative indicators of nutrient exchange between the soil and plants improve.

However, the efforts to use these soils were abandoned in the 1990s for a number of economic reasons. The earlier technology of chemical soil

amelioration is not cost-effective now because of its prohibitively high costs and lack of chemical ameliorants.

After the land privatization, the agricultural crop harvests significantly decreased because of the lack of needed amounts of fertilizers and their higher prices. Today farmers cannot afford to buy fertilizers in needed amounts, and reducing their harvests from cultivated crops. This has not only affected harvests of agricultural crops, but also caused secondary effects: plants draw from stocks of nutrients, accumulated over many centuries, the amount of organic matter decreases, and the soil structure is destroyed which ultimately leads to soil degradation [3].

Another factor contributing to desertification is erratic or nonexistent crop rotations. Small sizes of land parcels prevent farmers from having full-fledged crop rotations. The average area of privatized land per farm is 1.40 hectares—including 1.04 hectares of arable land, 0.12 hectares used in perennial plantings, and 0.24 hectares for haymaking.

Soil cover losses also result from irrigation that is not always well managed; new irrigation technology such as drip watering is applied in a very limited scale. One more desertification contributor is the abandonment of land cultivated earlier. Such soils tend to be rapidly overgrown with weeds, invasive aggressive species as a result of the lack of competition from native plants. This results not only in losses of cultivated soil, but also into weeded flora.

Impact of Waterlogging on Soil Degradation

To improve the status of irrigated land as well as to prevent waterlogging, the flooding of settlements, and the spread of malaria, drainage networks have been constructed since the 1950s. Their total length is 1,693.62 kilometers, including 1,064.12 kilometers of open networks and 629.5 kilometers of closed networks.

In 1991–97, to the situation's detriment, the network ceased to operate. In 1998, the operation of the drainage network was partially resumed. The public budget financed the cleaning of about one-third of the entire network on an annual basis, but in 2009 funding was reduced by 40 percent. Now only 14–15 percent of the network is cleaned every year, which would eventually lead to such adverse consequences as salinization, alkalization, and waterlogging. Currently the Ararat Valley is provided with 902.7 kilometers of open drainage networks with a total area of 25,000 hectares and 629.5 kilometers of closed drainage networks with a total area of 7,700 hectares.

Owing to the financing from the public budget made available in 1998–2014 and under the Millennium Challenges program in 2010–11, large-scale operations were completed to clean, maintain, and operate the drainage systems. This ultimately resulted in a reduction of waterlogged land (by 17,400 hectares); a reduction of land in poor condition (by 18.9 hectares); and a reduction of flooded land (by 49 hectares). However, these measures are not sufficient to cope with the situation.

In addition to the presence of alkali-saline soils in the Ararat Valley, since 2009 the confined groundwater level has been dropping in the Ararat Artesian Basin, closely linked to water withdrawal from 470 artesian wells of several hundred fish farms.

Fish Farming in the Ararat Valley

Armenia has vast experience in fish farming. As early as in the 1920s, trout-rearing farms started to operate in Lake Sevan to replenish fish resources. The next stage of fish farming development began in the 1970s when commercial operations were launched. Large fish farms were established to manage water resources and flooded areas of the Ararat Valley in a sustainable manner.

In the 1980s, the water surface area of the Armash and Sis fish ponds alone reached about 6,000 hectares and their annual commercial fish (primarily carp) output amounted to over 5,000 tonnes. In 1970–80, Armenia produced up to 7,500 tonnes of fish per year, including 5,000–6,000 tonnes of fish, reared by fish farms. It is noteworthy that fish farms were established on white alkali-saline soils, which required huge physical and financial resources. Studies show that fish farms sometimes had positive effects on physical and chemical soil properties: eventually, the positive processes of desalinization and dealkalinization were triggered.

Upon the disintegration of the USSR, fish farming experienced a drastic decline: for example, annual outputs of trout decreased almost 20 times—from 400 tonnes to 15–20 tonnes. The decline in fish harvests from fish farms was compensated for with increased harvests from lakes—in particular from Lake Sevan, which was exposed to the merciless overexploitation of fish resources.

The third stage of fish farming development started in the late 20th century and its key driver was the emerging new economic relations in the country.

At first, small fish farms were established; they were more competitive than larger ones. The most cost-efficient and competitive farms were those that used artesian flow water. Another important advantage was their gravity-fed supply of water to the ponds, with no need to spend electricity for pumping. Clearly it was very cost-efficient. The period since that time has seen an increase in the number of private fish farms, rearing fish in clean flow water and selling them for higher prices than state-owned fish enterprises that have higher production costs and lower selling prices. The fish product mix also changed. Carp farms completely disappeared. They were replaced with the 26 farms that reared primarily trout. Beginning in 1998, sturgeons have been produced in Armenia. These fish species require clean flow-through cool oxygen-rich water. For commercial purposes, successful efforts were made to rear Japanese carp (koi) and African loko because these fish species are distinguished by rapid growth, which makes it possible to reduce the duration of commercial fish rearing and, thus, to use water resources more efficiently. Today, fish farms rear the following fish species: two varieties of Sevan trout, Siberian sturgeon, Russian sturgeon, and white sturgeon (huso). It should be noted that the recent decade saw not only an increase in commercial fish outputs in the country, but also a broader fish product mix and an increase in the share of fish species that are expensive for the consumer. Currently, over 240 fish farms are registered in Armenia; about 75 percent of them operate in the Armavir and Ararat Provinces. To date, the Ararat Valley houses operating fish farms with a total water surface area of 3,033 hectares; almost 70 percent of them are found in Ararat Province and about 27 percent are in Armavir Province.

In 1996, the country's fish rearing output amounted to about 30–40 tonnes; by now it has increased 400 times—no other sector has been developing at such a rapid pace. Owing to the clean artesian water, the fish is very tasty and is in great demand in foreign markets. There is also a promising scope for the growth of its global market. Uncontrolled catches have been depleting fish resources in seas and oceans, and less than 75 percent of the global demand for fish products is actually met. For this reason, the fishery sector is significantly changing, shifting its emphasis toward aquaculture. Currently the country's commercial fish (mostly trout) harvest is about 14,000–15,000 tonnes per year. Owing to the high quality of Armenian fish, it is in high demand in the Russian Federation and other countries and about 20 to 30 percent of the output is exported.

Adverse Consequences of Groundwater Use

The development of fish farming brings about not only benefits, but also adverse environmental changes. For example, since 2009 the confined groundwater level of the Ararat artesian basin has been going down, and this process is caused by water withdrawal from almost 500 artesian wells by over 200 fish farms. Most farms use flow-through water. Both groundwater and artesian water levels have been rapidly going down.

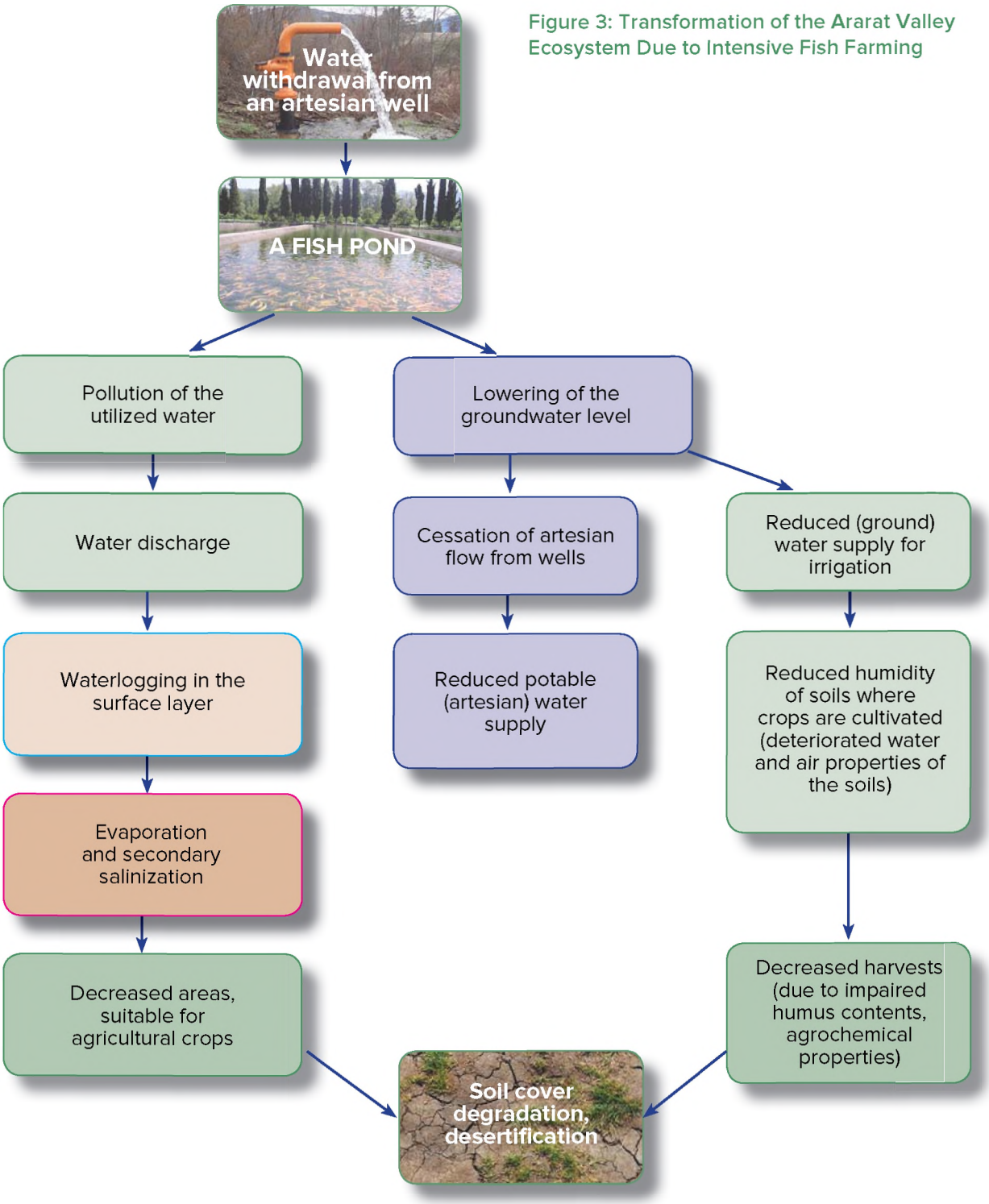
Note: *Groundwater* means water present at small depths—from 3 meters to 10–20 meters beneath the surface. It occurs in relatively small layers at these depths on seat clays and is the main source of moisture for the soil and of water supply for wells. These groundwater layers are fed, primarily, from penetrating precipitation (that is, from above). It is this water that is used by local farmers for irrigation and drinking. If a great deal of water comes from above in the form of rain, the soil is strongly saturated with water, and this leads to soil deoxygenation, acidification, and waterlogging, impairing soil fertility. And, vice versa, if groundwater drops—for example, during dry periods—or if it is pumped, both the soils and the wells dry up.

Artesian water lies deep down at about 100 meters or more under the land's surface. As a rule, it comprises water basins, fed from underground sources. Artesian water is usually under pressure (confined); it flows out in some places and blows from drilled wells. Cessation of artesian water flowing means dropped pressure in the basin—that is, that the water level has fallen drastically. The Ararat artesian basin is the main source of potable water for almost half of Armenia, including the City of Yerevan.

The adverse impact of fish farming on the ecosystem may be outlined as shown in Figure 3 below.

Because of underground water use for fish farming in the Ararat Valley, in recent decades the groundwater level fell by 3–4 meters, and even by 5–6 meters in the central part of the valley where crop farming is most prevalent. The soil humidity therefore decreased, which, in its turn, increased the irrigation depth, regimens, and the amount

Figure 3: Transformation of the Ararat Valley Ecosystem Due to Intensive Fish Farming

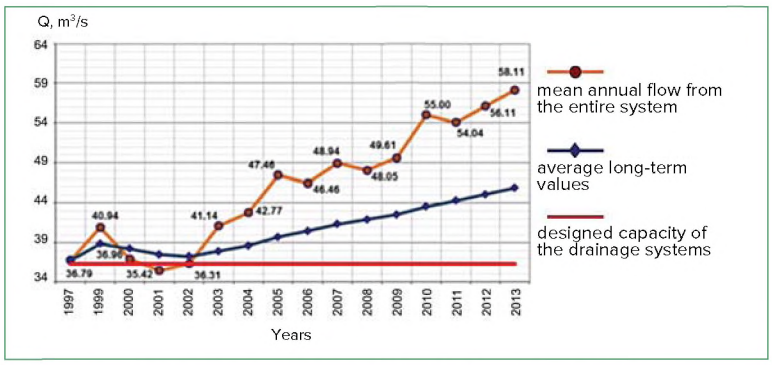


of irrigation needed for agricultural land [4]. On the other hand, the wastewater from fish ponds is watering neighboring areas (Figure 4).

Water discharges cause local waterlogging instead of watering that spreads the water over fields evenly and in required amounts. Figure 5 shows how the amounts of discharged water keep growing (by year), while the designed capacity of the drainage network remains unchanged. This results in a reflux, excessive moisture in the soil surface, and waterlogging. It means that drains fail to perform their functions to control adverse processes of waterlogging.

Source: Google Earth, February 2016.
Note: The dark-brown spots show the processes of watering with the discharged water in neighboring areas.

Figure 4: A Space Image of Fish Farms in the Ararat Valley



Source: Cadaster of irrigated and drained land in Armenia, 2014 [5].

Figure 5: Discharge Water Flow from the Drainage Systems in the Ararat Valley, 1997–2013

According to statistics, since the year 2000, groundwater has been rising (from 2.0–2.3 meters under the surface to 1.2–1.5 meters in the lower southern part of the valley where major fish farms are based).

An alarming situation is also looming over the artesian waters. According to the USAID assessment study of groundwater resources of the Ararat Valley (undertaken in 2013–14), during the period of 1983–2013, the underground artesian water area shrank by three times to 10,706 hectares; and the artesian water extraction rate increased from 34.7 cubic meters per second up to 80.0 cubic meters per second, primarily because of the growth in fish farming. This has disturbed the water balance. The Pan-Armenian Environmental Front reports that in 2013 alone, the extraction of water from the artesian

basin exceeded the admissible level 1.6 times. This level is 18 times as high as the water consumption in the City of Yerevan. In some locations of the Masis Municipality, the underground water level has dropped by 15 meters!

Thus, continued mismanagement of the water resources threatens to unleash the desertification processes in the Ararat Valley and to impair its fertility and harvests as well as to deplete its storage of potable water, which is also an important constituent of food security.

Policy Issues

In 2004, the Government of Armenia adopted a strategy aimed at introducing advanced technology in agriculture and developing research, education, and extension systems with due regard to interlinked challenges in agriculture and environmental management.

Fish breeding is of strategic importance for the country because fish farms could be established not only in the Ararat Valley, but also in piedmont and even mountainous areas, and especially in border villages where it may be deemed to be the only profitable sector in view of the rather limited feasibility of crop cultivation and cattle breeding. On the other hand, in Armenia—which has had its transportation routes disrupted since 1992—fish breeding addresses important issues of food security.

Policy questions and proposed answers:

1. How can the most enabling conditions for fish farming be created?

   It is necessary to explore opportunities to use available suitable water surfaces in full (not only in the Ararat Valley) because this would permit not only an increase of commercial fish outputs, but would also engage hundreds of households from mountainous and remote border communities in such operations.

2. How best can the profit-related interests of large and small entrepreneurs be accommodated?

   In future, Armenia can rear pond fish in great quantities. The challenge rests with another aspect: vested interests should not limit their focus only to the domestic market—there is simply no 'room' for their activities: eventually, the involvement of major investors would not meet their expectations but would only wipe out small and medium farmers to monopolize the market. At this point, it is important to enhance the role of government, which should monitor development processes, create enabling conditions for export, and guide producers toward cooperation and export. It is also necessary to address the issue of transporting the fish.

3. How can the increasing groundwater deficit be stopped?

   Today, the depletion of the underground water resources is the most important issue (perhaps this was not even foreseen 10 years ago). The first priority should be given to the following steps:

   - Introduce closed or semi-closed systems of water supply to fish ponds with at least 70 percent of the water to be repeatedly reused. A transition to the new system would require rather expensive new technology. Clearly some farms would not be able to afford such expenses. It would be advisable for the government to consider providing support for equipping fish farms with fish pond aerators, oxygenizing the water to make it possible to repeatedly reuse it.

   - Explore opportunities for cooperation between neighboring landowners and fish farmers so that fish farmers could supply their purified waste water to neighboring landowners for irrigation. Certainly supplying water to remote fields would entail high financial costs of water conduct and electricity.

4. Are controls and prohibitions necessary?

   It is the lack of control on the part of the country's authorities that has largely caused the currently alarming situation with water balance in the Ararat Valley. Most fish farmers have been practicing illegal, uncontrolled use of the water for a long time, and there has been no regular environmental monitoring or forecasts of the developing situation. Therefore it is currently necessary to assess the actual situation, undertake an environmental hydrological audit, and close or suspend the operations of some ponds and wells if emergency cases are detected.

Another option is to explore possibilities for converting fish farms to other agricultural uses. In this case, however, it would be necessary to develop recommendations for the fish farm owners on agricultural uses/operations/activities in which they could get engaged without a major detriment to their economic situation.

It is urgent to take measures because there are emerging conflicts between crop farmers and fish farmers. Urban dwellers are also raising alarm because they have already started to feel the deficit of potable water.

5. What arable farming policies should be adopted?

It is necessary to assess the situation in terms of flooding and soil drainage in different parts of area to identify their causes. It would be sensible to restore and expand existing drainage systems with a view to draining the soils and preventing secondary salinization. On the other hand, it is worthwhile recalling the project, financed by the World Bank in the 1990s, that was aimed at improving the profitability and sustainability of irrigated agriculture and creating basic opportunities to turn agriculture into a key source of employment. It would be quite appropriate to guide farms toward irrigated crop cultivation with the use of discharge water from fish farms.

Thus, in view of the current situation in the Ararat Valley, it is evident that degradation processes have become intensive there. To cope with them, it is necessary to implement agricultural policy reforms aimed at ensuring the sustainability of both the supply of agricultural products and the functioning of the whole ecosystem, including its water resources.

Stakeholder Groups

Dwellers of the Ararat Valley Engaged in Crop Cultivation

The average area of privatized land per farm/household is 1.4 hectares, including arable land (1.04 hectares), perennial plantings (0.12 hectares), and haymaking grounds (0.24 hectares).

During 1950–99, Armenian arable land shrank by 166,600 hectares, and the haymaking grounds and grazing land got reduced, respectively, by 15,600 hectares and 136,500 hectares. In contrast, perennial plantings increased by 28,800 hectares.

In the Ararat Province, farmers have to quit cultivating their land because they have no money for water, tillage, or seeding stock. According to local people, the price of tillage with the use of heavy machinery ranges from AMD 80,000 to AMD 100,000. They are forced to work for rich landowners for about AMD 3,000 per day. This issue is very 'acute' according to the opinion of those who participated in a roundtable, organized by EcoLur (an environmental nongovernmental organization) and hosted by the Ararat Aarhus Centre on April 5, 2012, as part of the *Make Your Voice Heard* project.

Pond fish farms are situated primarily on alkali-saline soils and practically have not contributed to the reduction of agricultural land areas, but they have driven the rise of the groundwater level around them and of waterlogging. The fish ponds discharge their water either simply into the soil or into the drainages that have ceased to perform their functions and turned into canals with high water levels and reflux, raising of the groundwater level in the southern part of the Ararat Valley, which results in such processes as salinization, alkalization, and waterlogging, but in many communities, both houses and facilities are also wet. On the other hand, in some places, the uncontrolled withdrawal of water for fish farms has lowered the groundwater level and, thus, led to soil drainage, especially in the habitable upper root layer, and to the need to increase the irrigation depth by 25 percent. Water pressure has decreased and farmers cannot obtain water on their own as they did earlier. For this reason, 31 communities are left without both irrigation and even potable water from flowing artesian wells. The Pan-Armenian Environmental Front predicts that, if the same water use scenario persists in the Ararat Valley, up to 400,000 people engaged in agriculture in the valley would lose their jobs and a new migration surge could be expected. So crop farmers need both land and water. It appears to be impossible to assess their attitude to fish farmers unambiguously.

Owners of Fish Farms

It is quite obvious that fish farming was very profitable until now. Using the high-quality water practically for free, fish farmers kept on increasing their outputs, often starting to rear more expensive fish species (trout, sturgeon) instead of cheaper fish. Euphorically, successful farmers were increasingly expanding their ponds, using cheap and sometimes free-of-charge water. Though fish farmers are aware of the emerged water balance crisis, they deem it unaffordable for many of them to introduce new

technology, which is rather expensive (its cost estimates range from €700,000 to €1.5 million). And, certainly, owners of fish farms are expected to resist new raised taxes if they are introduced.

The Ministry of Nature Conservation

Earlier, the Ministry of Nature Conservation (MNC) of the Republic of Armenia authorized the use of a total volume of 1.496 billion cubic meters of water by fish farms even though the renewable groundwater storage of the Ararat Valley is only 1.226 billion cubic meters [3]. As a result, 122 out of 638 artesian wells of the Ararat Valley have dried up, and 6,200 hectares practically faced the unavailability of water. To mend the situation, it was decided to increase the permissible volume for water released from Lake Sevan from 170 million cubic meters to 240 million cubic meters for five years [6]. In the meantime, the attempt to improve the situation by increasing the water released from Lake Sevan is not a fully positive decision. It is known that several years ago, the lowering of the Sevan water level caused many springs to dry up; hence, an increase in water released from Lake Sevan may indeed become very detrimental for underground water sources in a significant part of the country.

There are also public health concerns: the point is that fish ponds take pure artesian water and discharge polluted water. And since the Ararat underground basin is the main source of fresh water, in the near future this can lead to a deficit of potable water in Yerevan as well.

Nature conservation groups deem it necessary to reduce the underground water extraction and raise taxes on fish farms.

The Ministry of Agriculture

The Ministry of Agriculture is designated to cause food products to be supplied and to ensure their security. Key strategic documents are the Sustainable Agriculture Strategy (2004), the Poverty Reduction Strategy (2003), the Law on the Nature Conservation Frameworks (1991), the Land Code (2001), the National Plan of Desertification Control (2002), the Law on Agricultural Land Amelioration (2005), and the Technical Standards and Rules of Degraded Land Restoration and Classification (2006)[1].

Soil degradation (desertification) has become a serious challenge for the Ararat Valley. The ecosystem of this area has a sophisticated pattern, with its soils varying from brown long-cultivated soils to alkali-saline and waterlogged soils.

In the Ararat Valley, the changed water and thermal regimes of the soils account for the disturbance of the centuries-old equilibrium of the generation and destruction of organic matter that, in its turn, accelerated destructive processes, reduced the amount of humus in the soil by 0.5 percent–1.0 percent, caused its dispersal, deteriorated water's physical properties, and, ultimately, led to land degradation and lower yields of agricultural crops.

Regarding the use of fertile long-irrigated soils in the Ararat Valley, grain and fodder crops have been decreasing from year to year. On the one hand, their cultivation is partly profitable because these crops can give high revenues, but the infeasibility of their rotation results in soil depletion.

Clearly, the status and fertility of all the soils are directly dependent on the moisture regimens in the Ararat Valley; therefore restoring the water balance there is the most important goal for the Ministry of Agriculture because it is vital for food security in the country.

Research Community

Figure 3 is a generalized analytical picture of the current situation in the Ararat Valley (though in reality, it is much more complicated). As noted above, the valley is a complex ecosystem, generated by nature and man, with its relatively well established mode of functioning, evolved during many centuries of management. Now this mode is disturbed, and it has become evident that the entire ecosystem's environmental capacity has been significantly overused. The main mistake was transforming the area to make it perform functions that were alien to its nature as a desert/semi-desert geographic landscape. A similar mistake had been already made before, in the area between the Amu Darya and Syr Darya rivers with the Aral Sea.

Only scientists, focusing on such natural processes, can provide a comprehensive analysis of the situation and predict its development.

[1] All of these documents, available only in Armenian, can be found at http://minagro.am/

***Ashot Hoetsyan, a land degradation and desertification expert from the Ministry of Nature Conservation**, says: "The Ararat Valley situation is a particularly heart-breaking issue. The point is that it is the only more or less flat area (in comparison with other regions with their steep slopes—even with steepness of 5°–10°, the agricultural operations are difficult). The Shirak and Lori Plateaus are not a panacea either—their altitudes are too high (1,500–1,800 m above sea level). And the elevation of the Sevan basin is even higher—it reaches 1,900–2,000 m above sea level. That is why all our hope to supply agricultural products resides with the Ararat Valley, offering all needed conditions for agricultural development. But, alas, even here, desertification makes itself felt. This is not to say that fertile land of our breadbasket has degraded most of all. But! Sort of an Armenian 'desertification brand' is land salination. And of all places, the Ararat Valley is the only area, affected with it. Here, groundwater is very close to the surface and its evaporation is dispersing salts over ever vaster areas. No doubt, it benefits our salt producers. But it has tremendous adverse effects, especially as it is coupled with the predatory process of emptying the Ararat artesian basin. This refers to numerous pond fish farms, mercilessly consuming the ground water to meet their business needs. And in many cases, they do it without licenses. In the long run, the country is losing arable land for the benefit of someone's interests. And it is inevitably leading to impoverishment of farmers and further impairment of capacity to combat desertification." When asked about the area of land already lost for crop cultivation in the Ararat Valley, Ashot Hoetsyan said: "Nobody can give you exact data. But, in my opinion, in several decades, saline soils will cover over 30,000 ha in the Ararat Valley alone. To make you understand the seriousness of the situation, I shall say that in Armenia, the land area is 3 million ha and less than half of it is arable land! So, in 10–20 years, the Ararat Valley will lose its capacity to perform the agricultural function. As a matter of fact, when farmers are unable to handle difficult land, they tend to abandon such areas completely in search of better sources of income" (http://noev-kovcheg.ru/mag/2014-03/4349.html).*

Providers of Extension, Consultation, and Other Services

People need information and consultations about the advisability of taking up an occupation or engaging in a business, especially if there is a need to change it.

Policy Options

1. Develop a national integrated program aimed at optimizing the agricultural uses and sustainable development of the Ararat Valley ecosystem with due regard to the functional specifics of all its landscape components

It would be necessary to involve various specialists, including economists. A focus should be made on the groundwater status and changes in the Ararat artesian basin. These specialists should assess and estimate environmental capacity of the Ararat Valley.

2. Forbid granting new permits for water extraction from the Ararat artesian basin for fish farming

This would contain the depletion of artesian fresh water resources, and at the same time help to sustain the operation of fish farms—otherwise they would be gradually closed due to lack of water.

3. Conduct groundwater surveys to update the data to help address the issue of groundwater shortage in the basin and its surrounding areas

In view of the depletion of the usable groundwater storage in the Ararat artesian basin, it is necessary to conduct a retrospective analysis of changes in both underground and surface water storage, forecast the development of the situation, and organize detailed environmental monitoring in the basin.

4. Liquidate or conserve illegally used wells

The Government of Armenia should adopt a decision to take such measures as the liquidation and conservation of illegally used and abandoned deep wells. It is also necessary to introduce a valve operation mode for those wells where there are no valves and water is used inefficiently.

5. Introduce up-to-date water-saving technology of water use in fish farms

It is advisable to introduce semi-closed and closed systems of water supply to reduce the actual water consumption from 1,493 million cubic meters per year to 448 million cubic meters per year. It is estimated that to introduce new technology, fish farmers would have to invest €3 per 1 kilogram of produced fish; obviously, these are very expensive projects. Proceeding from the total number of fish farms in the Ararat Valley and their total production capacity, these investment needs of all the fish farms are estimated at about €23 million. It would be expedient on the part of the government to provide interest rate subsidies for loans to be borrowed from banks to implement such a program. Full-fledged implementation of such an important program should be preceded with a pilot project to identify all technical and economic issues. Since financial opportunities of fish farms vary, it is necessary to establish shorter periods for the introduction of new technology for large and medium-size farms and longer periods for small farms.

When selecting organizations to be supported, it is necessary to give preference to those organizations that would give firm guarantees of flawless operation of a semi-closed system of water supply, so that farms could have guarantees against financial losses.

6. Introduce economic levers for good natural resource management

Economic interventions are very important for water saving; and, in particular, they include rises in prices for water use and removal. Recent years saw a 10-fold increase in the price for water, used by fish farms: it has reached AMD 0.5 per m3, but overall, it has not led to significant water saving. Economic studies show that further growth of prices for both utilized and discharged water would increase the cost of fish production. With limited fish exports, it would have strong negative impact on farms. For this reason, it is necessary to find new production opportunities and markets, chiefly, foreign ones, alongside with the use of economic levers.

7. Use discharged water from fish farms for irrigation

A promising way to partially address the groundwater depletion in the Ararat Valley is to recirculate discharged water from fish farms to use it for irrigating fields. An analysis of such water shows that it is often suitable for irrigation although sometimes it should be purified. This practice would enable to reduce the consumption of water from those underground water sources that are designated for irrigation. However, this water is mostly found at lower levels and it is necessary to use pumps to extract to it. But this opportunity is limited because of the high costs of power (about AMD 50 per kilowatt hour). The issue could be addressed through:

a) constructing solar or wind power plants to use cheap power for water pumping;

b) receiving government subsidies to cover the costs of power; and

c) imposing obligations on farms to increase the area of their land parcels and introduce crop rotations.

8. Move fish farms from the Ararat Valley to higher altitudes

Another approach is to move fish farms from the Ararat Valley to higher altitudes. Recent years have seen specific steps in that direction. In particular, a caged fish farming program is ongoing in Lake Sevan and is expected to result into fish outputs of about 50,000 tonnes per year. However, it may be problematic because, in a colder climate, fish productivity is much lower and, hence, production cost would be higher. So this practice cannot be as competitive as fish farming in the Ararat Valley. In terms of fish rearing at higher altitudes in other regions of Armenia, it should be noted that though this trend is currently observed, there is a risk of contaminating rivers that are fairly clean in these regions and inflicting damage to the environment. To mitigate the risk, it is necessary to oblige owners to purify the water before discharging it back into the rivers, as is done in many other countries.

9. Resume the operation of the irrigation system

Currently, 24 communities have no irrigation water supply as a result of the lowering of the groundwater level. Their irrigation systems practically do not operate. The objective is to restore these systems and to have irrigation water supplied.

10. Promote local (focused) amelioration of white alkali-saline soils

It is necessary to promote focused amelioration of white alkali-saline soils. After chemical amelioration, these soils become fertile and may be used for perennial plantations. Due to the fact that most fish farms are located next to white alkali-saline soils, local reclamation of these soils by farm owners will lead to establishing fruit orchards and vineyards, which could be irrigated with water, discharged from the ponds. This would require modest efforts but could help to address both food supply needs and environmental protection objectives.

11. Promote collaboration of fish farmers and crop farmers

It is recommended to explore whether it would be appropriate to revive the Soviet practice of quite effective alternate uses of one and the same land area for crop cultivation and fish ponds. It is known that when water is removed from land upon completion of fish pond operation, the land has high yields during the first two or three years; later, its nutrient status deteriorates and it could be used for fish pond operation again for two years. In this case, not much artesian water is required. This problem is to be addressed by the Ministries jointly with respectively qualified experts.

12. Develop a system of environmental monitoring of the artesian basin and grant the Ararat Valley a Protection Area status

The Ministry of Nature Conservation has its Monitoring Centre, which monitors surface waters: rivers, lakes, and reservoirs. On the other hand, the Amelioration company (subordinated to the State Committee of Water Management under the Ministry of Agriculture of the Republic of Armenia) monitors ground and drainage waters. However, impact of water discharge from fish farms on surface waters has never been assessed. A full or partial nature conservation status of the valley would enable government agencies to legitimately restrict environmentally detrimental activities there.

13. Provide extension and consultation services

Extension/consultation service providers established under ministries, universities or institutions of higher education, and nongovernmental organizations possess respective databases, guidelines, information and relevant expertise. These organizations could help people to understand potential benefits and advisability of engaging in given economic activities.

Assignment

Drawing on an analysis of the current environmental situation in the Ararat Valley, resulting from the water balance disturbance due to intensive fish farming, your assignment is to appraise the potential effectiveness and feasibility of various policy options and propose adequate land use and fish farming measures to restore and stabilize the water balance.

It is recommended to use a SWOT analysis (a strategic planning method, consisting of the identification of various factors and their classification into the following four groups: Strengths, Weaknesses, Opportunities and Threats).

Policy Recommendations

For government entities (the Ministry of Agriculture, Ministry of Nature Conservation)

Objective: to stop the depletion of underground water resources. (*Stabilization and, if possible, restoration of the groundwater level are vital for both fish farmers and crop farmers as well as for sustainable water supply of this area and the City of Yerevan.*)

Action: To improve the situation, it is necessary, first of all, at the government level, to: (i) reform the system of fish farming in the Ararat Valley; (ii) undertake a thorough review of all existing fish farms, ranking the farms according to their environmental impact and impact on the water balance; (iii) close farms where wells have ceased to flow; (iv) introduce a recycling water supply for the fish ponds; (v) restrict rearing of fish species that require increased amounts of clean flow-through water; (vi) reform the system of

water use taxes; and (vii) support efforts to locate fish farms in mountainous areas.

Objective: to arrest the degradation of the Ararat Valley ecosystem.

Action: the Academy of Science together with the University and the Ministry of Nature Conservation should (i) develop a government-targeted program aimed at ensuring the sustainable development of the entire ecosystem of the Ararat Valley, and including detailed environmental monitoring; (ii) undertake an economic analysis and forecast the efficiency of land uses for purposes of supplying food products; and (iii) develop an environmental protection system and elaborate respective restrictive measures.

Objective: to resume active crop cultivation in the Ararat Valley, to recover its glory as the breadbasket of Armenia.

Action: (i) consider possibilities of cooperation between arable farms and fish farms; (ii) revise measures to provide farms with sufficient areas of land with recommendations on needed crop rotations to sustain natural fertility and yields; (iii) put in place a system of highly professional extension services and consultation support to be provided to farmers, farm managers and rural households, engaged in any agricultural activities and supplying food for their own subsistence and for sale.

References and Additional Readings

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