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THE CONCEPT OF AQUAPONIC AGRICULTURE

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Abstract: The trends, challenges and global guidelines facing agriculture and the agri–food system are multiple, a process of reflection by decision–makers, researches and businessmen being timely and necessary. The expansion of the agricultural and agri–food sector may be significantly limited by the already existing pressure on agricultural land and water resources. Innovative production models are needed to increase productivity while maintaining biodiversity and the quality of natural resources. Aquaponics can be considered a sustainable agricultural production system because it combines plant and animal production, integrates the flow of nutrients through natural biological cycles of nitrification, is carried out without exhausting available resources and without destroying the environment, so without compromising the possibilities of satisfaction of the needs of future generations.
Keywords: aquaculture, sustainability, common fisheries policies, environmental policies

INTRODUCTION

In the context of population growth around the globe and the negative consequences in following climate change, the need for food is increasing. At the same time, habitable surfaces are expanding more and more, especially in the urban environment, so that the land on which it is cultivated is shrinking. Under these conditions, the specialists in the field agricultural is looking for the best solutions to increase production and make resources more efficient.

Farmers around the world make decisions every year about the various tools and technologies they will use to produce the best possible crops. But changing the production system, or even adapting the techniques is a challenge for farmers. And investments are not the real bottleneck. In reality, we lack the agronomic and economic skills to ensure that the transformation of "conventional" farming in the new system will not compromise profitability economy of the farm.

We have to admit that, – and not only in Romania, – many farmers continue to practice conventional agriculture "out of convenience". For to solve problems that can reduce productivity and therefore income agricultural, it is enough to use chemical substances (sometimes of natural origin and ecological and sometimes of artificial origin) and more efficient equipment. But, of many times, we only treat the symptoms this way.

Rapid climate change is one of the most important aspects of the environment we face today, but which will be in our attention constantly and in the near future. These climate changes affect all life from around the globe, but we should be most concerned about the ways in which we will be able to let's continue to farm and produce food in the future.

Crops on today's farmland are probably going to be harder to grow managed tomorrow; the temperature, the precipitation and the transitions of the seasons are increasing unpredictable and difficult crop success. Socially responsible agriculture refers to sustainable production methods and new types of applied technologies and may even be the key to the creation of ecosystems urban nature.

At the same time, socially responsible agriculture can also refer to the product itself, to the simplicity of its production, but also to the multitude of benefits for people and for the environment. In this case, we can discuss one of the foods the future, about which, from the perspective of minimum needs, it can be said that it is produced only socially responsible.

Knowing the key global trends that can influence agriculture, the agri–food system, the management of natural resources and the rural economy, in general, in the next decade, is extremely necessary, given the importance that food has within every society. Awareness of the impact that these aspects can have contributes to drawing up an agenda that strengthens the resilience and sustainability of agricultural systems (*Gutierrez–Wing, M. and Malone R., 2006)*.

Although the efficiency of agriculture has increased in recent decades, the pressure on agricultural land has intensified, mainly due to demographic factors, changes in consumption patterns, and the urbanization process. If we also add the competition between food and non–food use of agricultural crops (fuel production), land ranges through erosion, desertification, salinization, sea level rise, etc. them.

A vicious circle is created by overexploitation of existing resources, their degradation, increasing pressure on the remaining resources and their further degradation (*FAO, 2017a, Adler P.R. et al, 1996*).

The agricultural area used per person is continuously decreasing from 1.30 to 0.7 ha, in the period 1967–2013 *(FAOSTAT, 2013, Bao, T. et. al, 2023*). There are regional differences in this phenomenon: production growth in Asia in recent decades has been achieved almost exclusively through increased productivity, without an increase in cultivated area, while in Africa, average cereal yields have remained constant, but more land became arable (*OECD, 2016, Basumatary Bwsrang et. al., 2023*).

The expansion of agricultural land takes place at the expense of forests, savanna and natural grasslands, a phenomenon accompanied by the increase in greenhouse gas emissions and the acceleration of the loss of biodiversity. Agriculture is also, and is projected to remain, the largest consumer of global freshwater resources.

Strong competition from the processing industry, power generation and domestic consumers will drive a 55% increase in global fresh water demand by 2050 (*Basumatary Bwsrang et. al., 2023*). Most of this demand is generated in emerging countries, in contrast to the decreasing trend in high–income countries due to the continuous improvement in the efficiency of its use in agriculture and investments in wastewater treatment (*OECD, 2016, Baptista P. 2014*).

Climate change will have a definite adverse impact, especially in countries in the southern regions, and the effects are on both supply and quality and access to food. Changes in the normal values of temperature and precipitation may contribute to the increase of food prices worldwide until 2050 (*Baptista P., 2014*), and this could reduce access to food for vulnerable categories of people (*FAO, 2017a, Bettina König et. al, 2018*). Opinions are nuanced about the impact on agricultural production in the Nordic countries, involving both positive and negative effects (*Brandon Yep et al, 2019*).

The impact for agriculture and the agri–food system is to reduce food loss and waste at all levels of the food chain. This is indeed a systemic change in the current methods of production and consumption, the relationship between producer and consumer and that of "consumers with products and materials" (*Patrick Kangas, 2004*).

Huge economic opportunities would be created, but a political decision, stimulating instruments are needed to promote the circular economy, the transition to this paradigm involving significant costs for the realization of the necessary infrastructure. On the other hand, the fact that this type of economic model operates rather at the regional, national level and does not depend on import markets to meet demand, makes it a serious alternative if reducing the trade deficit becomes a political objective (*OECD, 2016, Bettina König et. al, 2018*).

Aquaponics, or "aquaponics" in English, is the word made up of the first four letters of the word "aquaculture" (growing aquatic plants and animals for the purpose of their commercialization) and the last five letters of the word "hydroponics" (growing vegetables or flowers in nutrient solutions or on a substrate of gravel or sand through which water with chemical fertilizers circulates permanently) in order to name in one word the innovative technology that unites the two culture technologies in one, (*Bittsánszky, András et al, 2016*). Like many other scientific creations of the modern era, aquaponics has its origins in human practices from very distant times.

The Aztecs built floating islands, chinampas (30 x 2.5 m) on the lakes in the Xochimilco and Chalco areas, separated from each other by canals on which they travelled with canoes. On these islands they planted corn, beans, pumpkin, amaranth, tomatoes, chili peppers, flowers, etc. In China, Thailand, Indonesia, people have been growing fish in rice paddies since ancient times, but without knowing that they practice aquaponics. Scientific interest in combining

aquaculture and hydroponics began in the mid–1970s. Sneed, Allen, and Ellis, (1975) are among the first to experiment with soilless plant culture systems as a means of treating fishpond water and removing of nitrogen compounds in recirculating aquaculture systems (RAS).
Reducing the concentration of nitrogen compounds, toxic to fish, becomes a major challenge for recirculating aquaculture and the beginning of the aquaponic era, (*Bohl M., 1977, Collins M, Gratzek J, Shotts Jr E, Dawe D, Campbell L, et al., 1975*).

MATERIAL AND METHOD

The foundations of contemporary aquaponics were laid by researchers at The New Alchemy Institute in the US between the 1970s and 1980s. They first used hydroponic plant culture as a way to improve water conditions for fish, not as an innovative technology for food production. The water quality in fish ponds deteriorates rapidly and requires regular replacement. Starting from the finding that aquatic plants clean water in natural sites, they first added aquatic plants and later terrestrial plants to clean water in fishponds. Dr. John Todd and Nancy Jack Todd conducted research at The New Alchemy Institute that led to a natural wastewater treatment system called the "living machine."
Research by Ronald Zweig (1986) further promoted the idea of integrating plants into an aquaculture system. At the Agricultural Experiment Station of the University of the Virgin Islands (UVI), St. Croix, the first experiments were carried out by Barnaby Watten and Robert Busch, 1984. The most notable results, however, were obtained under the leadership of Dr. James Rakocy, who is called the "father of aquaponics".
The era of modern aquaponics began: Tom and Paula Speraneo, owners of S & S Aqua Farm near West Plains, Missouri, USA, created the first aquaponic system in which the hydroponic culture is on gravel support (Steve Diver, 2000; Rebecca Nelson and John Pade started the quarterly "Aquaponics Journal" in 1997, Pekka Nygard and Stefan Goes, based on the Speraneo model, create an aquaponic system in Harnosand, Sweden (*Bettina König et. al, 2018*).
Intensive recirculating aquaculture systems have important environmental problems because they maintain water quality in the system, in part, by discharging an amount of effluent of 5% to 10% of the recirculated water volume per day and replacing it with fresh water (*Timmons M.B., 2002*). Organic matter, inorganic concentration, and P concentrations in wastewater usually require in–system or post–discharge treatment of effluents (*Gutierrez–Wing M. and R.F. Malone, 2006*). This operation incurs investment and operating costs that negatively influence the selling price of the fish.
Nutrient uptake by plants is one of the most common biological processes involved in contaminant removal in artificial wastewater treatment wetlands (*Debusk, W.F., 1999, Mitsch, W.J. and Gosselink J. 2000*). Adler et al 1996, found that differences in nutrient removal rates of NO3–N and P were dependent on plant number and effluent flow. If plant numbers are high enough, the concentration of nutrients may drop to levels that may be too low to support plant growth.
Rakocy et al, 1997, were able to establish a balanced system by maintaining a large plant growth area relative to the fish production area in a commercial capacity aquaponic system. Rakocy showed that when the ratio between the amount of food given to fish and the area of cultivation for plants is kept within correctly established limits, the amount of nitrogen is sufficient for plant growth. Integrating nutrient flows between aquaculture and hydroponic systems turns a waste stream, toxic to fish, into a gain, given the resulting plant production.
In soil crops, nutrients move to the root surface by diffusion, (*Taiz, L. and E. Zeiger, 2016*). As the plant takes up nutrients from the soil, concentration gradients are formed in the vicinity of the root, and the concentration of nutrients at its surface is reduced compared to the surrounding area. This can lead to a zone of nutrient depletion near the root surface. The ability of continuous root growth, however, extends this region of nutrient uptake beyond the depletion zone. Thus, the optimal uptake of nutrients by plants depends both on the ability of the root system to absorb nutrients and on its ability to extend into the soil.
Unlike soil crops, in the case of hydroponic crops, which use soilless media, when there is a drop in nutrient concentration in the root zone, it is immediately corrected in the next irrigation stage.
Olson established that in hydroponic systems, plants take up nutrients at a constant rate regardless of concentration, as long as the overall ratio and concentration of nutrients in the solution remained nearly the same and the nutrient solution was well mixed and in constant

contact with the roots. (*Olson, C. 1950*). Mass balance nutrient management in closed hydroponic systems shows that once young plants have taken up a sufficient amount of nutrients, concentrations in solution can be reduced because the amount of nutrients required for plant growth is found either in the plant or in solution.

Concentrations of nutrients supplied by fish in the aquaponic system are significantly lower for most nutrients compared to hydroponic systems. However, plants grow very well in these solutions that have lower nutrient levels than "standard" hydroponic solutions, because the plant uptake of organic substances is higher than synthetic substances in hydroponic system solutions, (*Bittsánszky A. et al., 2016*). Rakocy et al, 1997, managed to obtain, for two and a half years, in the pilot aquaponic station at UVI, lettuce productions with nitrogen concentrations 3.5 times lower than in the solutions used in traditional hydroponic systems.

RESULTS

In soil production water is lost through evapotranspiration, percolation into the subsoil, runoff and weed growth. In hydroponic and aquaponic growing systems, water is recirculated. The water that is not taken up by the plants is recirculated. There are no weeds. Nutrients are constantly added by fish in aquaponic systems or humans in the form of nutrients in hydroponic systems and the water returns to the plants. Every drop of water is reused which cannot be achieved in traditional soil farming, (*Perry Baptista, 2014*).

In hydroponics and aquaponics, water loss occurs in two main ways: evapotranspiration and runoff. There is no way to eliminate evapotranspiration but in greenhouses or solariums it can be kept within reasonable limits by controlling the indoor temperature. Leaks sometimes form at the connections between pipes and technological objects that make up the aquaponic system, broken or cracked pipes. Careful and frequent monitoring of the system is the best way to identify and stop water losses. Since maintaining water quality in aquaponic systems is done by hydroponic culture, it is no longer necessary to discharge a quantity of water from the system into the environment and replace it with fresh water as in the case of aquaculture. This reduces the consumption of water, which is a strategic resource of mankind, and protects the environment by eliminating the discharge of effluents.

Aquaponics is a sustainable agricultural production system. Most plant nutrients come from the fish feed following the process of digestion/excretion and nitrification in the biofilter, thus integrating the nutrient flow.

Plants act as biofilters and take effluent from the system that would otherwise have been discharged into the environment and replaced with fresh water. Even though there are thousands of aquaponic systems of various capacities operating worldwide, there are only a few researchers who have reported information on productivity systems. Dr. Rakocy, obtained in the pilot aquaponic system from the University of the Virgin Islands (UVI) in St. Croix, U.S. Virgin Islands, occupying a total area of 500 m2, of which the hydroponic cultivation area is 214 m2, basil productions of 23.4 kg/m2 and 25.00 kg/m2. The production of basil planted in the field, in the same period, was 7.8 kg/m2. In the case of okra production, yields of 2.54 – 2.89 kg/m2 were obtained in the aquaponic system, and in the field, on the control lot, 0.15 kg.m2, (*Rakocy, J., et al., 2014*). In Canada, Dr. Nick Savidov, 2014, obtained 3.7 tons of fish and 3.5 tons of basil annually with a 73 m^3 aquaponic system that has 84 m^2 of hydroponics.

The treatment of solid waste from aquaculture, as a result of undigested feed and unmetabolized feed, is today an operational problem well known to aquaculturists. Solids build–up in aquaculture facilities reduces the quality of the rearing environment and can represent a major ecological footprint. In salmonid culture, the waste situation is better in the last decade, as a result of stricter regulations, a better quality of animal feed and the emergence of efficient technologies for the disposal and processing of waste. At a feed conversion ratio of 1.0 (kg feed/kg rear), the solid dry matter to be removed by mechanical filtration from the rearing water is approximately 100 g per kg feed used or fish produced. Current salmon farms are extremely large and produce many millions of fish each year. The biomass produced annually in most of these farms is between 100–1,000 tons. In addition, the production from farms in terrestrial recirculating system (RAS) and from floating cages, represents biomass 5–10 times higher, i.e. up to 10,000 tons per year per exploitation. These systems are suitable for solids removal.

Raising rainbow trout to optimum commercial size in freshwater farms also produces, in some countries, a substantial amount of biomass and sludge. Such farms discharge sludge into freshwater streams, lakes and rivers.

The waste discharge from these farms should be properly treated, before re–entering the watercourses. In fresh waters, the removal of phosphorus is vital in terms of eutrophication, hence the obligation to have well–designed and managed effluent treatment systems to effectively retain and neutralize phosphorus. Especially since most of the phosphorus lost from fish farms is usually incorporated into particles that could be filtered with simple, mechanical filters. Trout farmers in Denmark, for example, are subject to strict regulations by environmental authorities to protect freshwater bodies. The storage of solid or semi–solid waste takes place in artificial lagoons, isolated with impermeable membranes, for the removal of nutrients by plants.

Dewatered waste from trout farms contains high levels of nitrogen and phosphorus, the main nutrients for plant production, but is extremely low in potassium. Sludge from aquaculture farms, if stabilized with added lime, is considered a veritable fertilizer for any arable land.

Analysis of heavy metals such as chromium and lead indicates extremely low levels that are actually harmless to the environment. But in most cases, delivering sludge to agriculture means additional operating costs for fish producers.

CONCLUSIONS

In conclusion, the global trends and challenges facing agriculture and the agri–food system are multiple, a reflection process by decision–makers, researches, and business people being timely and necessary. Agricultural and food production is expected to increase due to population and income growth.

The expansion of the agricultural and agri–food sector may be significantly limited by the already existing pressure on agricultural land and water resources. Innovative production models are needed to increase productivity while maintaining biodiversity and the quality of natural resources.

Sustainable production practices are also required by increasing consumer awareness of sustainable and healthy consumption patterns. Success in setting up strong, resilient agri–food systems depends on smart strategies that will manage to integrate

Food security can be said to exist when people in that area have, at all times, physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. There are four pillars of food security that define, defend and measure the state of food security at local, national and international levels. These are: food availability, food access, food utilization and food stability.

Aquaponics is an opportunity for food security because it produces fish and vegetables simultaneously, can be implemented in any geographical area regardless of soil fertility, and if located in a greenhouse, independent of climate.

Unfortunately, today only a small part, about 1.5% of the total sludge produced in salmon and trout farms in Europe, is removed and processed. What is really serious is the fact that the predominant production of aquaculture products takes place in "cage" systems, floating cages, unsuitable for the collection and handling of waste, coastal areas being "scorched" by the destructive effects of waste from fish feed. This area, of the use of waste from aquaculture systems, remains the grand prize, being a double reward: on the one hand capitalizing on a new salable product line from aquaculture farms, and on the other hand protecting the environment.

An ideal farm or aquaculture system capitalizes on every element of its composition and has a zero nitrogen and carbon footprint. In this field, European and even global research proves to be still at the beginning of the road and the only way in which things can move in the right direction is a much more restrictive legislation on protecting the environment, combined with research programs on intelligent use of aquaculture waste.

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