Integration of Hydroponic Tomato and Indoor Recirculating Aquacultural Production Systems: An Economic Analysis

Special Report No. 6

July 2008
Alabama Agricultural Experiment Station

Auburn University

Printed in cooperation with the Alabama Cooperative Extension System (Alabama A&M University and Auburn University).

TABLE OF CONTENTS

page
Introduction.. 3
Background and Justification.. 3
Technical Analysis.. 5
Physical Plan... 7
Financial Analysis.. 9
    Investment Costs.. 9
    Catfish and Tomato Production... 10
    Tilapia and Tomato Production... 10
    Fish Only Production System... 12
Environmental and Natural Resource Advantages...................................... 13
Summary and Conclusion.. 14
References.. 15

LIST OF FIGURES AND TABLES

Figure 1. Design of the Tomato and Fish Production System 6
Table 1. Physical Plan for Channel Catfish Production in the Aquacultural System.... 8
Table 2. Selected Characteristics of the Integrated Tomato and Aquacultural System, Alabama, 2007 9
Table 3. Annual Operating Costs for Fish Greenhouse in an Integrated Tomato and Aquacultural System. Alabama, 2007 9
Table 4. Annual Operating Costs for Tomato Greenhouse in the Integrated Tomato and Aquacultural System, Alabama, 2007 10
Table 5. Investment Costs for the Fish Greenhouse in the Integrated Tomato and Aquacultural System, Alabama 2007 11
Table 6. Investment Costs for the Tomato Greenhouse in the Integrated Tomato and Aquacultural System, Alabama, 2007 12
Table 7. Costs and Returns for Integrated Tomato and Aquacultural (Catfish) System, Alabama, 2007 13
Table 8. Costs and Returns for Integrated Tomato and Aquacultural (Tilapia) System, Alabama, 2007 13
Table 9. Sensitivity Analysis of Net Returns at Selected Yields and Prices for Catfish and Tomato Production, Alabama, 2007 14
Table 10. Sensitivity Analysis of Net Returns at Selected Yields and Prices for Tilapia and Tomato Production, Alabama, 2007 14

Auburn University is an equal opportunity educational institution/employee.
Information contained herein is available to all persons without regard to race, color, sex, or national origin.

Issued in furtherance of Cooperative Extension work in agriculture and home economics, Acts of May 8 and June 30, 1914, and other related acts, in cooperation with the U.S. Department of Agriculture. The Alabama Cooperative Extension System (Alabama A&M University and Auburn University) offers educational programs, materials, and equal opportunity employment to all people without regard to race, color, national origin, religion, sex, age, veteran status, or disability.

http:www.auburn.edu
http:www.ag.auburn.edu/aaes

Integration of Hydroponic Tomato and Indoor Recirculating Aquacultural Production Systems: An Economic Analysis

J. B. Holliman, J. Adrian, and J. A. Chappell

INTRODUCTION

Like much of agriculture, Alabama's aquacultural production sector has been under stress for several years. Alabama producers and intermediaries in the system face competition from others in the fish and seafood industry, both domestically and internationally, as well as from producers and handlers of other protein sources. Prices for farm level products have generally been depressed and input costs have been on the rise. Thus, profit margins have become thin to nonexistent. Resource owners are interested in identifying and evaluating viable alternative uses for their productive assets.

To cope in this environment and be profitable, Alabama aquacultural producers must organize and operate to maximize efficiency and be innovative in decisions and actions. Existing fish production technologies and approaches, primarily pond culture, may not compete effectively. Increasing yield per unit of water, lowering cost per unit of product, and/or enhancing market access could improve the plight of producers.

This study aims to identify and assess the technical and economic feasibility of an alternative production system that integrates hydroponic tomato production with production of channel catfish or tilapia using recirculating water through a closed, controlled environment using separate greenhouses to produce tomatoes and fish throughout the year.

BACKGROUND AND JUSTIFICATION

Recirculating aquacultural systems offer fish producers a variety of important advantages over open pond culture. Among these are

- a means to maximize production using a limited quantity of water and land,
- almost complete environmental control of the system so as to maximize fish growth year round,
- potential to locate production facilities near markets,
- more convenient and efficient harvesting, and
- potential to quickly and effectively control diseases (Helfrich and Libey).

These intensive integrated systems are designed to raise relatively large quantities of fish in relatively small volumes of water by treating the water to remove waste byproducts and then reusing it. They also allow the producer to manage fish stocks more efficiently and allow a relatively high degree of environmental control over many parameters such as water temperature, dissolved oxygen, pH, and

Holliman is a former Graduate Research Assistant and Adrian is a Professor in the Department of Agricultural Economics and Rural Sociology, Auburn University. Chappell is an Associate Professor in the Department of Fisheries and Allied Aquacultures, Auburn University.

many excreted byproducts that are normally undesirable (Rakocy, 1992). In the process of reusing the water, nontoxic nutrients and organic matter accumulate. These metabolic byproducts can be channeled into secondary enterprises that have economic value or in some way benefit or complement the primary production system.

Feed is a major expense item for typical aquacultural operations, often accounting for 40 to 60 percent of the total operating expenses. Only 30 to 35 percent of the feed fed and consumed by the fish is utilized for growth. The rest, 65 to 70 percent, is lost to the water column (Brown, 2006). An integrated fish-vegetable greenhouse production system uses the energy lost in the unused feed by taking the effluent produced by catfish or tilapia culture and delivering enriched water to the vegetables from a portion of the culture water. This process allows regular water exchanges from the catfish or tilapia culture tanks; this exchange improves the overall water quality of the system. Also, essential nutrients, which would normally have to be purchased, are provided to the vegetable plants, rather than being discarded from the production site.

Plants, such as tomatoes, are an ideal complementary crop in an integrated system because they grow rapidly in response to the high levels of dissolved nutrients that are generated from the microbial breakdown of fish wastes. Since these systems have a small daily water exchange rate, dissolved nutrients accumulate and approach concentrations that are beneficial to hydroponic plants. Nitrogen, in particular, occurs at very high levels in recirculating systems. Fish excrete waste nitrogen directly into the water in the form of ammonia, which can be converted by a biofilter to nitrite and then to nitrate. Ammonia and nitrite are toxic to fish, but nitrate is relatively harmless and is the preferred form of nitrogen used for aquatic plants and vegetables such as tomatoes (Rakocy, 1992).

The level of water renewal in the recirculating aquacultural system depends, first, on the biofilter's efficiency in removing toxic nitrogen-rich waste resulting from fish metabolism and, second, on the amount of water that is lost when removing the accumulated waste products from the biofilters. Removal of the nitrogenous compounds from the water and incorporation of tomatoes into the recirculating system can improve water quality as well as potentially increase catfish and tilapia growth rates. This approach, together with the additional crop output from the integrated system, gives the potential to enhance revenue and hopefully profit when compared to production of aquacultural enterprises alone.

Combination of catfish or tilapia production with hydroponic tomatoes in a recirculating raceway system may have other potential economic benefits compared with separate operations in terms of reduced land requirements along with the combined use of structures, equipment, and inputs. This approach includes common pumps, filters, energy and—depending on the type of system utilized—vertical space in greenhouses (Rakocy, 1989)

The rapidly growing greenhouse tomato industry has become an important part of the North American fresh tomato industry. Greenhouse tomatoes now represent an estimated 17 percent of the U.S. fresh tomato supply (Calvin and Cook, 2005). Around 37 percent of all fresh tomatoes sold in U.S. retail stores are now grown in greenhouses, compared with negligible amounts in the early 1990s. While greenhouse tomatoes have higher per unit costs of production and generally higher retail prices in the U.S. than field-grown tomatoes, several other characteristics have contributed to the growth in this sector. Since they are protected from the water and other conditions that affect open field-grown tomatoes, greenhouse tomatoes generally have a much more uniform appearance than field-grown tomatoes as well as a fairly steady production volume (Calvin and Cook, 2005). These factors lead to greater consistency in quality, volumes, and pricing, which are issues of particular concern to the retail and food service industries. Producers also capitalize on higher prices in the off season when field-grown tomatoes are not being produced or readily available.

Total per capita consumption of fresh tomatoes increased to 19.2 pounds in 2003 from 12.3 pounds in 1981 (USDA, 2006). As of 2004, the U.S. fresh market for tomatoes was valued at $1.3 billion. Imports comprise a very large portion of the tomato consumption in the U.S. Fresh imports of tomatoes reached $900 million in 2004 with $750 million coming from Mexico, largely in the winter (USDA, 2006).

Seasonality is a major factor shaping the North American fresh tomato industry. Consumers increasingly demand a steady, year-round supply of tomato products (Calvin and Cook, 2005). These demands are better satisfied with greenhouse tomato production systems that can produce a fairly steady predictable yield through all four seasons as compared to field-grown tomatoes, which are more seasonal with weather patterns and source of supply. These characteristics result in tomatoes being an excellent complementary enterprise for greenhouse aquacultural systems.

Aquaculture is also a growing industry striving to satisfy a growing market for food fish while maintaining profitability. It currently is one of the fastest growing sectors of agriculture in the United States. Catfish and tilapia have been the new aquacultural cash crops since the 1990s (Helfrich and Libey). Growing public demand for healthy, tasty, and affordable food is steadily influencing profitability of the catfish and tilapia production sectors. Decline in wild fish populations as a result of over harvest and water pollution has promoted farming of fish grown in contaminant free, indoor recirculating aquacultural systems (Helfrich and Libey).

U.S. farm-raised catfish is the fifth most popular fish consumed in the U.S., behind tuna, pollock, salmon, and cod, respectively. Farm-raised catfish production for food-sized fish reached 608 million pounds liveweight in 2005 (2005 Census of Aquaculture, NASS, p. 27). The farm-raised catfish industry is centered in the southeastern United States, primarily on the lower Mississippi River flood plain. Alabama, Arkansas, Louisiana, and Mississippi account for 95 percent of farm-raised catfish production, with Mississippi growers producing 70 percent of the total (Avery, 2000).

As of 2005, there were 25,000 water acres on catfish farms in Alabama with about 215 producers (2005 Census of Aquaculture, NASS, p. 15). Eight Alabama farms used raceway production systems. Alabama producers ranked second to Mississippi in catfish sales in 2005, with more than 142 million pounds liveweight being harvested. Food-size catfish sales in Alabama totaled $93.1 million with an average price of $0.66 per pound.

Tilapia are a relatively new fish enterprise in the U.S. California and North Carolina growers were major suppliers of food-size tilapia in 2005, with 4.8 and 2.0 million pounds liveweight, respectively (2005 Census of Aquaculture, NASS, p. 31). Alabama growers supplied 98,000 liveweight pounds of food-size tilapia in 2005. Food-size tilapia sales in Alabama were $128,000 in 2005, with an average price per pound of $1.72.

This study includes an assessment of the economic potential of farming channel catfish or tilapia in a system incorporating tomatoes grown hydroponically inside two separate greenhouses. The study analyses both the technical and the economic feasibility of these systems and discusses potential advantages and disadvantages of these types of integrated systems.

TECHNICAL ANALYSIS

The planned recirculating aquacultural/vegetable crop system represents a new and unique way to produce fish. Instead of the traditional method of growing fish outdoors in open pond culture, recirculating systems produce fish at high densities in indoor tanks and a controlled environment.

The proposed recirculating aquacultural system will consist of two separate 88-foot by 12-foot raceways enclosed in a 96-foot by 30-foot greenhouse with 6-foot sides. An adjacent 96-foot by 30-foot greenhouse with 8-foot sides will be used for growing tomatoes using aquacultural effluents as nutrients. This system is to be located on a 10-acre tract with a 1-acre pond plus run-off area. The land is assumed to be owned and compatible to construction of the system. Thus, pond construction costs are included in the analysis while a land cost is not included. Figure 1 displays a diagram of the planned system.

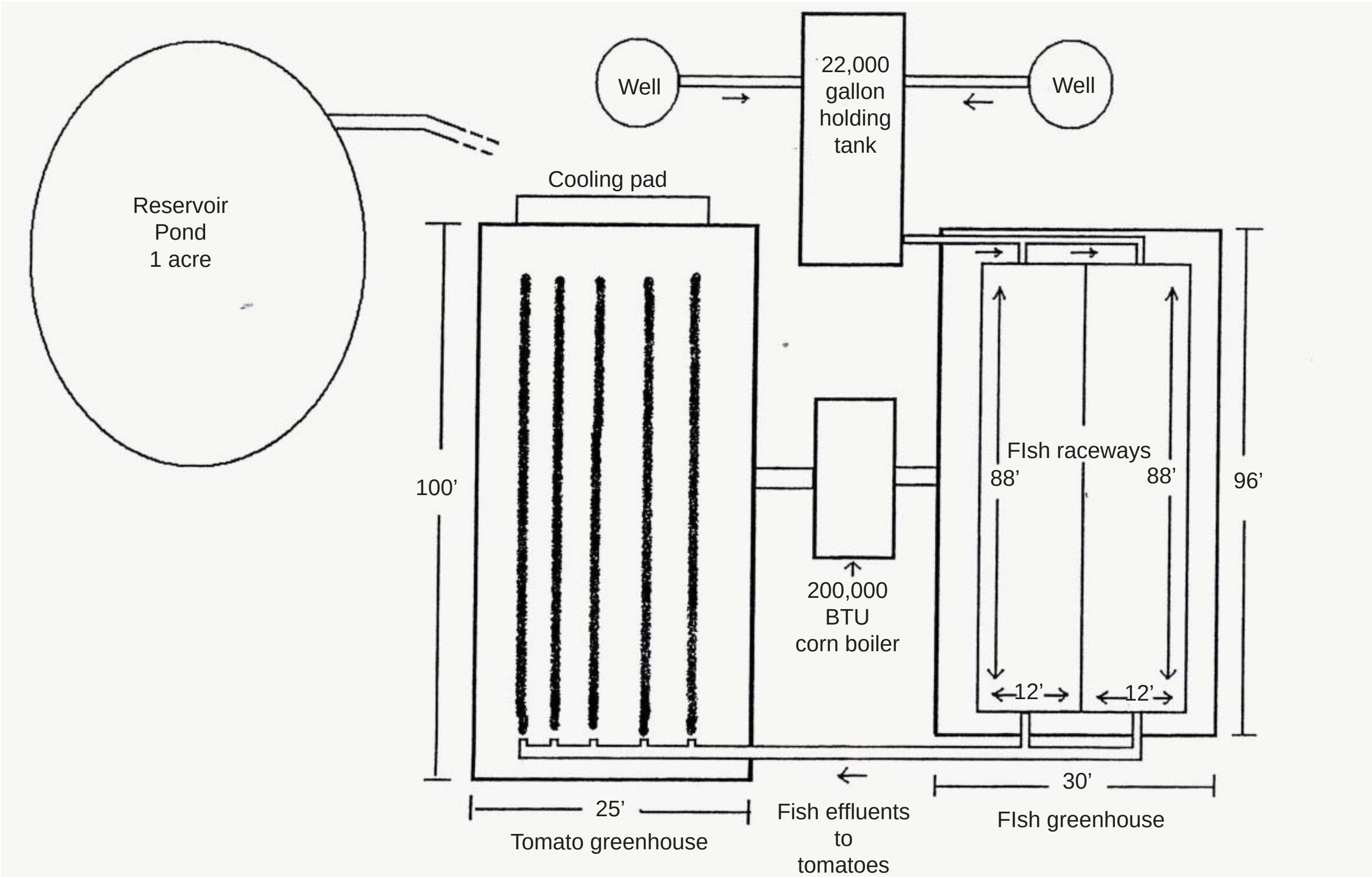


Figure 1. Design of the tomato and fish production system.

The greenhouse for growing the aquacultural enterprise will consist of two 88-foot long by 12-foot wide by 4-foot deep raceways. There will be four Sweetwater blowers, one single horsepower and three others that are 2.5 horsepower each. These will provide sufficient aeration and water flow for the projected annual yield of 44,000 pounds of channel catfish or 27,600 pounds of tilapia. Tomatoes will be cultivated in five troughs, 90 feet long by 2 feet wide and 1.5 feet deep, within the tomato greenhouse. These ditches will be filled with 100 percent cotton gin compost, which has been shown to increase tomato production (Cole, 2002).

The water source will be supplied primarily from two wells, which provide approximately 10 to 15 gallons per minute flow. The well water will be pumped into a 22,000 gallon holding tank 10 feet above the level of the greenhouse tanks to provide water for the fish and emergency water for the tomatoes. Because well water often has low hardness and alkalinity, $CaCO_3$ will be added as needed to the culture water to improve productivity and eliminate wide pH swings associated with low alkalinities (Brown, 2006). Access to city water also will be provided for emergency purposes, but it will not be utilized frequently, other than for washing the inside of the greenhouses when needed. Most city water contains chloramines, which are not volatile. During emergency situations, sodium thiosulfate will be used to neutralize the toxic chlorine in the city water before it is transferred to the fish culture tanks. Water supply for this system was never considered to be a limiting factor for production because of the large volume of water that is constantly available.

Design of the system, the stocking rate, and the system of operation were planned with the objective of disease prevention through water quality monitoring, biological control methods, and biofilters incorporated in order to avoid any need for treatments that would be toxic to or accumulate in the plants. The appropriate combination of tomato and fish production was analyzed with the level of crop production dependent on plant nutrients provided by fish production. The feasible level of tomato production was determined and the requirements for hydroponic structures were calculated. Fish production and the following technical requirements of fingerlings, feed, and physical facilities were configured in terms of a physical plan to produce 44,000 pounds of channel catfish or 27,600 pounds of tilapia per year.

These levels of production were chosen as likely minimum levels for economic efficiency estimated for a system manager along with hourly laborers. The manager's and hourly laborers' duties will be to operate and maintain the production system daily. Additional labor will be required during harvest periods for fish as well as for tomatoes.

PHYSICAL PLAN

The integrated system plan was based on producing fish at a desired market weight of 1.1 pounds (500 grams) for catfish and 1.0 pound for tilapia (Brown, 2006). Most cultured channel catfish sold for food are harvested at 340 to 680 grams (0.751 pounds) in body weight (Chapman, 2006), which comes to approximately 11,000 pounds per quarter for the system when the fish are cultured under favorable conditions. For tilapia, 6,900 pounds per quarter is the defined yield for the system. These conditions include a desirable water temperature of 73 degrees F for efficient production as well as an indoor environmental temperature between 82 and 87 degrees F, which will be maintained by a 200,000 BTU Grain Burner for heating. Ventilation fans, along with a drip cooling system, will be used to maintain desired temperatures (Chappell, 2006). Producing catfish, tilapia, or any other warm water fish in a nontropical environment introduces problems for the farmer that need to be addressed in order to culture them economically (Brown, 2006). Food availability and good sanitary conditions promote optimum growth as well.

Fingerling requirements were based on a mortality rate of 3 percent per quarter. Fingerlings will be purchased at an average weight of 15 grams or 0.5 ounce and the grow-out period is budgeted to be six months for catfish. A 28 to 32 percent protein diet of floating feed ranging in size from 1.0 to 5.0mm will be fed (Brown, 2006) with a feed conversion ratio of 2:1 assumed. Facilities required for this study are based on a stocking rate of 2.5 pounds per cubic foot of system volume (Klinger, 1983). A staggered stocking process allows for a constant supply of market-sized catfish while not oversupplying the local market. The incoming fingerlings will be graded thoroughly for size consistency before stocking into the system. Stocked fish will be separated by dividers in the raceways with the dividers expanding the production area to ensure sufficient tank space as the fish grow (Brown, 2006).

Water flow requirements were based on average hourly oxygen consumption of 2.94 grams per pound of feed distributed (Jarboe, 1996) and a minimum dissolved oxygen level of 151 milligrams per gallon (Landau, 1991). Dissolved oxygen will be monitored twice per day with the first measurement starting in early morning and the second coming just before dusk. To ensure water circulation and proper aeration, blowers and a diffuser hose will be utilized with this system. The pH level will be monitored in the morning and just before sunset to minimize large pH swings in the system. Supplemental water also will be added every day, mainly to replace water loss due to tomato watering and evaporation from the large water surface area of the raceways. Ammonia, nitrite, and nitrate levels will be recorded daily. Water hardness, alkalinity, and chlorides will be monitored daily to ensure optimal production conditions. Supplemental nutrients such as fertilizers containing calcium nitrate and potassium nitrite will be mixed and added directly to the tomatoes as needed to maintain maximum production (Brown, 2006). Water flow requirements together with the total system fish volume will be calculated for the maximum fish weight level present at any time during the production cycle.

Levels of tomato production and the respective number of plants required were calculated using the ratio of 0.084 square feet of growing area per gallon of fish volume (Sutton and Lewis, 1982). Tomato plant production density was calculated as 0.25 plants per square foot (Harris, 1994). Tomato yield was specified at 20 pounds per plant (Sutton and Lewis, 1982).

Water exchanges will take place on a daily basis depending on water quality in the fish tanks and nutrient requirements for the tomatoes (Brown, 2006). Depending on the tomato plant needs, the tomatoes will be watered three to 12 times per day to ensure proper water and nutrient levels. Proper watering will be accomplished by using an automatic siphon from the fish tanks to the plant greenhouse (Brown, 2006). To supply water to the catfish or tilapia raceways, a 3-inch line capable of supplying a minimum of 200 gallons per minute will run from the holding tank. There also will be a 4-inch line originating from the reservoir pond supplying the same flow rate for emergency situations. The well water also will be used in watering the tomatoes and mixing any essential nutrients that the fish effluent water did not provide (Brown, 2006).

The fish production plan was based on the purchase of 0.5 ounce fingerlings, which will be grown to market sale weights of 1.1 pounds for catfish or 1 pound for tilapia. For the annual production of 44,000 pounds of channel catfish, 43,000 0.5-ounce (5 gram) fingerlings will be purchased in batches of 10,638 per quarter. A total of 34,558 tilapia fingerlings will be stocked per year to produce 27,600 pounds per year.

At the end of the first quarter, there should be 10,319 catfish available due to the 3 percent mortality rate. The average weight of the fish is expected to be 4.5 ounces per fish and the total weight of all the fish should be 2,902 pounds (Table 1). The second quarter allows for continuous growth of the catfish to the market weight of 1.1 pounds. Therefore, the total weight of the fish at the end of the second production cycle should be 10,152 pounds meaning that the maximum level of catfish in the system at any time is 13,054 pounds (10,152 + 2,902), which will occur after a six-month period, the average length of a production cycle for channel catfish. This staggered stocking process allows for a constant supply of market-sized catfish while hopefully not oversupplying the local market (Brown, 2006).

The water flow required for the stated amount of production will be 3,000 feet per hectare as produced by the four blowers. Since the catfish were to be stocked at 2.5 pounds per cubic foot of the system's volume (Klinger, 1983), the total water volume required will be slightly more than 39,000 gallons (Table 2). The hydroponic tomato growing area required was 3,294 square feet (39,000 x 0.084 square feet) and, consequently, 826 (0.25 plants per square foot of hydroponics growing area x 3,294) plants will be needed per cycle. The expected tomato output should be 16,587 pounds per cycle and 33,175

Table 1. Physical Plan for Channel Catfish Production in the Aquacultural System

Year 1									
Quarter 1					**Quarter 2**				
Purchases	**End Stocks**				**Purchases**	**Sales**	**End Stocks**		
Number of fish (0.5 oz.)	Number of fish		Weight (oz.)	Total (lb.)	Number of fish (0.5 oz.)	Number of fish (1.1lb)	Number of fish	Weight (oz.)	Total (lb.)
10,638	10,319		4.50	2,902.22	10,638	10,000	10,319	4.50	10,152.00
Quarter 3					**Quarter 4**				
Purchases	**Sales**	**End Stocks**			**Purchases**	**Sales**	**End Stocks**		
Number of fish (0.5 oz.)	Number of fish (1.1 lb.)	Number of fish	Weight (oz.)	Total (lb.)	Number of fish (0.5 oz.)	Number of fish (1.1lb)	Number of fish	Weight (oz.)	Total (lb.)
10,638	10,000	10,319	4.50	2,902.22	10,638	10,000	10,319	4.50	10,152.00
Years 2-10									
Quarter 1					**Quarter 2**				
Purchases	**Sales**	**End Stocks**			**Purchases**	**Sales**	**End Stocks**		
Number of fish (0.5 oz.)	Number of fish(1.1 lb.)	Number of fish	Weight (oz.)	Total (lb.)	Number of fish (0.5 oz.)	Number of fish (1.1lb)	Number of fish	Weight (oz.)	Total (lb.)
10,638	10,000	10,319	4.50	2,902.22	10,638	10,000	10,319	4.50	10,152.00
Quarter 3					**Quarter 4**				
Purchases	**Sales**	**End Stocks**			**Purchases**	**Sales**	**End Stocks**		
Number of fish (0.5 oz.)	Number of fish(1.1 lb.)	Number of fish	Weight (oz.)	Total (lb.)	Number of fish (0.5 oz.)	Number of fish (1.1lb)	Number of fish	Weight (oz.)	Total (lb.)
10,638	10,000	10,319	4.50	2,902.22	10,638	10,000	10,319	4.50	10,152.00

pounds per year based on two production cycles per year. The first crop will be transplanted in August and harvested from November to the end of December and a second crop will be transplanted at the first of January and harvested from March through early June (Brown, 2006).

A total of 34,558 tilapia will be stocked per year, and the stocking will be segmented into two-month stocking regimes (Brown, 2006). With an estimated total production of 13,800 pounds produced per tank per year, the estimated grow-out time for each individual tilapia cohort is six months to reach 1 pound, which results in a minimum of 27,600 pounds produced per year (Brown, 2006).

FINANCIAL ANALYSIS

Costs for the equipment required to operationalize the physical plan for the production of the fish along with hydroponic tomatos were determined from information supplied by commercial operations and retailers. Items included two greenhouses, generators, an irrigation system, lumber, aerators, and a Polyurea waterproof liner for the two raceways. Catfish output was budgeted to be marketed at $0.77 per pound while tilapia was priced at $1.80 per pound (USDA, 2006). Due to the seasonality of tomato prices, an average market price from 2000 to 2005 was used to determine the expected return from tomato production. The average market price of tomatoes in 2000 was $1.38 per pound and the average market price in 2005 was $1.61 per pound (USDA, 2006). Therefore, the tomato price used in the analysis to determine the expected return was $1.50 per pound.

Table 2. Selected Characteristics of the Integrated Tomato and Aquacultural System, Alabama, 2007

Item	Units	Amount
Growing area per gallon of catfish volume	sq. ft./gal.	0.08
Tomato plant density	plants/sq. ft.	0.25
Tomatoes per plant	lb/plant	20.06
Fingerling weight	ounces	0.53
Catfish market weight	lbs	1.10
Days for catfish to reach market weight	days	185.00
Expected annual catfish yield	lbs	44,000.00
Maximum level of fish present at any time	lbs	13,054.22
Waterflow for catfish	cu. ft./h	3,000.00
Catfish stocking rate	lb/cu. ft	2.50
Total system water volume required	gal	39,060.93
Tomato growing area required	sq. ft.	3,294.40
Tomato plants per cycle	plants	826.89
Expected tomato output per cycle	lbs	16,587.50
Number of tomato cycles per year	cycles	2.00
Tomato output per year	lbs	33,175.00

Interest on operating capital was charged at 8 percent for six months while investment capital was charged at 8.5 percent for the year. Investment capital was assumed to be 80 percent borrowed and 20 percent owner provided, Tables 3 and 4. Employment taxes were included at defined rates of 6.2 percent for Social Security and 1.45 percent for Medicare. Property taxes were allocated using a 10 percent assessment rate at a 0.030 millage rate. Land was valued at the USDA average for Alabama of $3,100 per acre. The 10 acres was assumed to be owned and appropriate for construction of the fish/tomato system. Thus, a land outlay was not included in the financial analysis but pond construction costs were allocated.

Table 3. Annual Operating Costs for Fish Greenhouse in an Integrated Tomato and Aquacultural System. Alabama, 2007

Item	Units	Price/Unit	Quantity	Cost
Fingerlings	per	0.15	43,000.00	6,450
Labor (avg10hrs/week)	hr	10.00	520.00	5,200
Electrical	Kwh	0.08	25,000.00	2,000
Water (city)	Total	500.00	1.00	500
Feed	tons	280.00	10.00	2,800
Corn (Fuel for heat)	bushel	3.50	771.00	2,699
Fish Protectants	total	100.00	1.00	100
System Manager	total	30,000.00	0.50	15,000
Maintenance and Repair	total	200.00	1.00	200
Insurance	total	500.00	0.50	250
Property Taxes	total	286.00	1.00	286
Employment Taxes	total	1,545.00	1.00	1,545
Interest: Annual Operating capital	total	2,518.06	1.00	2,518
Fixed capital	total	4,520.94	1.00	4,521
Total				44,069

Investment Costs

The financial requirement for the initial investment to establish a system that produces 44,000 pounds of channel catfish or 27,600 pounds of tilapia was $70,640 with an annual depreciation of $6,456 (Table 5). The greenhouse and related machinery and equipment needed to produce 33,175 pounds of tomatoes per year would cost approximately $43,072 with annual depreciation of $3,475 (Table 6). Therefore, the total initial investment outlay for the system was estimated to be $113,712, excluding land, with an annual depreciation at $9,930.

Table 4. Annual Operating Costs for Tomato Greenhouse in the Integrated Tomato and Aquacultural System, Alabama, 2007

Item	Units	Price/Unit	Quantity	Cost
Tomato Seeds/Plants	per	0.25	2,000.00	500
Labor (15 hrs/week)	hr	10.00	780.00	7,800
Electricity	Kwh	0.08	35,000.00	2,800
Corn (fuel for heat)	bushel	3.50	771.00	2,699
Water (city)	total	500.00	1.00	500
Fertilizer	total	55.00	1.00	55
Chemicals/Plant Protectants	total	250.00	1.00	250
Poly Duct	roll	280.00	2.00	560
Beneficial insects	total	810.00	1.00	810
Waxed boxes	per	1.25	1,400	1,750
Buckets (5 gal.)	per	1.00	50	50
Water Sample Analysis	per	70.00	6.00	420
Leaf Tissue Analysis	per	80.00	6.00	480
System Manager	total	30,000.00	0.50	15,000
Maintenance and Repair	total	200.00	1.00	200
Insurance	total	500.00	0.50	250
Property Taxes	total	148.00	1.00	148
Employment Taxes	total	1,744.00	1.00	1,744
Interest: Annual Operating capital	total	2449.05	1.00	2,449
Fixed capital	total	2,756.61	1.00	2,757
TOTAL				41,221

Catfish and Tomato Production

Annual operating costs for the system were $85,290, with $44,069 allocated to the catfish/tilapia production component and $41,221 from the tomato production component, Tables 7 and 8. Adding $9,931 for depreciation produced an annual cost outlay of $95,221. Major annual cost items for the fish greenhouse were manager salary (34 percent), fingerlings (14.6 percent), seasonal labor (11.8 percent), interest on fixed capital (10.3 percent), and feed (6.4 percent), Table 3. Major annual cost allocations for the tomato greenhouse included manager salary (36.4 percent), seasonal labor (18.9 percent), electricity (6.8 percent), and interest on fixed capital (6.7 percent).

At expected prices ($0.77 per pound for catfish and $1.50 per pound for tomatoes) and yields, the integrated catfish/tomato system was not profitable, Table 7. A loss of $11,579 was generated. On a component basis, tomatoes covered their costs while catfish did not. Thus, the integrated catfish/tomatoes system does not seem to be economically feasible at expected prices and yields.

To analyze the responsiveness of net returns to alternative prices and yields, a sensitivity analysis was conducted, Table 9. Prices were varied by $0.05 from $0.62 to $0.92 for catfish and from $1.35 to $1.65 for tomatoes. Yields were varied at 10 percent and 20 percent of the base levels of 44,000 pounds for catfish and 33,175 pounds for tomatoes. Net returns became positive ($520) at 20 percent yield increases with $0.05 declines in prices from expected levels. Also, at 10 percent yield increases and $0.10 increases in prices from expected levels, net returns were positive at $5,276. Thus, it is clear that fairly large positive market forces or large production efficiency gains are needed to generate feasibility of the system that includes catfish and tomatoes.

Tilapia and Tomato Production

Total tilapia production was estimated to be a minimum of 27,600 pounds per year with an estimated grow out period of six months to reach the marketable size of 1 pound (Brown, 2006). With two crops of tomatoes produced per year, the estimated total production of tomatoes in the greenhouse system was 33,175 pounds per year.

At expected prices ($1.80 per pound for tilapia and $1.50 per pound for tomatoes) and yields, the integrated tilapia/tomato system showed positive annual net returns of $4,222, Table 8. Tilapia and tomatoes contributed almost equally to returns. Thus, integration of tilapia production with tomatoes is economically feasible at expected prices and yields.

To analyze the responsiveness of net returns to alternative prices and yields, a sensitivity analysis was conducted, Table 10. Prices were varied by $0.05 from $1.65 to $1.95 for tilapia and from $1.35 to $1.65 for tomatoes. Yields were varied at 10 percent and 20 percent of the base levels of 27,600 pounds for tilapia and 33,175 pounds for tomatoes. At $1.95 per pound for tilapia and $1.65 per pound for tomatoes, yields could decline by 10 percent each for tilapia and tomatoes and still maintain positive annual net returns of $2,483. Similarly, if yields of both items increased by 10 percent, prices could decline to $1.65 for tilapia and $1.35 for tomatoes and still maintain positive annual net returns of $4,139. With 20 percent increase in yields for both items and the highest analyzed prices, net returns would be $35,050 annually. Thus, an aquacultural/vegetable system incorporating tilapia and tomatoes shows potential for development.

Table 5. Investment Costs for the Fish Greenhouse in the Integrated Tomato and Aquacultural System, Alabama, 2007

Item	Unit	Price/Unit	Quantity	Cost	Yrs of Life	Annual Depreciation
Greenhouse (30’ x 96’ x 6’ side, Atlas Greenhouse System)						
Basic Structure	per	6,500	1	6,500.00	20	325.00
Poly Roof Covering (2 ply)	per	3,500	1	3,500.00	20	175.00
Ventilation	per	2,760	1	2,760.00	20	138.00
Shade Cover	per	330	1	330.00	20	16.50
Door (3’ x 6’ 8”)	per	180	1	180.00	20	9.00
Door (10’ x 10’, roll up)	per	560	1	560.00	20	28.00
Freight	per	450	1	450.00	20	22.50
Installation	per	5,000	1	5,000.00	20	250.00
Baseboard (2a’ x 8”, treated with clamps)	per	550	1	550.00	20	27.50
Subtotal: Fish Greenhouse			**Total**	**$19,630.00**		**$991.50**
Raceway System (2 raceways @ 88’ x 12’ x 3 ¼’ each)						
Wooden posts (4’ x 4’ x 8’ treated, 100 @ $5 each)	per	5	100	500.00	15	33.33
Plywood (5/8” x 4’ x 8’ treated. 48 @ $40 each)	per	48	40	1,920.00	15	128.00
Wooden Caps (2” x 4” x 16”; 18 @ $10 each)	per	10	18	180.00	15	12.00
Drain Structures (two 8” x 4’ PVC pipe plus two 8” ells)	per	60	2	120.00	20	6.00
Walkway (Crushed Limestone)	cu.yd.	25	4	100.00	5	20.00
Tank Dividers	per	400	3	1,200.00	15	80.00
Waterproofing: Polyurea waterproof liner (All Coat, etc.)	per	12,300	1	12,300.00	5	2,460.00
Aeration						
One Sweetwater S41 blower, 1 hp	per	500	1	500.00	5	100.00
Three Sweetwater S51 Blowers, 2.5 hp	per	750	3	2,250.00	5	450.00
Aeration Hose + PVC pipe and fittings	per	500	1	500.00	5	100.00
Subtotal: Raceway system			**Total**	**$19,570.00**		**$3,389.33**
Machinery and Equipment						
Corn boiler and accessories	per	7,000	1	7,000.00	15	466.67
Generator	per	560	1	560.00	5	112.00
Garden Hose (100’, heavy duty, adjustable flow nozzle)	per	90	1	90.00	5	18.00
Dissolved Oxygen Meter	per	760	1	760.00	3	253.33
Dissolved Oxygen Monitoring System	per	940	1	940.00	5	188.00
Water Quality Test Kit (Hach Fish farm Kit, FF-1A)	per	240	1	240.00	2	120.00
Harvesting Dip Net (heavy duty, 22” x 18” x 24” deep, two)	per	60	2	120.00	5	24.00
Baskets, Poyurethene (10.4 gal. 19” x 14” deep. Delta Twins, six)	per	15	6	90.00	3	30.00
Scale (Mettler Model XW560MS, 100 lb. capacity, 0.02 resolution)& Platter (Toledo XLS; heavy wash down, stainless AC adapter)	per	626	2	1,250.00	5	250.00
Temperature Controller and DO Probe	per	940	1	940.00	5	188.00
Well	per	1,050	1	1,050.00	10	105.00
Water Tank: 22,000 gallons	per	3,200	1	3,200.00	10	320.00
Reservoir Pond: one acre	acre	15,000	1	15,000.00		0.00
Subtotal: Machinery and Equipment			**Total**	**$31,240.00**		**$2,075.00**
Land	acre	3,100	8	—	—	—
TOTAL				**$70,640.00**		**$6,455.83**

Fish Only Production System

The differences in capital requirements for the production of the same quantity of channel catfish or tilapia without the hydroponic tomato production system required purchase of biofilters. Since this system consists only of fish (with no tomatoes), a biofilter was required with the recirculation capacity of 3,000 feet per hectare; the biofilter was estimated to cost $7,500 and was depreciated over five years with no salvage value. Since the cash value of tomatoes was foregone, the only source of income was the channel catfish or tilapia. If the expected 44,000 pounds of catfish or 27,600 pounds of tilapia were

Table 6. Investment Costs for the Tomato Greenhouse in the Integrated Tomato and Aquacultural System, Alabama, 2007

Item	Unit	Price/Unit	Quantity	Cost	Yrs of Life	Annual Depreciation
Greenhouse (36' x 100' x 8" side, Atlas Greenhouse Systems)						
Basic Structure	per	8,500	1	8,500.00	20	425.00
Poly Roof Covering	per	6,250	1	6,250.00	20	312.00
Ventilation and Cooling	per	6,500	1	6,500.00	20	325.00
HAF Fans (4)	per	100	4	400.00	20	20.00
Door (10' x 10', double sliding)	per	750	1	750.00	20	37.50
Shade Cloth	per	900	1	900.00	20	45.00
Freight	per	500	1	500.00	20	25.00
Installation	per	6,000	1	6,000.00	20	300.00
Drainage	per	500	1	500.00	20	25.00
Baseboard (2" x 8", treated)	per	550	1	550.00	20	27.50
Subtotal: Plant Greenhouse				$30,850.00		$1,542.50
Machinery and Equipment						
Generator	per	560	1	560.00	5	112.00
Irrigation System	spool	500	1	500.00	5	100.00
Support Wire for Poly Duct	per	5	2	10.00	10	1.00
Posts	per	113	12	1,356.00	15	90.40
Pipe (20' sections @$210 each, 12)	per	210	12	2,520.00	15	168.00
Tee (one per post @ $50 each, 12)	per	50	12	600.00	15	40.00
Caps (two per post @ $35 each, 24)	per	35	24	840.00	15	56.00
Eye bolts (stainless. 6" x 3/8" includes washer & nut @ $3 each, two post , 2	per	3	24	72.00	15	8.40
Quikcrete (three bags /post @ $4/bag, 36 bags)	per	4	36	144.00	15	9.60
Support wire for tomatoes	spool	10	5	50.00	10	5.00
Extension Cord (100')	per	40	1	40.00	5	8.00
Hose (100'. Heavy duty)	per	90	1	90.00	5	18.00
Hose Reel	per	30	1	30.00	7	4.29
Backpack Sprayer	per	100	1	100.00	2	50.00
Respirator	per	100	1	100.00	1	100.00
Spray Suit	per	20	1	20.00	1	20.00
Pruning Shears	per	30	1	30.00	15	2.00
Wheelbarrow	per	100	1	100.00	5	20.00
Plant Calipers	per	10	1	10.00	5	2.00
Trashcans (50 gallon, 2)	per	20	2	40.00	3	13.33
Ladder (6', aluminum)	per	60	1	60.00	15	4.00
Rake	per	10	1	10.00	3	3.33
Utility Cart	per	200	1	200.00	3	66.67
Meter: EC, pH	per	420	1	420.00	3	140.00
Meter: Potassium	per	310	1	310.00	3	103.33
Meter: Nitrate	per	320	1	320.00	3	106.67
Hydrometer: Wet-Dry Bulb	per	30	1	30.00	3	10.00
Recorder: Humidity and Temperature	per	350	1	350.00	3	116.67
Thermalarm III	per	50	1	50.00	5	10.00
Solar Irrigation Controller	total	800	1	800.00	5	160.00
Sensaphone plus 1 Remote Sensor	per	450	1	450.00	5	90.00
Cotton Gin Compost			60	960.00	5	192.00
Well	per	1,050	1	1,050.00	10	105.00
Land	acres	3,100	2	—	—	—
Subtotal: Machinery and Equipment				$12,222.00		$1,932.09
TOTAL				$43,072.00		$3,474.59

produced and sold at $0.77 per pound for catfish and $1.80 per pound for tilapia (USDA, 2006), the total cash inflows would be $33,880 for catfish and $49,680 for tilapia. These cash inflows do not cover the annual operating costs and annual depreciation, which amounted to $52,025. This system would be losing roughly $18,145 annually producing only catfish and $2,345 annually producing only tilapia (Table 8). Therefore, producing only catfish or tilapia without integrating hydroponic tomatoes into this type of system is unprofitable.

Due to the lack of profitability of producing only tilapia or catfish without the integration of tomatoes, possible changes in the fish only production system were analyzed. Some suggestions to increase the profitability would be to use less expensive equipment or integrate technology into the system, which could possibly reduce labor hours and costs. Integrating the technology may increase initial investment costs, but should decrease the initial annual labor costs substantially. Assuming there is already an established niche market, another option would be to become strictly a fingerling production system to commercial buyers (Goodman and Trimble, 2006).

ENVIRONMENTAL AND NATURAL RESOURCE ADVANTAGES

This analysis was made from the viewpoint of an individual investor. When one considers the environmental and natural resource factors associated with both production systems analyzed, there are further potential societal benefits from combining fish and tomato cultures into recirculating systems.

The effluents discharged into bodies of water from the recirculating system that are not integrated with hydroponic plants, such as tomatoes, do not have an immediate serious pollution effect, but the cumulative effect over time may contribute to problems that would conflict with and limit other activities using the same water resource. In areas that face significant pollution problems, this may be an important issue.

Combination of fish and plant production within an indoor water recirculating production system reduces the total water requirement compared with outdoor flow-through systems and plant irrigation systems. This advantage would

Table 7. Costs and Returns for Integrated Tomato and Aquacultural (Catfish) System, Alabama, 2007

Item	Units	Price/Unit	# Units	Total
Returns				
Catfish	lbs	0.77	44,000	33,880
Tomatoes	lbs	1.50	33,175	49,763
			Total	83,643
Annual Operating Costs				
Catfish	total	44,069	1.00	44,069
Tomatoes	total	41,221	1.00	41,221
			Total	85,290
Return Above Operating Costs				(1,648)
Depreciation				
Catfish	total	6,456	1.00	6,456
Tomatoes	total	3,475	1.00	3,475
			Total	9,931
Net Return				($11,579)

Table 8. Costs and Returns for Integrated Tomato and Aquacultural (Tilapia) System, Alabama, 2007

Item	Units	Price/Unit	Quantity	Cost
Returns				
Tilapia	lbs	1.80	27,600	49,680
Tomatoes	lbs	1.50	33,175	49,763
			Total	99,443
Annual Operating Costs				
Tilapia	total	44,069	1.00	44,069
Tomatoes	total	41,221	1.00	41,221
			Total	85,290
Return Above Operating Costs				14,153
Depreciation				
Tilapia	total	6,456	1.00	6,456
Tomatoes	total	3,475	1.00	3,475
			Total	9,931
Net Return				$4,222

be very desirable in areas with limited water supplies. Integrating hydroponic plants such as tomatoes to utilize by-products from fish production also reduces the dependency on artificial fertilizers, which are produced using nonrenewable resources such as natural gas.

If the combination of hydroponic tomatoes with fish production improves the economics of recirculation systems, the inherent environmental advantages of such systems will be more widely realized in that there will be reduced effluent discharges into bodies of water, reduced land use compared with conventional aquacultural systems, and greater flexibility in locating such units because of the great reduction in water requirements (Timmons and Losordo, 1997).

SUMMARY AND CONCLUSION

Incorporating hydroponic tomatoes along with an indoor recirculating tilapia production facility inside two adjacent greenhouses has been shown to be profitable and can be desirable for environmentally and resource use-conscious investors. This system has the potential to provide both financial and environmental benefits in terms of shared resources, reduced labor input hours, reduced effluent discharges into local bodies of water, improved water quality, and lower water use.

This system will require an initial capital outlay of almost $114,000, excluding land, plus an annual operating cost of roughly $85,000. At prices of $1.80 per pound for tilapia and $1.50 per pound for tomatoes, annual net return will be modest at $4,222. These price and cost levels will generate an 8.05 years payback period and a simple rate of return of 7.4 percent. At optimistic prices of $1.95 per pound for tilapia and $1.65 per pound for tomatoes, annual net returns will be $13,338. These levels result in a 4.9 years payback period and a 23.4 percent simple rate of return.

At expected prices of $0.77 per pound for catfish and $1.50 per pound for tomatoes, the integrated system will generate a negative net annual return of $11,579. Even at substantially higher prices of $0.92 per pound for catfish and $1.65 per pound for tomatoes, the system will roughly break even at -$2.00 annual net return.

Analysis of the integrated system and comparison to an alternative system for catfish and tilapia without the hydroponic tomatoes unit indicates substantial differences in net returns. The indoor recirculating system with only catfish will have a negative net return of about $18,145 annually while a similar system for tilapia will lose $2,345 annually.

Table 9. Sensitivity Analysis of Net Returns at Selected Yields and Prices for Catfish and Tomato Production, Alabama, 2007

Yield	Price ($/lb.)						
Catfish	0.62	0.67	0.72	0.77	0.82	0.87	0.92
Tomato	1.35	1.40	1.45	1.50	1.55	1.60	1.65
35,200 26,540	-37,568	-34,481	-31,394	-28,307	-25,220	-22,133	-19,046
39,600 29,857	-30,362	-26,889	-23,416	-19,944	-16,471	-12,998	-9,525
44,000 33,175	-23,155	-19,296	-15,437	-11,579	-7,720	-3,861	-2
48,400 36,493	-15,948	-11,703	-7,458	-3,214	-1,031	5,276	9,521
52,800 39,810	-8,742	-4,111	520	5,150	9,781	14,411	19,042

Table 10. Sensitivity Analysis of Net Returns at Selected Yields and Prices for Tilapia and Tomato Production, Alabama, 2007

Yield	Price ($/lb.)						
Tilapia	1.65	1.70	1.75	1.80	1.85	1.90	1.95
Tomato	1.35	1.40	1.45	1.50	1.55	1.60	1.65
22,080 26,540	-22,960	-20,529	-18,098	-15,667	-13,236	-10,805	-8,374
24,840 29,858	-13,927	-11,192	-8,457	-5,722	-2,987	-252	2,483
27,600 33,175	-4,895	-1,856	1,183	4,222	7,260	10,299	13,338
30,360 36,493	4,139	7,481	10,824	14,167	17,509	20,852	24,195
33,120 39,810	13,171	16,817	20,464	24,110	27,757	31,403	35,050

REFERENCES

Avery, Jimmy L. 2000. A Little History on the Catfish Industry. Freshwater Farms Catfish, Belzoni, Mississippi.

Brown, Travis. 2006. Personal Communication. Fisheries and Alllied Aquacultures, Auburn University, Alabama.

Calvin, Linda and Roberta Cook. 2005. "North American Greenhouse Tomatoes Emerge as a Major Market Force." Amber Waves. United State Department of Agriculture, Volume 3, Issue 2.

Chapman, Frank A. 2006. Farm Raised Channel Catfish. Department of Fisheries and Aquatic Sciences. Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, Florida.

Chappell, Jesse A. and Jerry R. Crews. 2006. 2005 Alabama Aquaculture Factsheet. Agricultural Economics and Rural Sociology, Auburn University, Alabama.

Chappell, Jesse A. and Jerry R. Crews. 2006. U.S. Catfish Industry: Situation in 2005 and Outlook for 2006. Agricultural Economics and Rural Sociology, Auburn University, Alabama.

Chappell, Jesse A. 2006. Personal Communication. Fisheries and Allied Aquacultures, Auburn University, Alabama.

Cole, David M. 2002. "Evaluation of Cotton Gin Compost as a Horticultural Substrate." A Research Paper Presented at the Southern Nursery Association Researcher's Conference. Department of Horticulture, Auburn University, Alabama.

Goodman, Randell and Bill Trimble. 2006. Personal Interview Discussing Alternative Methods to Increase Profitability of the Fish Only Production System. Fisheries and Allied Aquacultures, Auburn University, Alabama.

Harris, D. 1994. Illustrated Guide to Hydroponics. London, New Holland.

Helfrich, Louis A. and George Libey. Fish Farming in Recirculating Aquaculture Systems. Department of Fisheries and Wildlife Sciences, Virginia Tech, Virginia.

Jarboe, H.H. 1996. "The Water Exchange Rate on Diel Ammonia Production and Oxygen Consumption of Channel Catfish in a Closed Recirculating Raceway System." Journal of Applied Aquaculture. Volume 6:1-12.

Kay, Ronald D. and William M. Edwards. 1999. Farm Management, Fourth Edition. McGraw-Hill Companies, Inc., Boston, Massachusetts.

Klinger, H. 1983. "Water Quality and Stocking Density as Stressors of Channel Catfish." Aquaculture. Volume 30:263-272.

Landau, M. 1991. Introduction to Aquaculture. John Wiley, Chichester.

Lutz, C.G., W.B. Richardson, J.L. Bagent. 1998. Greenhouse Tilapia Production in Louisiana. Louisiana State University Agriculture Center. Publication No. 2705.

Malone, R., B.S. Chitta, and G. Drennan. 1993. "Optimizing Nitrification in Bead Filters for Warmwater Recirculation Systems." Techniques for Modern Aquaculture Proceedings of an Aquacultural Engineering Conference. Southern Regional Aquaculture Center. 315-325. Spokane, Washington.

National Agricultural Statistics Service (NASS). 2005. 2005 Alabama Agricultural Statistics Bulletin 47. Alabama Field Office, Montgomery, Alabama.

Rakocy, James E. 1992. Recirculating Aquaculture Tank Production Systems: Integrating Fish and Plant Culture. Southern Regional Aquaculture Center, Stoneville, Mississippi.

Rakocy, James E. 1989. "Vegetable Hydroponics and Fish Culture: A Productive Interface." World Aquaculture. Volume 20:42-47.

Sutton, R.J. and W.M. Lewis. 1982. "Further Observations on a Fish Production System That Incorporates Hydroponically Grown Plants." Progress in Fish Culture. Volume 44:55-59.

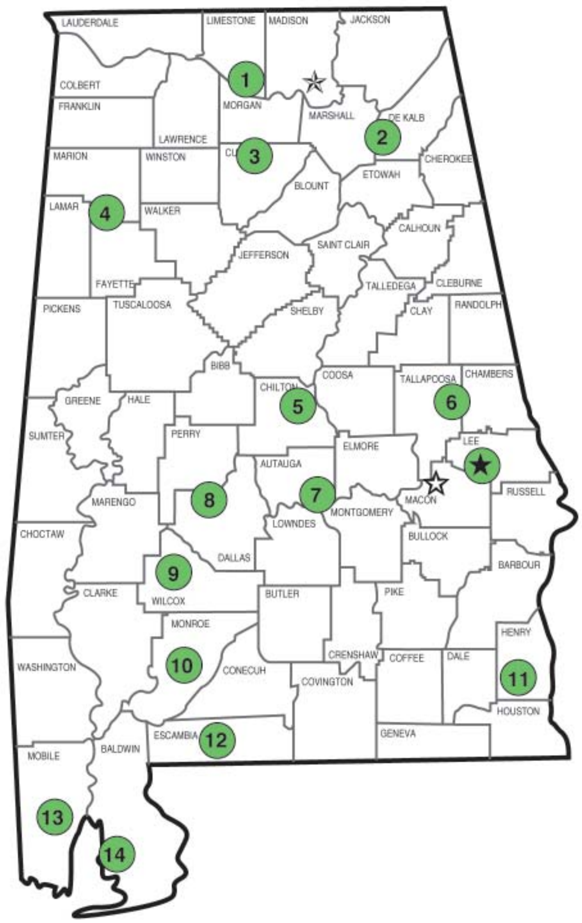
Timmons, M. and T. Losordo. 1997. “Developments in Aquaculture and Fisheries Science.” Vol. 27. Aquaculture Water Reuse Systems: Engineering Design and Management. Elsevier, Amsterdam; Oxford.

United States Department of Agriculture (USDA). 2006. Aquaculture Outlook: Domestic Aquaculture Competing Worldwide.

United States Department of Agriculture (USDA). 2006. Vegetables and Melons Outlook: Fresh Tomato Prices Ease As Supply Recovers.

Alabama's Agricultural Experiment Station
AUBURN UNIVERSITY

With an agricultural research unit in every major soil area, Auburn University serves the needs of field crop, livestock, forestry, and horticultural producers in each region in Alabama. Every citizen of the state has a stake in this research program, since any advantage from new and more economical ways of producing and handling farm products directly benefits the consuming public.



Research Unit Identification

★ Main Agricultural Experiment Station, Auburn.
☆ Alabama A&M University.
☆ E. V. Smith Research Center, Shorter.

1. Tennessee Valley Research and Extension Center, Belle Mina.
2. Sand Mountain Research and Extension Center, Crossville.
3. North Alabama Horticulture Research Center, Cullman.
4. Upper Coastal Plain Agricultural Research Center, Winfield.
5. Chilton Research and Extension Center, Clanton.
6. Piedmont Substation, Camp Hill.
7. Prattville Agricultural Research Unit, Prattville.
8. Black Belt Research and Extension Center, Mari
9. Lower Coastal Plain Substation, Camden.
10. Monroeville Agricultural Research Unit, Monroev
11. Wiregrass Research and Extension Center, Hea
12. Brewton Agricultural Research Unit, Brewton.
13. Ornamental Horticulture Research Center, Sprin
14. Gulf Coast Research and Extension Center, Fair