ASPIRED PROJECT

ASSESSMENT OF OPPORTUNITIES FOR APPLICATION OF ADVANCED TECHNOLOGIES

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Acronyms

AFFEF	*Association of Fish Farmers and Exporters of Fish*
AMD	*Armenian Dram*
AUA	*American University of Armenia*
EUR	*Euro*
ERGIS	*Environmental Research and GIS Center NGO*
FAO	*Food and Agriculture Organization of the United Nations*
GEF	*Global Environmental Fund*
GIS	*Geographical Information Systems*
MNP	*Ministry of Nature Protection*
NGO	*Non-Governmental Organization*
O&M	*Operation and maintenance*
PE	*Polyethylene*
PIU	*Program Implementation Unit*
PSRC	*Public Services Regulatory Commission*
UNDP	*United Nations Development Program*
USAID	*United States Agency for International Development*
USD	*United States Dollar*
WB	*World Bank*
WRMA	*Water Resource Management Agency*
WTP	*Wastewater treatment plant*
WUA	*Water Users' Association*

Contents

Assessment of Opportunities for Application of Advanced Water and Energy Saving Technologies

1 Introduction

1.1 Purpose of the Assessment

The quick depletion of underground water resources in Ararat Valley caused by human activity, more specifically – by fish industry, has been repeatedly emphasized by different governmental and environmental organizations of the Republic of Armenia during the recent years as a serious problem that is likely to grow into a full-fledged environmental hazard if no mitigation measures are undertaken. According to a study carried out by the Clean Energy and Water Program (CEWP), the annual consumption of artesian water by fisheries located in Ararat Valley totaled at 1,493 million m^3, while the self-recovery potential of the artesian aquifer is only 1,226.2 million m^3 per year[1].

To find possible solutions and suggest practical mitigation measures for overcoming this challenge, the ASPIRED Project (hereafter – the Project), in cooperation with ICARE and USAID Global Lab, initiated a preliminary study and assessment of the sector with the purpose of:

- Assessing the current practices of fish farming with regard to water-use efficiency;
- Identifying the main problems of the fish-farming industry and estimating their impact on the sustainability of aquaculture business in Ararat Valley;
- Identifying incentives (if any) among fish-farmers for reducing water intake from artesian aquifers;
- Identifying and evaluating past, present and forthcoming initiatives for improvement of water-use efficiency in fisheries;
- Identifying opportunities for application of water and energy saving technologies and assessing the sustainability and replicability of proposed technological solutions;
- Evaluating perspectives for secondary use of water (irrigation, renewable energy, etc.).

It is expected, that based on the results of this assessment, ASPIRED and its partners will design and implement pilot projects to demonstrate how different technologies and methods can be used to improve the water efficiency in Ararat Valley and particularly in fish-farming industry.

It is worth mentioning that this document is at identifying the main opportunities for application of advanced technologies and a more detailed description, calculation, feasibility analysis for each technologies will be provided at the time of preparation of concept-level designs of respective pilot projects.

1.2 Sources of Information

As mentioned above, in this phase of preliminary study and assessment, the Project Staff cooperated closely with ICARE (USAID PEER Grant Project) and USAID Global Lab. In the process of this cooperation, a working group of experts was formed (hereafter – the Assessment Team) to share opinions on the findings of the study and to develop a uniform approach for designing feasible and replicable solutions to the identified problems.

[1] Similar figures were presented also in the report of the ERGIS Center: "The use of outlet water from fisheries of Ararat Valley for irrigation and melioration of saline lands", ERGIS Center, 2015

In addition to the information collected from the field by the Project staff, the Assessment Team made extensive use of the information collected previously by different international organizations, NGOs and governmental agencies (hereafter – Partner Organizations).

During the study, as part of the data collection effort, the Assessment Team contacted the following organizations:

International organizations:

- FAO, office in the Ministry of Agriculture;
- JICA country representative;
- GIZ Armenia Office;
- UNDP, GEF Small Grants Program;
- World Bank Irrigation Rehabilitation Project PIU;
- IFAD;
- UNDP, Agriculture Development Project.

NGOs:

- Environmental Research and GIS Center;
- Association of Fish Farmers and Exporters of Fish;
- Water Users' Association of Masis Region.

Businesses:

- "Inter-Aqua" fishery;
- "Aror Bagrat" fishery (non-operational);
- "Emi Fish";
- "Masis Dzuk";
- "Artezianica" fishery;
- Samvel Lablajyan PE;
- Karapetyan Khachatur PE;
- Khalatyan Arsen PE;
- Armen Torosyan PE;
- Sedrakyan Sara PE;
- Tukhikyan Satenik PE;
- Zakaryan Vahan PE;
- "Khayts Ishkhan" (rented fishery in Sypanik);
- "Armavir Farmer" fishery (non-operational);
- Medisar LLC;
- Coca-Cola HBC Armenia.

Governmental agencies and municipalities:

- Marz Executives of Ararat and Armavir;
- Ministry of Agriculture;
- Ministry of Nature Protection;
- Local officials from *Darbnik, Nizami, Hayanist, Griboyedov, Lusagyugh* and other municipalities.

The data collection activities included written and oral communications with Partner Organizations, meetings and site visits to potential project locations for collection of additional information, and measurements and assessment of project implementation feasibility.

2 Background Information

The oldest fish-farms in Ararat Valley were established back in Soviet times, and were mainly located in two areas – Armash (south-eastern part of the Valley) and Metsamor (at the natural springs feeding the Sev-Jur River). At that time, the fish-farming industry was well balanced with the local market demand and did not present any danger for the environment, since it mainly used the natural outlets of artesian aquifers and did not exceed the self-recovery potential of the underground water resource.

In the 2000s, the region witnessed a real boom of fish-farming industry. Numerous fish-farms were built, often next to each other[2], without any consideration of the environmental impact or medium and long-term market demand. The drilling of artesian wells took place without any control or supervision by respective public agencies. This inaction of national environmental authorities resulted in widespread and careless wastage of strategic freshwater reserves in violation of basic principles for safe usage of underground water resources. At the same time, the lack of proper development strategy for the fish-farming sector from the Ministry of Agriculture resulted in significant overproduction and decline of sector revenues.

Here are some of the most important environmental and economic consequences of the above mentioned factors:

- The geographical area of artesian aquifer (with self-emission potential) shrank more than 3 times: from 32,760 ha (in 1983) to 10,706 ha (in 2013).*(ref. "Ararat Valley Groundwater Resources Assessment Study", USAID Clean Energy and Water Program, March 2014)*.
- Many communities that previously used 80-100mm self-emission artesian wells for irrigation were left without irrigation water after the geographical area of artesian aquifer shrank. In more than 10 years the abandoned irrigation networks completely deteriorated without proper maintenance, while most farmers left their land and communities and became labor migrants.
- The overproduction of fish and problems with exports[3] on one hand, and the reduction of self-emission potential of wells on the other hand, resulted in bankruptcy and collapse of many fish-farms. According to the information provided by the Association of Fish Farmers and Exporters of Fish (hereafter – AFFEF), in 2015 around 35 fish farms became bankrupt and stopped operation[4].

Despite the above mentioned economic problems that the fish industry in Ararat Valley has been facing during the last 1.5 years, and despite the obvious environmental damage that the industry has been causing to the region, there is no policy for supporting a profile change in the sector. (Here, by "profile change" we mean a transition to other agricultural activity or production of other aquaculture goods that are less water consumptive.) Authorities do not provide (or plan to provide) financial support or economic incentives to businesses involved in fish-farming to encourage a shift to other forms of agricultural activity.

The main mitigation measure considered by the Government so far is linked to reduction of water-use limits set by water use permits. By this the Government is planning to encourage the businesses to apply more efficient and water-saving technologies in fish-farming. At the request of the Ministry of Agriculture, FAO (Food and Agriculture Organization of the United Nations) has recently started a large-scale pilot project on redesign and reconstruction of one of the fisheries (Begama Fruit) in Ararat Valley to use a semi-closed system of water circulation that, according to the designer of the project, guarantees significant (around 70%) water savings.

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[2] According to the data of the Ministry of Agriculture, in 15 years (2000-2015) around 233 fish farms were built. The total pond area of these fish farms is around 3530 ha! *(ERGIS Report, 2015)*

[3] Fish exporters are mostly oriented at the Russian market. Following the western sanctions and the devaluation of Russian Ruble the revenues of exporters dropped significantly. *(AFFEF)*

[4] Different sources provide different figures; some say the real figure is lower, other say it is significantly higher. In any case, the AFFEF figure is closer to the officially registered number of non-operational fish-farms (57 as of October 2015).

The Government also allocated some money in 2015 to seal abandoned and/or illegal wells in Ararat Valley. According to the information provided by the WRMA, this money was used to effectively seal 8 wells. The initiative will be continued also in 2016; for this reason the Government made some provisions in the State Budget of 2016. Although this is a very good initiative, the rate at which illegal or abandoned wells are sealed is not comparable with the scope of the problem; according to the President of the EFBEF, in different parts of the Valley there are around 560 abandoned wells, of which 100 – with significant self-emission capacity[5].

Another potential mitigation measure discussed in the Government is linked to the amount of the water resource fee (which is currently set at AMD 0.5 for 1 cubic meter of artesian water). Although all the agencies and stakeholders agree that the depletion of artesian aquifers exists and it should be addressed, there is no unanimity among different governmental agencies on the water resource fee issue. While the Ministry of Nature Protection calls for a fee increase, the Ministry of Agriculture opposes the idea.

3 Best Aquaculture Practices

3.1 Quality vs Efficiency

Best Aquaculture Practices (BAP) is a set of farm-raised seafood certification standards developed by Global Aquaculture Alliance (GAA). GAA is the world's leading standards-setting organization for aquaculture seafood. The BAP program is a comprehensive certification system for aquaculture facilities, addressing every key element of responsible aquaculture, including environmental responsibility, social responsibility, food safety, animal welfare, traceability and more. (See the complete set of BAP standards at: http://bap.gaalliance.org/bap-standards/).

From environmental perspective BAP require that minimum amount of water and energy resources are used for production of maximum amount of aquaculture goods. In other words, the higher the efficiency of the farm, the higher is the saving of water and energy. To achieve this, farms have to aim for higher stocking density (fish population) in the ponds and higher rate of recirculation.

On the contrary, to achieve higher product quality standards and use the “organic product” label, fish farms have to sacrifice certain level of efficiency; reduce the stocking density and recirculation rate, add a certain amount of natural feed and use high quality water and earthen ponds. The cost of “organic” products will be naturally higher in those regions where land and water resources are relatively expensive.

Currently the conditions in most Armenian fish farms are quite close to the standards set for production of “organic” seafood. As mentioned below, in section 4 of this study, 56 % of all the fish in Ararat Valley is produced in earth bottom ponds, and 44 % - in ponds lined-up with stone and/or concrete (concrete ponds).

Earthen ponds in Darbnik fish farm

3.2 Recirculating Aquaculture Systems (RAS)

*Section prepared with the assistance of ICARE Aquaculture Specialist, AUA Faculty **Dr. Karen Aghababyan***

[5] The inventory of artesian wells initiated by the ASPIRED Project will give more accurate figures as to the number and the total yield of abandoned wells in Ararat Valley.

According to the definition of Wikipedia: ***"Recirculating aquaculture systems (RAS) are used in home aquaria and for fish production where water exchange is limited and the use of biofiltration is required to reduce ammonia toxicity"***.

The main benefit of RAS is the ability to reduce the need for fresh, clean water while still maintaining a healthy environment for fish. To be operated economically commercial RAS must have high fish stocking densities, and many researchers are currently conducting studies to determine if RAS is a viable form of intensive aquaculture.

In general, all recirculating aquaculture systems are based on three main components: **biofiltration**, **removal of solid organic particles**, and **aeration** (oxygenation).

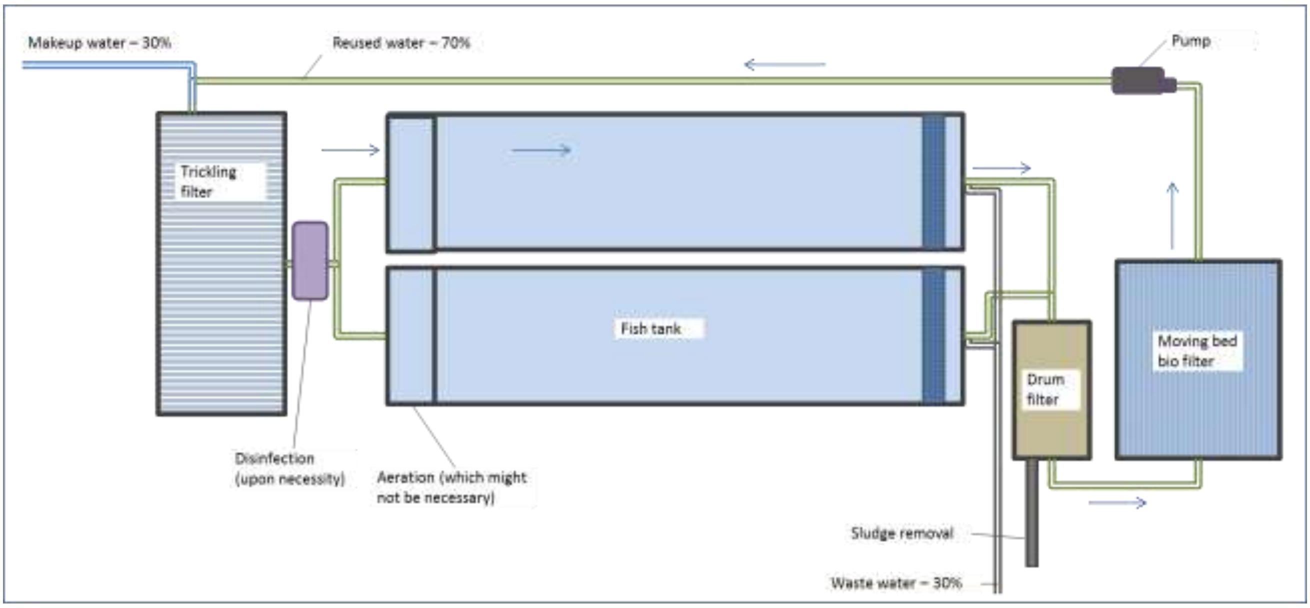
Biofiltration is needed to convert ammonia (NH_4+ and NH_3) excreted by the fish into nitrate. Ammonia is a waste product of fish metabolism and high concentrations (>.02 mg/L) are toxic to most finfish. A biofilter provides a substrate for the bacterial community, which results in thick biofilm growing within the filter. Water is pumped through the filter, and ammonia is utilized by the bacteria for energy. Nitrate is less toxic than ammonia (>100 mg/L), and can be removed by a denitrifying biofilter or by water replacement.

In addition to treating the liquid waste excreted by fish the solid waste must also be treated, this is done by concentrating and flushing the solids out of the system. **Removing solids** reduces bacteria growth, oxygen demand, and the proliferation of disease.

Aeration (oxygenation) of the system water is crucial to obtaining high production densities. Fish require oxygen to metabolize food and grow, as do bacteria communities in the biofilter. Dissolved oxygen levels can be increased through two methods aeration and oxygenation.

The following two RAS models for water-efficient trout farming that are relatively simple to implement may have a good potential for application in Armenia.

1. ***Model 1: 70% RAS (see picture below).***

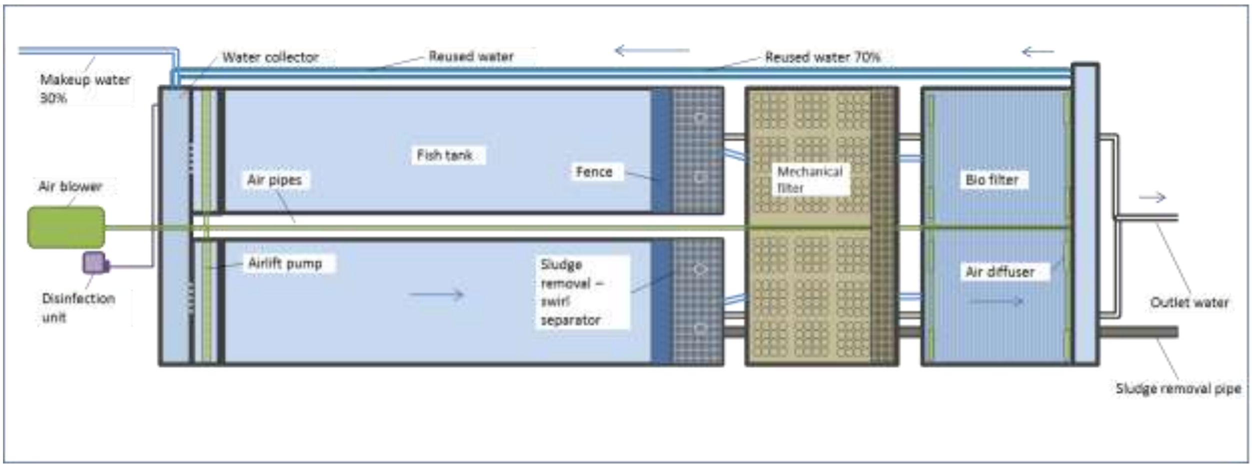


The model consists of two fish tanks, drum filter, moving bed bio filter (can be substituted by submerged bio filter), pump, trickling filter, disinfection block, and aeration.

Water from the fish tank is divided into two flows: recycled water (70-72%) and waste water (28-30%). Waste water is removed from the system by pipe. Recycled water passes through fences (aimed at prevention of fish escape), and reaches drum filter (operated by electricity), where it becomes filtered from particles (mechanical filtration). The sludge pipe removes the sediment and filtered particles out of the system. From drum filter, the water reaches moving bed biofilter (operated by electricity, however the submerged biofilter doesn't require that), where toxic ammonia is transformed into less toxic nitrates. From the biofilter the water reaches pump by gravity and then is pumped back (operated by electricity) to the top of the system where degassing and aeration (in some extent) takes place in trickling filter. From trickling filter the water reaches the disinfection unit (operated by electricity and which is installed upon necessity). From disinfection unit the water reaches first section of the fish tanks, where additional aeration can take place (installed upon necessity). Then the water reaches the fish tank closing the loop. Makeup water (30%) flows into trickling filter, passes disinfection, aeration and reaches the fish tank.

Questioning of farmers in Denmark shows that the use of electricity varies from 1.5 to 3.0 kWh per one kg of trout produced.

2. ***Model 2: 70% RAS see picture below***



The model consists of two fish tanks, mechanical filter based on bio-blocks, moving bed bio filter, airlift pump, and disinfection block.

The water from fish tank is divided into two flows: recycled water (70-72%) and waste water (28-30%). Waste water is removed from the system by a pipe. Recycled water passes through fences (aimed at prevention of fish escape), and reaches swirl separator, which secures sedimentation of larger fraction of the particles. The sludge here is removed through sludge removal pipe. Then the water reaches second part of mechanical filtration – mechanical filter, which is based on the bio-blocks where it becomes filtered from fine particles. The same sludge pipe removes filtered particles out of the system. Then, the water reaches moving bed biofilter (operated by electricity), where toxic ammonia is transformed into less toxic nitrates. From the biofilter the water reaches beginning of the system by gravity where it flows into canal; then in the canal the disinfection takes place. Then, from disinfection canal the water reaches first section of the fish tanks, where it is pumped using airlift pumps which secure lifting of the water and in the same time degassing and aerating it. Then the water reaches the fish tank closing the loop. In some systems additional aeration id required. Makeup water (30%) flows into disinfection canal, passes disinfection, airlift pumps and reaches the fish tank.

Questioning of farmers in Denmark shows that the use of electricity varies from 1.0 to 1.5 kWh per one kg of trout produced.

3.2.1 Advantages of Recirculating Systems

All the advantages of recirculating systems are described above, but if we try to summarize those we will come-up with the following statement: recirculating systems allow fish producers the flexibility to grow fish intensively and get more fish in smaller space and with less water.

The current policy of the WRMA in Armenia incorporates such measures as establishment of strict water extraction quotes for fish-farms located in Ararat Valley. This may become a critical incentive for application of recirculating technologies, especially by those fish-farms that do not have problems with sales of their products and that are more or less successful in their business.

3.2.2 Disadvantages of Recirculating Systems

Recirculating fish production systems as shown in above diagrams are relatively expensive systems to build (building, tanks, plumbing, biofilters…) and operate (pumping, aerating, heating, lighting). Moreover, they are complex systems and require skilled management to reliably produce fish.

Constant supervision and skilled technical support mean increased labor costs and greater risk of mechanical, electrical or other system failure. This will result in rapid fish mortality. To counter these dangers emergency alarms and backup power and pump systems are needed. The business and biological risk factors are correspondingly high. This greater risk means higher production costs due to the need for backup systems and crop insurance.

Another problem is that the quality of fish is somehow compromised for better efficiency of production. In an environment of strong competition this minor change in the quality of the produced fish may often become critical.

3.2.3 Coproducts, Cost Reduction Opportunities

Blackworms

As mentioned above, recirculating systems require permanent filtration of water and separation of solid organic particles (fish effluents). This increases the cost of production, but at the same time creates a number of opportunities for producing additional goods (coproducts) from the separated organic wastes.

Two byproducts or coproducts could be produced from the effluents presently discharged untreated into receiving waters in the Ararat Valley. In California and North Carolina effluents from raceway trout farms are used to grow blackworms, (*Lumbriuculus variegatus*). There is a small but profitable market among tropical fish hobbyists in Europa and America to buy blackworms as feed for their ornamental fish (aquarium fish). Blackworms are aquatic oligochaete worms living in ponds receiving effluent waters from fish farms. They are collected and sold as food for aquarium fish. Trout farmers in North Carolina and California collect blackworms from ponds receiving effluent from trout raceways. This activity provides a supplemental income for fish farmers and helps recycle fish wastes which would otherwise pollute local streams.

Lumbriuculus variegatus

The potential for marketing blackworms in Armenia local market has yet to be explored. Certainly, as aquarium fish feed, blackworms will sell at much higher price and offer much higher benefits for the producers than if used as industrial fish-feed in neighboring farms.

Duckweed

Another valuable product that could be grown on trout effluents is duckweed. The nitrogen, phosphorus and other plant nutrients present in trout effluents can be used to grow duckweed and carp in integrated systems. Many flow-through fish-farms in Ararat Valley currently use this practice in a very simple but quite effective way: after passing through all the trout ponds the effluent-rich water flows into an earthen pond where carp is grown.


Lemna gibba

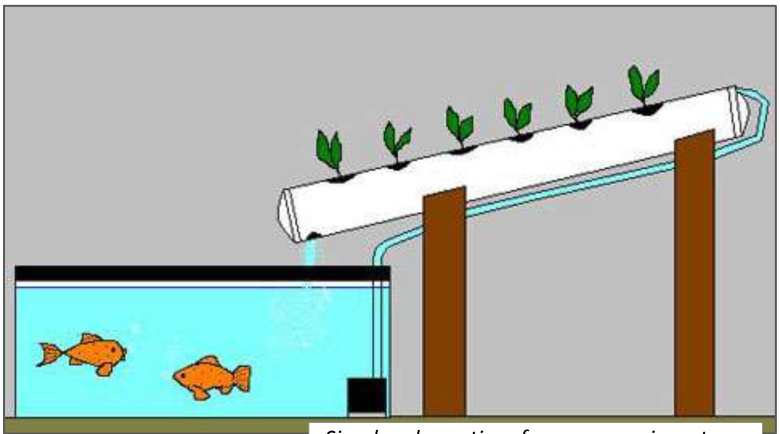
This effluent grown duckweed can be used as a high protein feed ingredient in diets for pigs, dairy cattle and poultry. Availability of duckweed in Armenia will reduce the need to import expensive imported protein feed ingredients like soya bean and fish meal. Valuable aquatic plants like water lilies and the endangered Armenia lotus could also be grown on trout effluents. However, like in the case with blackworms, the potential for marketing of duckweed and other aquatic plants in the local market has yet to be carefully assessed.

Aquaponics, phytofilter technologies

According to the definition of Wikipedia, ***"Aquaponics refers to any system that combines conventional aquaculture with hydroponics (cultivating plants in water) in a symbiotic environment"***.

In normal aquaculture, excretions from the animals being raised can accumulate in the water, increasing toxicity. In an aquaponic system, water from an aquaculture system is fed to a hydroponic system where the by-products are broken down by nitrification bacteria into nitrates and nitrites, which are utilized by the plants as nutrients, and the water is then recirculated back to the aquaculture system.

In other words, in addition to **mechanical filters** (that clean the water from solid waste particles) and **biofilters** (that break down ammonia into nitrates) present in a standard recirculating system (as shown in the above schematics) the water also passes through a phytofilter that consumes nitrates and phosphates.


Simple schematics of an aquaponic system

The picture on the right in simple schematics shows the organization of a classic aquaponic system: the water from the fish tank is fed to a hydroponic tray and flows back into the tank.

In reality, of course, the aquaponic systems are more sophisticated and their specific structure depends a lot on the type of farmed fish and on climate conditions in the given location. In warm regions where the temperature does not fall below the freezing point aquaponic production could be much cheaper. In Armenia, with its sharp continental climate, aquaponic farms should be organized in seasonal greenhouses to protect the plants from extreme frosts in winter.

In case of Ararat Valley, however, the greenhouse heating costs can be significantly reduced if heat pumps are used to capture the thermal potential of artesian water (see section *4.3.3 Using geothermal potential of artesian water* below in this report).

Water Hyacinth is one of the most frequently used plants in aquaponics phytofilters; it grows fast, produces protein-rich crops and consumes most nitrates and phosphates dissolved in water.

Eichhornia crassipes or Water Hyacinth

In practice, however, farmers use those plants in aquaponics that are easier to market or that can be used directly by the farm to reduce costs or increase yields , and since **aquaponics** is a combination of **aquaculture** and **hydroponics**, in an aquaponic farm one may grow almost everything grown with hydroponic technologies.

To help farmers in different regions with the choice of aquaponic plants United Nations Food and Agriculture Organization (FAO) prepared guidelines providing technical advice on 12 the most popular vegetables to grow in aquaponic systems: http://www.fao.org/3/a-i4021e/i4021e12.pdf.

One of the leading aquaponic farms in the US Nelson and Pade, Inc. recommends the following plants for heavily stocked, well established aquaponic systems[6]:

- tomatoes
- peppers
- cucumbers
- beans
- peas
- squash
- broccoli
- cauliflower
- cabbage

At least 6 plants from this list are among the most popular crops grown in Ararat Valley. Thus, introduction of aquaponics in the fish-farms of Ararat Valley will not imply any significant change in the variety of agricultural goods grown traditionally in the region.

[6] See at: http://aquaponics.com/recommended-plants-and-fish-in-aquaponics/

4 Main Findings of the Study

4.1 Aquaculture Technologies Used

4.1.1 Structure and organization of ponds

Fish farming in Ararat Valley is mostly done in rectangular artificial ponds filled with fresh water from artesian wells. As mentioned above, the total surface of all the operational ponds is around 3530 ha *(ERGIS Report, 2015)*. No standards as to the dimensions or construction materials used were applied or observed during the construction of the ponds. Neither are there any uniform practices with regard to water flow, aeration and feeding. From what the ASPIRED Team observed during its field visits, it could be assumed that the efficiency of water-use had been one of the last considerations at the time of construction of the fisheries.

According to the data of regional authorities of Ararat and Armavir marzes, rainbow trout (410 metric tons/year) and sturgeon (95 metric tons/year) are the main types of fish produced in the fisheries of Ararat Valley[7]. Roughly 56 % of all the fish is produced in earth bottom ponds, and 44 % - in ponds lined-up with stone and/or concrete (concrete ponds).

Almost everywhere the ponds are constructed in cascades, one after the other, as shown in Figure 1 below. Larger fisheries have two and more parallel cascades fed from a number of wells.

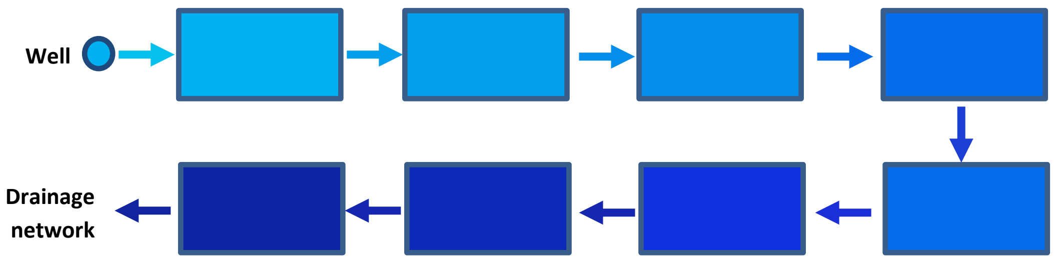


Figure 1: Fish-ponds organized in a cascade

According to the assessment of the aquaculture specialist of ICARE (USAID PEER Grant Project) Team, ponds are mostly oversized, leading to extra O&M costs and losses related to inefficient use of feed and steeling of young fish by birds and wild animals.

4.1.2 Aeration and recirculation

After the decline of the self-emission potential of artesian wells in Ararat Valley, and following the decision of the WRMA to reduce the intake limits set by water use permits, many fisheries started using aeration tools (mostly paddle wheel aerators) to improve water use efficiency.

Most fisheries apply aeration only in the last ponds in cascades, assuming that the level of oxygen in the first ponds should be sufficient. This, however, is not correct, since the measurements done by different organizations and individual fisheries (such as "Amy Fish") show that the level of dissolved oxygen in artesian water at the outlet of the well is low in comparison to the actual oxygen demand of the fishes, and this deficit of oxygen influences the stocking density and decreases the productivity. This means that some initial aeration is required immediately after extraction of water from the well.

Although the use of aerators somehow improved the efficiency of fisheries, it is still very low compared to European and international norms. According to the research done by the American University of Armenia (AUA), the productivity of most ponds in Ararat Valley does not exceed 25 kg

[7] These figures may be incorrect, since fisheries often tend to hide the real volumes of their production to avoid taxes.

of fish per cubic meter of water, while the international norms are for 75-100 kg of fish per cubic meter of water[8].

Only a few fisheries ventured to apply recirculation technologies (or something similar to that) along with aeration to further improve the water-use efficiency. This can be explained by high capital investment and energy consumption requirements related to construction and operation of recirculation systems. The capital investment required for an “average” recirculation system is around USD 150,000, which is beyond the affordability limit for most small-size fisheries. Energy consumption by pumps along with the cost of capital and the O&M costs of the system are likely to increase the cost of 1 cubic meter of recirculated water to AMD 20, while the resource fee for 1 cubic meter of clean artesian water is only AMD 0.5.

Figure 2: Typical concrete pond with a paddle wheel aerator *(Masis Region, v. Sipanik)*

“Inter Aqua” was one of the first fisheries to install a partial recirculation system on two of its ponds. The decision was taken back in 2013 when the prices and demand on rainbow trout and sturgeon were significantly higher and most fisheries were considering the possibility of expanding the production. However, in the light of water extraction limits imposed by the WRMA, that could be done only by making a better use of the available amount of water.

The existing recirculation systems (including simple pumping schemes, like in “Khachatur Karapetyan PE” fishery) do not include any treatment of water from ammonia and organic waste. This shows some lack of professionalism and knowledge by fishery managers, since without proper mechanical and biological (or chemical) filtration the efficiency of recirculation systems is compromised, and such systems cannot ensure the highest level of water saving[9].

4.1.3 Feeding and water temperature

Fish feed is the most expensive item in the cost structure of fisheries in Ararat Valley. It accounts for over half of the expenses entailed in fish production. The retail price of fish feed in Armenian marked is around AMD 1,000 per kilogram. Feed is mainly imported from EU states, the USA and Chile[10]. Although some local entrepreneurs started fish feed production in Yeghvard and Zovuni, the local feed did not become popular among fish-farmers in Armenia, since its quality was significantly lower compared to the imported feed and did not secure proper growth of the fish.

In all the fisheries visited by the Team feeding was done manually by the fishery staff. Compared to automatic feeding systems, like the **demand feeders**, manual feeding is more expensive and less efficient in terms of feed consumption (Hinshaw, 1999).

Another factor that can contribute significantly to the efficiency of both feed-use and water-use is the appropriate temperature of water. The temperature of artesian water in Ararat Valley is relatively stable throughout the year and holds around 13°C (± 1°C). However, for some fish species (like sturgeon) higher water temperature (20-26°C) is required for better metabolism and ideal

[8] This indicator refers more to the efficiency of using the pond space than the water resource; however, it is linked directly to the cost/benefit ratio and overall efficiency of the farm. See: “Towards Sustainable Aquaculture in Armenia” by G. Khanamirian and K. Aghababyan, Sep. 2015

[9] It is assumed that a full-fledged recirculation system with proper filtration and aeration can save 70-95% of water (Timmons et al. 2001)

[10] “Aquaculture Sector Review, Armenia”, IFC in partnership with BMF, 2015

growth (especially for young fish)[11]. At the same time, for spawning and production of trout egg, lower temperature range (7-13°C) is preferred.

To ensure better temperature conditions for the fish, the fish farms of Ararat Valley are populating the rainbow trout in the first ponds of the cascades (see figure 1), while the sturgeon goes to the last ponds. The problem with this solution is that it works only in warmer seasons of the year, when the air temperature is high enough to warm-up the water while it flows through the cascade.

4.2 Opportunities and Incentives for Improving Water Efficiency

4.2.1 Recirculation systems

As mentioned above, if implemented properly, recirculation systems can ensure as high water saving as 70-95%. This means that even in the 70% scenario there is a theoretical potential for reducing the annual aggregate extraction of water by fisheries in Ararat Valley from 1,493 million m^3 to 447.9 million m^3 without affecting the volumes of production. A restrained assessment, however, shows that the reality is less optimistic than the theoretical calculations. There are two main reasons for this:

1. Design and construction of full-fledged recirculation systems requires significant investments. Considering the current financial status of the sector and the problems with fish exports and devaluation of Russian Ruble, the chances for widespread application of this technology among the fisheries in Ararat Valley are quite slim.
2. O&M costs associated with the use of recirculation systems are higher than that of conventional open flow systems. As long as the resource fee for 1 cubic meter of artesian water in Ararat Valley is below AMD 20, the fisheries will get no direct benefit from saving of water after application of recirculation technologies.

Nevertheless, there is a possibility that with improvement of the economic situation in Russia and with stabilization of the Russian currency profitability of fish farming industry again reaches a point where introduction of full-fledged recirculation systems is feasible. Another possibility is related to search for new markets and increasing the production standards to the requirements of such markets. Otherwise, there will be little incentive on behalf of businesses to invest in recirculation systems.

4.2.2 Secondary use of water for irrigation

As mentioned above, many farmers in Armavir and Ararat marzes do not use their agricultural land because of the absence of irrigation water. The lack of irrigation water causes erosion of agricultural lands and emigration of rural population, while the amount of water dumped into the drainage network by fisheries located in the same area could be quite enough to ensure regular and reliable irrigation for the communities during the irrigation season. This option has been positively assessed and recommended by the ERGIS Center in its final report to UNDP GEF (2015). Officials from the Ministry of Agriculture, the WRMA and the Water Users' Association of Masis Region contacted by the Assessment Team during the study also expressed positive opinions on this option.

In addition to this, the study showed some genuine interest among land-owners in Hayanist, Nizami, Darbnik, Sayat Nova and Lusagiugh communities for using this opportunity. Fishery owners, too, showed interest in providing their outlet water for irrigation and expressed willingness to cooperate with land-owners and municipalities in setting-up new irrigation systems.

[11] "Production of Sturgeon", Steven D. Mims, Andrew Lazur, William L. Shelton, Boris Gomelsky and Frank Chapman, 2002, Southern Region Aquaculture Center, *http://www2.ca.uky.edu/wkrec/SturgeonProduction.pdf*, *page 2*

If properly replicated in other communities of the region, this measure is likely to reduce the extraction of water from underground sources up to 0.3 billion cubic meters per year.

Furthermore, the measure will result in effective melioration of agricultural lands, decreasing the need for mineral fertilizers (since the outlet water contains phosphorus and nitrogen substances) and thus reducing the cost of crops and increasing the competitiveness of local agricultural products.

In many areas this measure will help to prevent further degradation of soil.

According to initial calculations, the required investment for building an irrigation system to be fed from a fishery outlet is around 2,500 USD per ha of land. At the same time, the expected gross income from crops is around USD 3,160[12]. If we deduct from the gross income the required agricultural inputs and the cost of irrigation and labor, the net income will be around USD 1,260. Thus, a full return on investment will be achieved in 2-3 years. This is a good rate of return that will ensure high sustainability and replicability of the project.

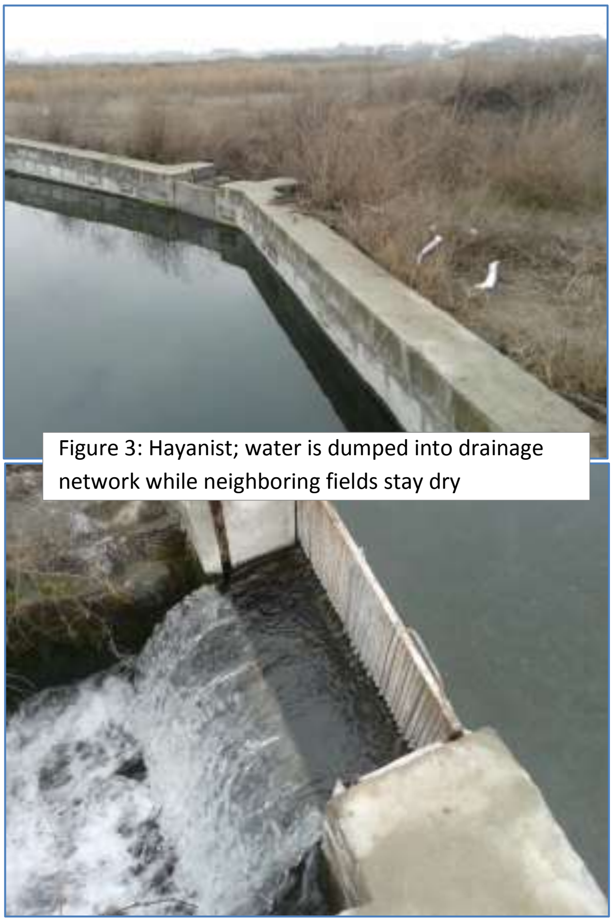


Figure 3: Hayanist; water is dumped into drainage network while neighboring fields stay dry

4.2.3 Re-profiling of fish farms

Considering the current financial status of the sector and the unoptimistic statistics of the last year when many fisheries went bankrupt and closed their businesses, the idea of re-profiling could attract a lot of interest.

The study showed that with a reliable and practical model and some economic incentives in place many businesses involved in fish-farming will be encouraged to shift to other forms of agricultural activity that are less water intensive. This could become a real opportunity for reducing the water consumption from artesian aquifer of Ararat Valley. A successful pilot project implemented in a fishery that recently closed its business or is about to do that could be a good start for the process.

A promising alternative to fish could be for example the Australian Red Claw Crayfish. This is a product that is highly demanded not only in Armenia and Russia, but also in all neighboring countries and EU states. There are a number of advantages for transition to this product:

- The existing infrastructures could be adapted for the new product with relatively moderate capital costs;
- The unit price of the product is higher both in local and foreign markets;
- Production of crayfish is 10-15 times less water intensive;
- Feed for crayfish is cheaper (it can be imported and produced locally).

The main difficulty is maintaining the required temperature of water; the ideal temperature for optimal growth of the crayfish ranges between 22-28°C. However, with the use of renewables and/or heat pumps the required temperature could be maintained at relatively low cost.

[12] This calculation is done for low-value crops (mainly grains and forage); in case of farming of higher value crops, the figure will be significantly higher.

4.2.4 Sealing of abandoned wells

During the field trips the Assessment Team observed many abandoned wells with different self-emitting potentials. These mainly included:

- Old irrigation wells (80-100mm) that are no longer good for irrigation (since the yield dropped significantly) but that are still emitting water;
- Wells of the closed and/or liquidated fish-farms (150-300mm) that are no longer good for flow-through type fish-farming, but that still have quite significant self-emitting potential.

Figure 4: Abandoned irrigation well in Hayanist village, Masis region

According to different assessments there might be up to 560 such wells in the region. The total yield of these wells is unknown; some experts speak about 1-2 m^3/sec, others about 3-4 m^3/sec.

Just the sealing of one or two such wells will have almost no impact on the situation. However, a systemic approach with clear economic incentives for involvement of private sector resources may produce some tangible results. For example, the WRMA can increase the water extraction limits set in water use permits for those fish-farms that invest in sealing of identified abandoned wells; the increase can be proportional to the aggregate yield of the sealed wells.

ASPIRED is planning to carry out the inventory of all the artesian wells in Ararat Valley. This inventory will cover also the abandoned wells. A complete list of all the abandoned wells, with the measured yield and GPS coordinates of each well, will provide a useful tool to the WRMA for planning, budgeting and implementing respective mitigation measures. The abandoned well for sealing will be identified by ASPIRED and WRMA based on the data received upon completion of above mentioned inventory. The procedure of the well sealing will be presented to local companies as well as to WRMA.

4.2.5 Other opportunities

In general, there are many opportunities for improving the production efficiency in the fisheries of Ararat Valley. Except for a few large fisheries, where at the time of construction the owners had enough resources to invest in proper design and professional consulting services, as well as in proper training of the staff, in most cases the fisheries are poorly designed, poorly constructed and poorly operated. And very often the defects of design and construction are compensated by abundant use of cheap water resources.

Potential improvement opportunities include, but are not limited to:

- Application of more efficient aeration methods;
- Redesign of water-supply and drainage systems to provide for better distribution of oxygen in ponds and better removal of organic waste;
- Use of demand feeders to increase the efficiency of feeding;
- Use of heat pumps and other renewables (such as biogas) to maintain proper water temperature in ponds;
- Production of co-products from fish effluents: These coproducts include blackworms (Lumbriculus vaiegatus) and duckweed (Lemna species);
- Use of aquaponics and bio-filters to clean the outlet water from ammonia and reuse it.

Some of the improvement opportunities are easier and cheaper to implement, others are more costly, but what makes them similar is the general mistrust on behalf of the businesses towards any improvement and/or innovation proposed by an international or governmental organization. After dramatic reduction of the sector revenues, the businesses have become even more cautious of any initiative that involves additional costs.

The main question that worries the businesses with regard to any improvement opportunity or innovation is whether the respective technology or approach has been ever tested or applied in Armenia.

The general conclusion of the Assessment Team after all the site visits and interviews, was that in most instances demonstration of a working model (even a small-scale one) would be more effective than presentation of theoretical calculations and handouts. For this reason, establishment of an experimental aquaculture center where different technologies and methods could be tested, validated and demonstrated at smaller scale may be a good start for improvement of water efficiency in the sector.

4.3 Opportunities and Incentives for Improving Energy Efficiency

4.3.1 Micro Hydro Turbines

At the beginning of the study different experts made assumptions about the possibility of using the hydro-potential of self-emitting wells. However, during the study it appeared that:

1. The self-emitting potential of wells declined significantly during the recent years; even at the largest wells the calculated energy yield potential will be less than 1.5 kW. This is almost nothing compared to the energy consumption by aerators and other equipment of a fish farm (on average 40-80kW for a medium fish-farm).
2. The owners of fish-farms are not interested in (or better say - strongly object to) the idea of installing turbines at the outlets of the wells, since they have concerns that this would reduce or stop the water flow and harm their main business.

The Team also explored the possibility of installing a micro turbine at the outlet of the ponds. However, even in the best location (Lusagiugh village, were the water from the ponds is discharged into river Sevjur) the maximum head difference is 3m (between the outlet and the level of the river), and considering the amount of discharged water, the energy yield of the turbine would be only around 2kW.

4.3.2 Photovoltaic panels

The idea of using the solar energy seamed very attractive to almost all the fish farmers contacted during the field visits. (According to National Hydro Meteorological Service, Ararat Valley is one of the sunniest regions of Armenia.)

Most farmers, however, did not link the use of photovoltaic panels to introduction of a recirculation system or intensive aeration. Instead, they considered production of solar energy as a second business and opportunity to make additional income.

Nevertheless, installation of solar panels may be considered by ASPIRED as part of a broader pilot project aimed at improvement of water efficiency.

4.3.3 Using geothermal potential of artesian water

The temperature of artesian water in most areas in Ararat Valley is around 13 °C. This is quite enough for effective operation of thermal pumps that can be used for heating of greenhouses or pond with sturgeon or crayfish (see the “Feeding and water temperature” section above). According to the estimates of our specialists, a geothermal heating system that uses 13 °C water from fishery outlets would be almost 2 times cheaper to operate than the conventional natural gas heating systems!

The cost of such projects would not be high, but the outcome could be quite substantial. Besides, since the payback period of such projects is less than 7 years, the replicability may be quite high.

However, this is one of those innovative ideas for which a working model is needed to demonstrate before recommending a project idea.

4.3.4 Biogas

The idea of using biogas reactors interested mainly those farmers who already started the process of transition from fish-farming to other forms of agricultural activity. This is mainly explained by the fact that fish production does not generate wastes that could be used as feedstock in anaerobic digesters.

However, this opportunity may be considered by ASPIRED for initiating a pilot project, if it leads to effective re-profiling of a fish-farm and subsequent saving of water.

5 Identification of Pilot Project Opportunities

5.1 Objectives

As already mentioned above, the results of this study will be used by the ASPIRED Project and its partners for designing and implementing pilot projects to demonstrate how different technologies and methods can be used to improve the water efficiency in Ararat Valley.

Considering the scope of the problem, and the fact that the main actors in the fish-farming industry are private businesses, it is obvious that if focused only on the direct impact (i.e. water or energy saving) ASPIRED with its limited budget and just a couple of pilot projects will not be able to change the situation dramatically. Therefore, a greater emphasis will be placed on the indirect impact, namely the replicability of pilot projects. Another important consideration will be the sustainability of the project. Project evaluation criteria, presented below in this section, have been carefully designed to address these concerns.

ASPIRED will, to the extent possible, avoid implementing such pilot projects that:

1. Do not have the potential of having a positive impact on all or at least part of the sector, rather than on one specific entity;
2. Have little perspectives as to the sustainability of project results;
3. Provide unfair and unjustified competitive advantages to one or a few private entities.

5.2 Process

The process will start from identification of potential pilot projects. This will be done in close cooperation with the main partner organizations- USAID Global Lab and the USAID /PEER Grant Project (implemented by ICARE). An emphasis will be given to the possibility of funding certain elements and/or components of a project from any of the Global Lab's grant funding initiatives.

In addition to this, ASPIRED will cooperate with other international organizations, NGOs and public agencies in an attempt to identify better opportunities for pilots.

The initial phase of identification of project opportunities started already while conducting this study; during field visits, interviews with stakeholder organizations and individual farmers. A special emphasis was given to synergy with past, present and pending projects of other international organizations.

Considering the limitations of the Project budget, it is possible that not all the identified projects are selected for implementation. For this purpose a set of objective criteria have been developed and recommended in the following section.

5.3 Project Selection Criteria

5.3.1 Overview

Below, in this section, the proposed selection criteria are organized into three main groups: Economic Criteria, Environmental Criteria and Social Criteria. It is important to mention, however, that this separation is somewhat conditional and all the criteria are strongly interrelated.

All the selection criteria were carefully developed to be measurable, so that the selection process is, to the extent possible, protected from subjective judgment

5.3.2 Economic Criteria

1. Payback period

This is one of the most important criteria for determining the viability and **replicability** of the project. To some extent it intersects with a number of the criteria listed below, particularly with “Annual energy saving” and “Annual water saving” criteria. However, it reflects also the operation and maintenance costs which are essential for determining the sustainability of the project.

2. Recipient (community) contribution

Expressed in numerical value (in USD), this criterion will also demonstrate the willingness and the interest of the project recipient to implement the project. In certain cases it may be required to convert labor or in-kind input into monetary value.

3. Synergy with other projects

Like the previous one, this criterion will also be expressed in numerical value, and it will show the amount of other donors’ relevant contribution in the given community. The main idea of this criterion is to demonstrate how the project complements or adds value to the existing or pending efforts of partner organizations.

5.3.3 Environmental Criteria

4. Annual energy saving

This criterion shows the total amount of energy in KWh or MWh saved annually further to project implementation.

5. Annual water saving

This criterion shows how much water in 1,000 m^3 is saved annually further to project implementation.

6. Annual amount of clean energy produced (renewables)

Apart from energy saving, another high priority is the use of renewable sources of energy. Although the use of renewables (like solar collectors) ultimately results in saving of energy from conventional sources, it was decided to have a special criterion on renewable energy to address that priority.

7. Annual amount of clean water produced (pollution reduction)

Protection of water resources from pollution is another priority. In addition to saving of clean water (and especially the strategic groundwater resources) it is very important to protect the water resources from pollution by domestic, agricultural and industrial wastewater.

This criterion shows how much wastewater has been treated (in 1,000 m^3/year) or how much clean water has been spared from pollution further to project implementation.

5.3.4 Social Criteria

8. Number of beneficiaries

This criterion shows the number of entities or households that will benefit from the project. It applies mainly to irrigation projects, and shows how many households are able to generate additional incomes due to the improvements achieved by the project.

5.4 Recommendations

Based on the findings of this study and the initial assessment presented above in this Report, the Assessment Team recommends the following three main types of projects for piloting:

I. Secondary use of water for irrigation,

Project opportunities were identifies in Hayanist, Darbnik, Nizami, Sayat Nova and Lusagiugh communities. At the time of this assessment the project in Hayanist was the most feasible for piloting according to the criteria listed above in section 5.3.

Rationale

The lack of irrigation water causes erosion of agricultural lands and emigration of rural population, while the amount of water dumped into the drainage network by fisheries located in the same area could be quite enough to ensure regular and reliable irrigation for the communities during the irrigation season. This option has been positively assessed and recommended by the ERGIS Center in its final report to UNDP GEF (2015). Officials from the Ministry of Agriculture, the WRMA and the Water Users' Association of Masis Region contacted by the Team during the study also expressed positive opinion on this.

In addition to this, the study showed some genuine interest among land-owners for using this opportunity. Fish-farm owners, too, showed interest in providing their outlet water for irrigation and expressed willingness to cooperate with land-owners and municipalities in setting-up new irrigation systems.

If properly replicated in other communities of the region, this measure is likely to reduce the extraction of water from underground sources up to 0.3 billion cubic meters per year.

In addition to this, the measure will result in effective melioration of agricultural lands, decreasing the need in mineral fertilizers (since the outlet water contains phosphorus and nitrogen substances) and thus reducing the cost price of crops and increasing the competitiveness of local agricultural products.

In many areas this measure will help to prevent further degradation of soil.

II. Development of a practical re-profiling model, and

Project opportunities were identified in Metsamor, Griboyedov and Lusagiugh communities. At the time of this assessment the project in "Armavir Farmer" fishery of Metsamor was the most feasible for piloting according to the criteria listed above in section 5.3.

Rationale

Considering the current financial status of the sector and the unoptimistic statistics of the last year when many fisheries went bankrupt and closed their businesses, the idea of re-profiling could attract a lot of interest.

The study showed that with a reliable and practical model and some economic incentives in place many businesses involved in fish-farming will be encouraged to shift to other forms of agricultural activity that are less water intensive. This could become a real opportunity for reducing the water consumption from artesian aquifer of Ararat Valley. A successful pilot project implemented in a fishery that recently closed its business or is about to do that could be a good start for the process.

III. Creation of an experimental aquaculture center for testing and demonstration of water and energy efficient technologies and methods.

"Ami Fish" and "Khaits Ishkhan" fisheries expressed initial interest in establishing experimental aquaculture centers in their premises. At the time of this assessment the project with "Khaits Ishkhan" was the most feasible for piloting according to the criteria listed above in section 5.3.

Rationale

There are many opportunities for improving the production efficiency in the fisheries of Ararat Valley. Except for a few large fisheries, where at the time of construction the owners had enough resources to invest in proper design and professional consulting services, as well as in proper training of the staff, in most cases the fisheries are poorly designed, poorly constructed and poorly operated. And very often the defects of design and construction are compensated by abundant use of cheap water resources.
Potential improvement opportunities include, but are not limited to:

- Application of more efficient aeration methods;
- Redesign of water-supply and drainage systems to provide for better distribution of oxygen in ponds and better removal of organic waste;
- Use of demand feeders to increase the efficiency of feeding;
- Use of heat pumps and other renewables (such as biogas) to maintain proper water temperature in ponds;
- Production of co-products from fish effluents: These coproducts include blackworms (Lumbriculus vaiegatus) and duckweed (Lemna species);
- Use of aquaponics and bio-filters to clean the outlet water from ammonia and reuse it.

Some of the improvement opportunities are easier and cheaper to implement, others are more costly, but what makes them similar is the general mistrust on behalf of the businesses towards any improvement and/or innovation proposed by an international or governmental organization. After dramatic reduction of the sector revenues, the businesses have become even more cautious of any initiative that involves additional costs.
The main question that worries the businesses with regard to any improvement opportunity or innovation is whether the respective technology or approach has been ever tested or applied in Armenia.
The general conclusion of the Assessment Team after all the site visits and interviews was that in most instances demonstration of a working model (even a small-scale one) would be more effective than presentation of theoretical calculations and handouts. For this reason, establishment of an experimental aquaculture center where different technologies and methods could be tested, validated and demonstrated at smaller scale may be a good start for improvement of water efficiency in the sector.

5.5 List of References and Citations

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