Fish farm management and microcontroller based aeration control system

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Abstract: Fisheries are required to grant convenient environmental conditions for fish growth with minimum cost afford. Providing these environmental conditions should essentially correlate fish type, pond dimensions, water properties, and weather conditions to the fish growth rate, feeding and metabolism. The large uncertainty margin of such parameters relations and effects drives the farmers to have economically inefficient practices in their farms. The present work was divided into two parts. The first part introduced an interactive Microsoft Excel spreadsheets as a decision support system (DSS) for the purposes of fish farm area planning according to the different required purposes of ponds, water evaluation to insure the most suitable environment of fish growth, and mechanical aeration management. The design of this DSS took the simplicity of required input data and data output into consideration. The second part was a microcontroller based open loop control system for mechanical aeration process based on the calculations of the DSS. The aeration management part input and output data fed to the control system with a specially developed program using µC-language. This program performs the calculations of aeration requirements and energy demands based on the DSS calculations. Furthermore, the controller had the feature of working from isolated power supply or in collaboration with renewable energy system. These utilities have been created to be suitable for three fish types, which are Mullet, Tilapia, and Carp fish. These types have a wide acceptance in the aquaculture activities under warm water conditions. The data obtained from the calculations of the spreadsheet under simulated and real field conditions were compared to a reference data. The spreadsheet showed an agreement with the reference values. The control systems succeed to operate 1hp-3phase induction motor for a time that was identical to the required aeration time calculated through the DSS. It was recommended to rely on the created DSS and the control system for farm area planning, water environment evaluation, and mechanical aeration management and operation. In addition, improvements for the control system should be carried out to be a real-time system especially with water quality parameters considering system power requirements and operating costs.

Keywords: control system, fish farm, management, microcontroller, aeration

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1 Introduction

Production in capture fisheries is stagnate and aquaculture output is expanding faster than any other animal-based food sector worldwide (FAO, 2006). This sector alone contributes nearly a third of the world's supply of fish products (Mallya, 2007). There is a need for utilities to help the fish farmers especially callow ones to manage and plan their farms and equipments they use. Farmers, planners, and managers will go through a decision-making process for all items related to fish farming activity. The decision-making process typically requires some expertise on the part of the planner, manager or extension agent. Operational research (OR) is the use of the applications of advanced analytical methods to help the managers to take better and quicker decisions. It increases the number of alternatives, helps the managers to evaluate the risk and results of all the

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alternative decisions. So, OR makes the decisions more effective. Bjorndal et al. (2004) reviewed different OR tools applied to fishery and aquaculture. Decision support systems (DSSs) add the use of interactive software to the OR tools. DSSs have emerged as a computer-based approach to assist decision-makers in addressing problems by allowing them to access and use data and analytic models. DSSs may introduce an acceptable solution for callow farmers to follow and evaluate their planning and management processes. DSSs that have been developed for aquaculture can be classified into two broad categories, farm management-planning tools (Gempesaw et al., 1992; Ernst et al., 1993; Lannan, 1993; Silvert, 1994; Itoga and Brock, 1995; Ernst et al., 2000) and macro-economic tools (Pedini et al., 1995; El-Gayar and Leung, 1996). Seginer and Halachmi (2008) mentioned that most of management tools did not have the ability to deal with particular management, but just made a comparison between different management scenarios to decide which is better. These systems should save time and power that will result in culture cost reduction. Halachmi et al. (2005) advised to develop commercial software to enable persons with no simulation or programming expertise to conduct simulation experiments. El Nemr et al. (2012) designed and developed a DSS for mechanical aeration management purpose. They recommended using their DSS output data with a control system to facilitate the operation of mechanical aerators. The purpose of applying process control technology to aquaculture encompasses many socioeconomic factors, including variable climate, high labor costs, increased competition for dwindling water and land resources and an unsympathetic regulatory bureaucracy (Lee, 2000). Applications of control technology process included algae and food production (Rusch and Malone, 1991 and 1993), feed management (Hoy, 1985), and filtration systems (Whitson et al., 1993; Lee et al., 1995; Turk et al., 1997). It also covers vision systems (Whitsell and Lee, 1994; Whitsell et al., 1997), environmental monitoring and control (Hansen, 1987; Ebeling, 1991, 1993; Munasinghe et al., 1993), and integrated system management (Lee, 1991, 1993; Lee et al., 1995; Turk et al., 1997). Several models incorporating the biochemical mechanistic characterization and physical bioprocesses in ponds are available in literature (Cathcart and wheaton, 1987; Losordo, 1988; Losordo and piedraheta, 1991). The objectives of the present work are: I) designing and developing a spreadsheet working as a management-planning DSS for different fish farms' management purposes including farm area planning, pond's water environment evaluation, and mechanical aeration process management. II) Using low-cost control system based on the developed DSS mechanical aeration output data to help the farmers in operating their aerators.

2 Materials and methods

2.1 DSS and control system general description

This work was divided into software and hardware parts. Software part included designing and developing interactive software to create a DSS that helps the decision maker of aquaculture systems in planning farm area, evaluate the pond's water environment, and managing the mechanical aeration process. This design of the software was considered the first step for controlling the aeration process, which is considered one of the most important operations that affect the fish production and directly related to energy and financial resources consumption. The hardware part was a microcontroller based control system to synchronize the mechanical aerator(s) operation time with that calculated by the DSS. This study was conducted as a part of the research work plan for the "Small Wind Turbines in Rural and Urban Environment Project (SWTRUE)". The project is cooperative work between German and Egyptian Partners. The Egyptian side is funded by the Science and Technology Development Fund (STDF), Egyptian Ministry of High Education. In this project, the integration of power generated from wind and its use in fishery activities was proposed. Figure 1 shows the basic concept of the project. The main principle is that a small wind turbine would generate diminutive amount of energy compared to water-exchange energy requirements. However, it would be suitable for the short time – discontinuous aeration operation. For coordination between the discontinuous energy generation from wind and the aerator demands, a battery system was placed as energy buffer. Backup Diesel system has been also provided. The full system consists of turbine, electrical generator, generator, tower, power converter, and its control circuits, batteries, aerator controller, switchgears, aerator and emergency Diesel generator. In addition, accessories and measurement meters are required. Typical experimental rig is designed, manufactured and installed in village 69 (31°29′N-31°4′ E-2.13 m Altitude), Kafrelsheikh governorate, North of Egypt. The next sections will present the essential theory and considerations deployed to develop the software utility –the spreadsheets- and hardware utility namely the aeration controller.

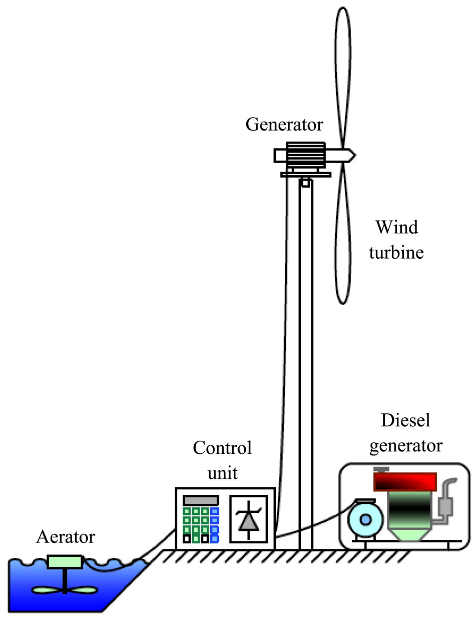


Figure 1 Schematic diagram for the basic concept of SWTRUE project

2.2 Considerations of systems' design

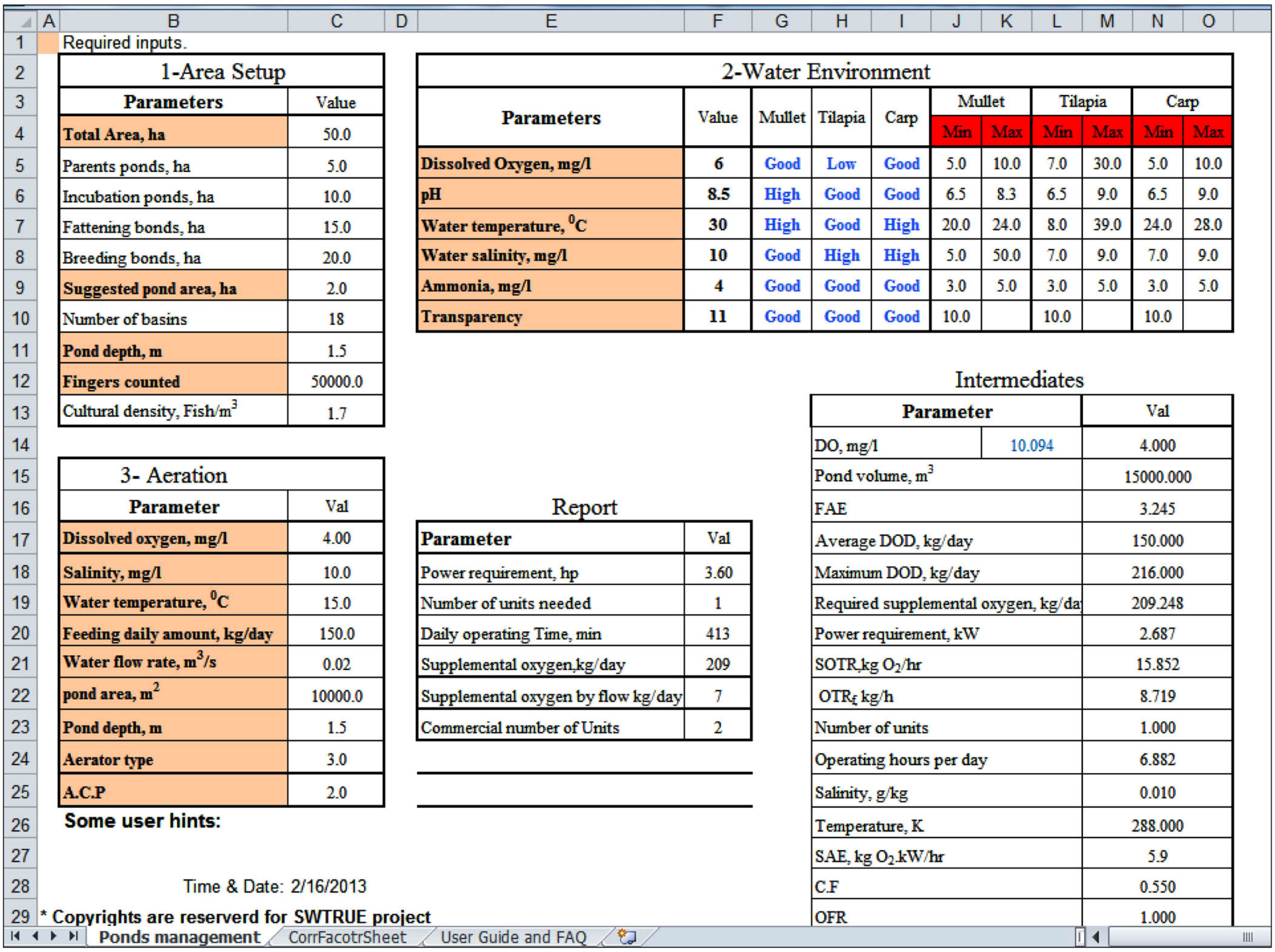
The DSS was designed to provide the user(s) with the following features: I- user friendly software that is applicable where appropriate for both computers and mobile devices to enable farmers, planners, and/or managers to use this application during field visits; II-keeping away from the need of huge or complicated input data; III-Provided with a help guide to improve the familiarity of the users with the system; and IV-one page reporting for the studied case results, supported with time and date in order to provide the farmers, planners, and managers with records they may need in the future. The portability of MS-Excel across devices and platforms such as computers, websites and mobile phones has encouraged the extension of the spreadsheets capabilities to provide scientific support for farmer decision making during the stages of planning and management of farm resources including land, water and energy. The aeration control system was designed to work as an open loop control system due to the cost and/or unreliability of sensors and associated equipment. Most automated aquaculture systems do not attempt to monitor and control all the important water environment parameters like dissolved oxygen, temperature, ammonia, alkalinity, etc. (Fowler et al. 1994). They recommended to depend on monitoring the dissolved oxygen and temperature directly as they rapidly change.

2.3 Software

2.3.1 Spreadsheets design and development

A Microsoft Excel 2007 workbook had been designed and developed in order to plan the farm area, evaluate fish ponds' water environment, and manage the different types of mechanical aerators used in fish farms. Water environment evaluation and mechanical aeration parts were suitable for three types of fish species, Tilapia, Mullet, and Carp fish. The management of mechanical aeration process includes time of operation (T_o), number of aerator units needed (*NU*), power requirements (P_i), field oxygen transfer rate (OTR_f), and expected field aeration efficiency (*FAE*).

The workbook was composed of three worksheets that were named ponds management (Figure 2), correction factor, and user guide. User guide worksheet is a user help work sheet (Figure 3) to point out the used abbreviations and their meanings, besides describing how the user can deal with the spreadsheet systematically. The ponds management worksheet is composed of five parts, three editable parts that were named area setup, water environment, and aeration. The other two parts were mainly for aeration management output data. Intermediates part will show the calculated intermediates' values, which will be used to obtain the final mechanical aeration output data that will be shown in the report part (Figure 2). The Intermediates and report parts are non-editable by the user. Required input data of each editable part will be shown in the following sections.



Required inputs.

1-Area Setup	
Parameters	**Value**
Total Area, ha	50.0
Parents ponds, ha	5.0
Incubation ponds, ha	10.0
Fattening bonds, ha	15.0
Breeding bonds, ha	20.0
Suggested pond area, ha	2.0
Number of basins	18
Pond depth, m	1.5
Fingers counted	50000.0
Cultural density, Fish/m^3	1.7

2-Water Environment										
Parameters	Value	Mullet	Tilapia	Carp	Mullet Min	Mullet Max	Tilapia Min	Tilapia Max	Carp Min	Carp Max
Dissolved Oxygen, mg/l	6	Good	Low	Good	5.0	10.0	7.0	30.0	5.0	10.0
pH	8.5	High	Good	Good	6.5	8.3	6.5	9.0	6.5	9.0
Water temperature, ^{0}C	30	High	Good	High	20.0	24.0	8.0	39.0	24.0	28.0
Water salinity, mg/l	10	Good	High	High	5.0	50.0	7.0	9.0	7.0	9.0
Ammonia, mg/l	4	Good	Good	Good	3.0	5.0	3.0	5.0	3.0	5.0
Transparency	11	Good	Good	Good	10.0		10.0		10.0	

3- Aeration	
Parameter	Val
Dissolved oxygen, mg/l	4.00
Salinity, mg/l	10.0
Water temperature, ^{0}C	15.0
Feeding daily amount, kg/day	150.0
Water flow rate, m^3/s	0.02
pond area, m^2	10000.0
Pond depth, m	1.5
Aerator type	3.0
A.C.P	2.0

Report

Parameter	Val
Power requirement, hp	3.60
Number of units needed	1
Daily operating Time, min	413
Supplemental oxygen,kg/day	209
Supplemental oxygen by flow kg/day	7
Commercial number of Units	2

Intermediates

Parameter		Val
DO, mg/l	10.094	4.000
Pond volume, m^3		15000.000
FAE		3.245
Average DOD, kg/day		150.000
Maximum DOD, kg/day		216.000
Required supplemental oxygen, kg/da		209.248
Power requirement, kW		2.687
SOTR,kg O_2/hr		15.852
OTR_f kg/h		8.719
Number of units		1.000
Operating hours per day		6.882
Salinity, g/kg		0.010
Temperature, K		288.000
SAE, kg O_2.kW/hr		5.9
C.F		0.550
OFR		1.000

Some user hints:

Time & Date: 2/16/2013

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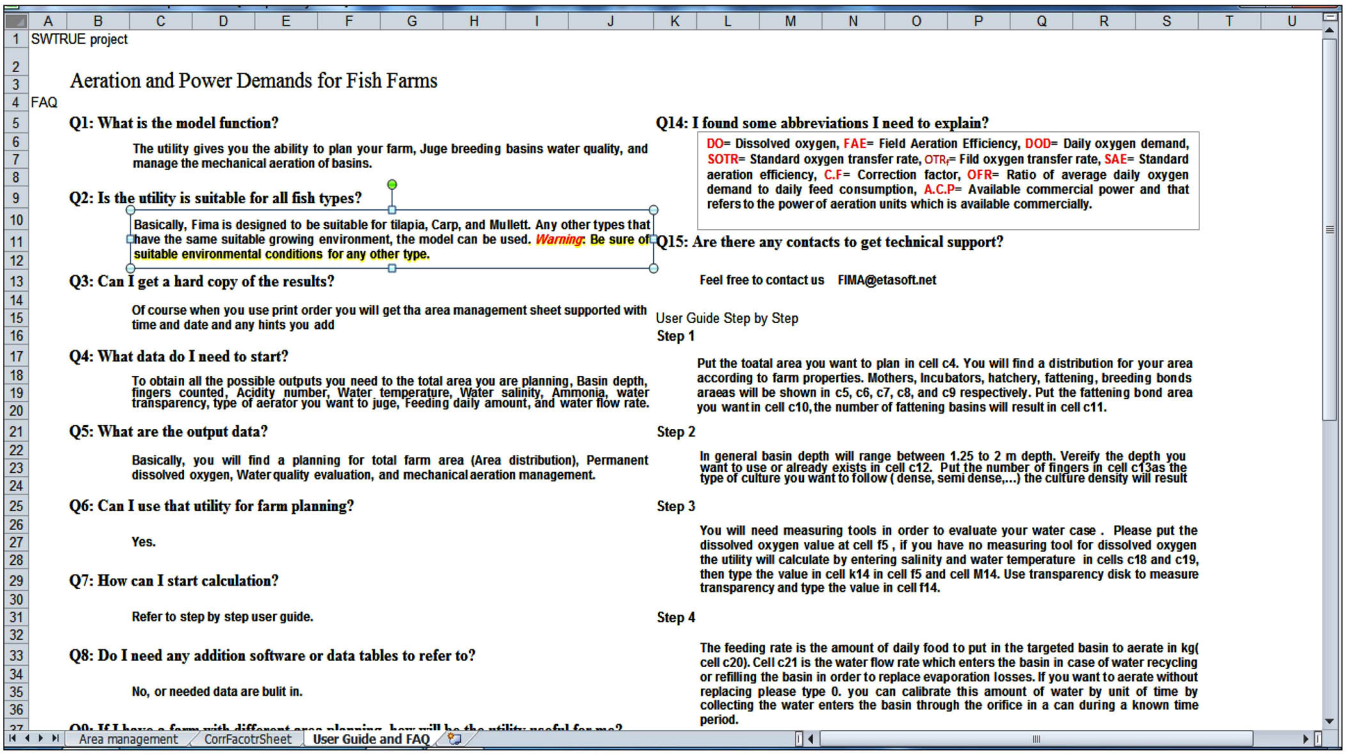
Figure 2 Management worksheet



SWTRUE project

Aeration and Power Demands for Fish Farms

FAQ

Q1: What is the model function?

The utility gives you the ability to plan your farm, Juge breeding basins water quality, and manage the mechanical aeration of basins.

Q2: Is the utility is suitable for all fish types?

Basically, Fima is designed to be suitable for tilapia, Carp, and Mullett. Any other types that have the same suitable growing environment, the model can be used. *Warning*: Be sure of suitable environmental conditions for any other type.

Q3: Can I get a hard copy of the results?

Of course when you use print order you will get tha area management sheet supported with time and date and any hints you add

Q4: What data do I need to start?

To obtain all the possible outputs you need to the total area you are planning, Basin depth, fingers counted, Acidity number, Water temperature, Water salinity, Ammonia, water transparency, type of aerator you want to juge, Feeding daily amount, and water flow rate.

Q5: What are the output data?

Basically, you will find a planning for total farm area (Area distribution), Permanent dissolved oxygen, Water quality evaluation, and mechanical aeration management.

Q6: Can I use that utility for farm planning?

Yes.

Q7: How can I start calculation?

Refer to step by step user guide.

Q8: Do I need any addition software or data tables to refer to?

No, or needed data are bulit in.

Q14: I found some abbreviations I need to explain?

DO= Dissolved oxygen, FAE= Field Aeration Efficiency, DOD= Daily oxygen demand, SOTR= Standard oxygen transfer rate, OTR_f= Fild oxygen transfer rate, SAE= Standard aeration efficiency, C.F= Correction factor, OFR= Ratio of average daily oxygen demand to daily feed consumption, A.C.P= Available commercial power and that refers to the power of aeration units which is available commercially.

Q15: Are there any contacts to get technical support?

Feel free to contact us FIMA@etasoft.net

User Guide Step by Step

Step 1

Put the toatal area you want to plan in cell c4. You will find a distribution for your area according to farm properties. Mothers, Incubators, hatchery, fattening, breeding bonds araeas will be shown in c5, c6, c7, c8, and c9 respectively. Put the fattening bond area you want in cell c10, the number of fattening basins will result in cell c11.

Step 2

In general basin depth will range between 1.25 to 2 m depth. Vereify the depth you want to use or already exists in cell c12. Put the number of fingers in cell c13as the type of culture you want to follow (dense, semi dense,...) the culture density will result

Step 3

You will need measuring tools in order to evaluate your water case . Please put the dissolved oxygen value at cell f5 , if you have no measuring tool for dissolved oxygen the utility will calculate by entering salinity and water temperature in cells c18 and c19, then type the value in cell k14 in cell f5 and cell M14. Use transparency disk to measure transparency and type the value in cell f14.

Step 4

The feeding rate is the amount of daily food to put in the targeted basin to aerate in kg(cell c20). Cell c21 is the water flow rate which enters the basin in case of water recycling or refilling the basin in order to replace evaporation losses. If you want to aerate without replacing please type 0. you can calibrate this amount of water by unit of time by collecting the water enters the basin through the orifice in a can during a known time period.

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Figure 3 User guide worksheet

Figure 4 shows the data flow diagram of the DSS. It describes the sources of input data and paths they go through to show the output data for the users. The input data was classified into three types according to the source, I) farm data II) literature data III) field measurements. The farm data included total farm area and suggested breeding pond area. These data will be used directly for farm area planning. The literature data included the relationship between initial dissolved oxygen content (DO_{in}) and water temperature (T) in addition to the optimal ranges of water environmental evaluation parameters. The relationship between DO_{in} and T will go through numerical linear interpolation to obtain the correction factor (*c.f*) value, which will be stored as an intermediate parameter to obtain the mechanical aeration management output data. El Nemr et al. (2012) listed the different values of *c.f* cited from the nomograph introduced by Boyd (1998). They used linear interpolation to find in-between values which can't be found directly from the listed *c.f* values. The third type of information is the field measurements, which included DO_{in}, pH, T, salinity (S), Ammonia (NH_3), and transparency that will be used for the aeration management process, besides being compared with the optimal ranges of water environment parameters for evaluation. Transparency evaluation was designed to be compatible with Secchi desk method (Stickney, 2000).

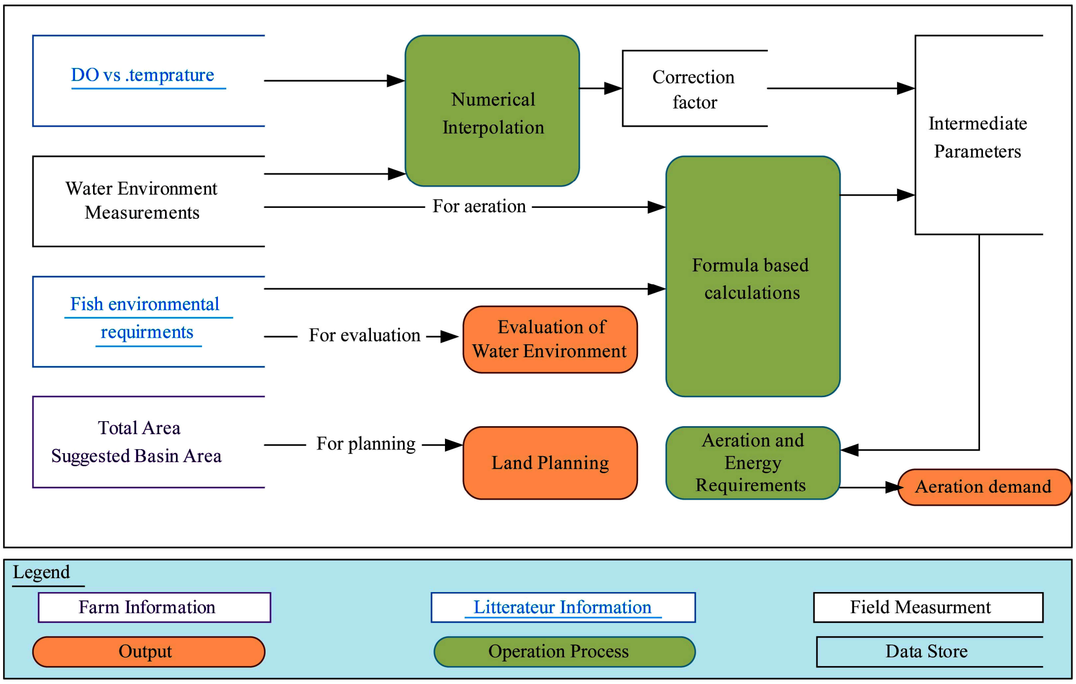

Figure 4 Data Flow Diagram (DFD) of the MS-Excel Workbook.

2.3.1.1 Farm area planning

The part of farm area planning introduces a suggestion for the user about how to plan and distribute his farm area according to different purposes of ponds, and what percentages they should act from the total farm area. The user will input total farm area in hectares to get the suggested area of parents' ponds, incubation ponds, fattening and breeding ponds as shown in area setup part (Figure 2). Table 1 lists the suggested farm area distribution planning referring to (Kaoud, 2003).

Table 1 Suggested farm area distribution based on ponds' purposes

Pond type	Symbol of pond area	Percentage of total farm area/%
Parents ponds	A_{PP}	10
Incubation ponds	A_{IP}	20
Fattening ponds	A_{FP}	30
Breeding ponds	A_{BP}	40

Note: source: (Kaoud, 2003).

The user can suggest the pond depth and area of breeding and fattening ponds. The spreadsheet will offer the number of ponds for fattening and breeding by dividing summation of A_{BP} and A_{FP} by the suggested pond area. By entering the decided number of fingers in the pond, the density of culture will be calculated by dividing number of fingers by pond volume (V_p).

2.3.1.2 Water environment evaluation

The water environment evaluation parameters included *DO*, *pH*, *T*, *S*, NH_3, and water transparency. These values will be entered respectively in cells F5-F10 as shown in Figure 2. The water environment evaluation part was designed referring to the recommended optimal ranges for the previously mentioned parameters by (Kaoud, 2003) that are listed in Table 2.

Table 2 Recommended optimal ranges for suitable water-environment evaluation parameters

Indicator	Symbol	Measuring unit	Optimal range		
			Tilapia	Mullet	Carp
Dissolved oxygen	DO	mg l^{-1}	7-30	5-10	5-10
pH	pH	—	6.5-9	6.5-8.3	6.5-9
Water temperature	T	℃	8-39	20-24	24-28
Water salinity	S	mg l^{-1}	7-9	5-50	7-9
Ammonia	NH_3	mg l^{-1}		3-5	
Transparency	—	cm		≥10	

2.3.1.3 Mechanical aeration management

The mechanical aeration management covers the most known types of aerators including paddle wheels, propeller-aspirator pumps, vertical pump, sprayer, and diffusion aerators. The mechanical aeration management part calculations of the spreadsheet were cited from El Nemr et al. (2012). The input data included DO_{in}, *T*, *S*, daily feeding consumption (*R*), water inlet flow rate Q_w, pond area (A_p), and d_p. There are two options in the spreadsheet for entering DO_{in} value. The user has the opportunity to enter the DO_{in} mg l^{-1} directly if known by any dissolved oxygen-measuring tool, or predicting DO_{in} in the pond by entering *S* and *T* in Equation (1) (Weiss, 1970):

$$\ln(DO_{in}) = A_1 + A_2(100/T) + A_3\ln(T/100) + A_4(T/100) + S[B_1 + B_2(T/100) + B_3(T/100)^2] \quad (1)$$

where, ln is the natural logarithm; DO_{in} /mg l^{-1}; *A* and *B* are constants. *A* and *B* constants' are shown in Table 3.

Table 3 Constants A and B in Equation (1)

A_1	-173.4292	B_1	-0.033096
A_2	249.6339	B_2	0.014259
A_3	143.3483	B_3	-0.001700
A_4	-21.8492		

Note: source: (Weiss, 1970).

The predicted value of DO_{in} will appear in the merged cells K14 and L14. In Equation (1) the value of *T* should be in kelvin (°K). The measured DO_{in} will be entered in cell C17 and it will be pasted automatically to cell M14 in intermediates part (Figure 2). The spreadsheet will convert the entered *T* value from ℃ to °K (°K =℃+273) to be applied in Equation (1). In order to help the farmer to choose the most suitable aerator type according to the entered data of his farm ponds conditions based on the *FAE*, and/or *Pi*, and/or OTR_f. The user will enter a code from 1 to 5 to indicate one of the known aerator types. This code will be used to pick the standard aeration efficiency (*SAE*) for the chosen type in the calculation process as is shown in Table 4.

Table 4 SAE values for different aerator types /kg O_2.kW^{-1}h^{-1}

Aerator type (code)	Average of SAE
Paddle wheel, all types (1)	9.145
Propeller-aspirator pump (2)	6.785
Vertical pump (3)	5.900
Pump sprayer (4)	5.600
Diffusion (5)	3.835

Note: source: (Boyd, 1998).

The OTR_f and *FAE* were calculated according to Equations (2) and Equation (3) (Boyd, 2010):

$$OTR_f = SOTR\ X\ c.f \quad (2)$$

$$FAE = SAE\ X\ c.f \quad (3)$$

where, OTR_f /mg h^{-1}, *SOTR* /mg h^{-1}. The different values of c.f were automated using Visual Basic code as macros. The user will enter the given values of DO_{in} and *T* in order to get the correction factor value automatically, which will be used directly in calculations (Figure 5). The user will be notified if the *c.f* value was found to insure entering correct values of water temperature and initial dissolved oxygen inside the limits of *DO* and *T* showed by Boyd (1998) and El Nemr et al. (2012).

Temp	DO, ppm	Factor	Note	
29.5	2	0.71	Found	Acceptable

Water Temp, C	DO,ppm 0	1	2	3
4	0.92	0.85	0.79	0.71
5	0.92	0.85	0.78	0.7
6	0.92	0.85	0.76	0.69
7	0.91	0.84	0.76	0.68
8	0.91	0.83	0.75	0.68
9	0.91	0.83	0.75	0.68
10	0.91	0.82	0.74	0.68
11	0.91	0.82	0.74	0.67
12	0.91	0.82	0.74	0.67
13	0.91	0.81	0.73	0.66
14	0.91	0.81	0.73	0.65
15	0.91	0.81	0.72	0.64
16	0.91	0.81	0.72	0.63
17	0.91	0.81	0.72	0.63
18	0.91	0.81	0.72	0.62
19	0.92	0.81	0.72	0.62
20	0.92	0.81	0.72	0.61
21	0.93	0.81	0.72	0.61
22	0.93	0.82	0.72	0.61
23	0.94	0.82	0.72	0.61
24	0.94	0.82	0.72	0.6
25	0.94	0.82	0.72	0.6
26	0.95	0.82	0.72	0.59
27	0.96	0.83	0.72	0.59
28	0.96	0.83	0.72	0.59
29	0.97	0.83	0.71	0.59
30	0.97	0.84	0.71	0.59
31	0.98	0.85	0.71	0.58
32	0.99	0.85	0.71	0.58

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Figure 5 Correction factor auto finding worksheet

Standard oxygen transfer rate (*SOTR*) was calculated according to the following Equation (4) and Equation (5) (Colt, 2000):

$$SOTR = SAE\ X\ P_i \quad (4)$$

$$P_i = O_S / FAE \quad (5)$$

where, P_i is total power delivered (kW), and O_s is supplemental oxygen kg d^{-1}. There is a need for water supply from an outside source to the fishpond in order to replace the evaporation water loss or to cure any change in water chemical or physical specifications that may undesirably affect the fish production. This water will provide the pond with additional oxygen content. O_S is the supplemental oxygen needed by mechanical aerator (kg d^{-1}) which equals difference between total oxygen demand and the outside water oxygen transfer as follows (Equation (6)):

$$O_S = 1.44(OFR\ X\ R) - 84.4X\ Q_w(DO_{out} - DO_{in}) \quad (6)$$

where, DO_{out} is the effluent *DO* concentration (mg l^{-1}) and assumed to be 8 mg l^{-1} as safe value for all the targeted fish types (Kaoud, 2003), *OFR* is the Oxygen: feed ratio which is the ratio of average daily oxygen demand (kg) to daily feed consumption (kg), and *R* is daily feed consumption (kg d^{-1}), and Q_w is the inlet water flow rate ($m^3\ s^{-1}$). If there was no outside supplemental oxygen, the value of Q_w will be entered as zero. Number of needed aeration units (*NU*) was calculated according to Equation (7) as follows:

$$NU = O_S / OTR_f \quad (7)$$

The *OFR* was assumed 1.0 as a suitable value for warm water fish types (Colt, 2000). Aerator operation time T_o was calculated using the following Equation (8):

$$T_o = (DO_{out} - DO_{in})V_p / OTR_f \quad (8)$$

where, V_p/m^3. If the DO_{in} value ≥8 mg l^{-1}, the user will get a hint directly that "no aeration needed" and the operation time will be zero. If the calculated power of aerator is not available in markets, users can put directly the nearest available power specification in markets to modify the number of units needed according to the entered market data. The required data for mechanical aeration management will be entered in the part called aerator and the elements of the previously mentioned equations will be entered c17-c25 as is shown in Figure 2.

2.4 Hardware

The control system was designed mainly to use the DSS aerator operation time data to be applied in the ponds mechanical aeration purpose. The hardware implementation of the described system would require input/output data storage and processing. Several varieties are available in markets to perform similar tasks with reasonable cost. These include economical programmable logic controllers (PLC), microcontroller-based systems, and digital signal processing modules. The comparison between these controllers is based on the efficient utilization of available functions. Alongside, the low power consumption is a critical factor of selection criteria that the system is proposed to the isolated rural areas. Hereby, economical microcontroller-based system with sufficient memory and input/output requirements is nominated. The selected microcontroller is Microchip-PIC16F877A with 40 pins and enhanced flash memory. The flash memory is required to allow literature and measurements data storage. The FEPSP3 development kit was utilized for development and testing. The kit is supported with two line text screen, keypad, input/output switches and variable resistor. Figure 6 shows a block diagram for the main components of the microcontroller kit and its interaction with aeration-control system components. A program is specially developed using µC-language. The program performs the calculations of aeration requirements and energy demands. In consequence, it performs the *c.f* interpolation. The controller is used to operate an industrial inverter (LS Startvert IC5 AC) that drives 1hp, 3-phase induction motor, which is a typical load of aerator motor. Several scenarios were tested on the hardware controller system in comparison to the MS-Excel software utility. Good correspondence was found in terms of calculation accuracy and consistency. In addition, accurate operation timing was achieved for starting and operation period. Switching between manual and automatic modes of operation provided adequate performance that satisfies the design objectives. The hardware topology allows for the operating four units simultaneously. It should be noted that, the controller will serve the aerators regardless of their rates or similarities.

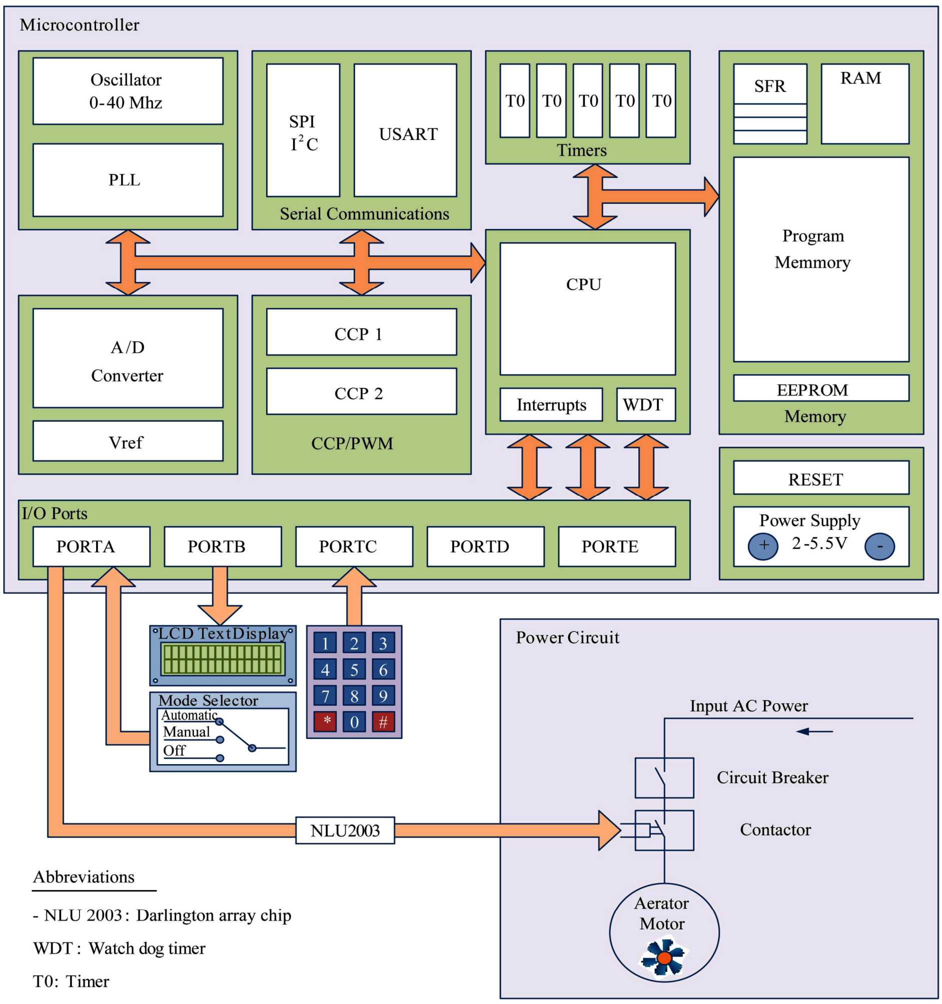

Figure 6 Block diagram of control system components

2.5 System data flow chart

Figure 7 shows the data flow chart of the control system and different operation modes of aeration systems. The user has two operation modes to control the mechanical aerator. The user has to choose between manual mode and automatic mode. Automatic mode leads to operate the mechanical aerator for a certain time defined by the user. The user will be asked in the automatic mode to choose between entering the DO_{in} value directly or using the DO_{in} prediction feature with a known salinity and water temperature values. The system will require entering the rest of the necessary data for calculating the operation time to be entered as is shown in section 2.3.1.3. The type of aerator will be entered as a code as is shown in Table 4. If DO_{in}< 8 mg l^{-1} the aeration process will start depending on the calculated aeration time till the end of the loop.

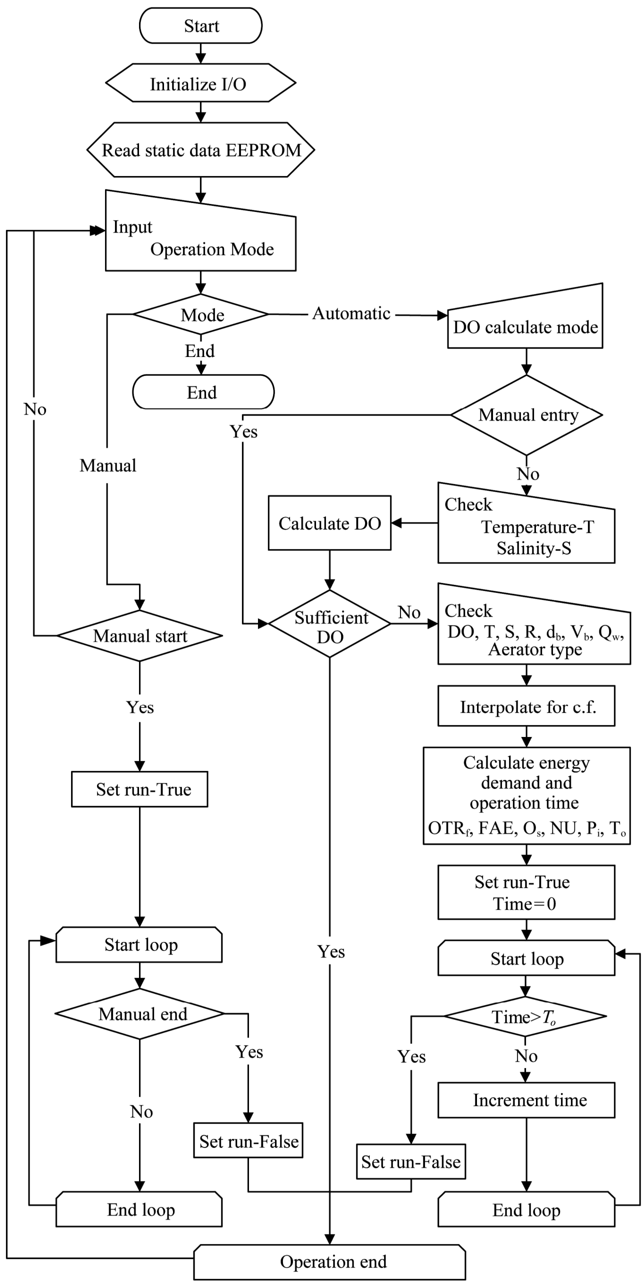

Figure 7 Data flow chart

2.6 DSS and control system validation

The validation of the DSS for the aeration management process was examined under field conditions (El Nemr et al., 2012). Field experiments on mechanically and non-mechanically aerated ponds were conducted to examine the validation of the spreadsheet under fishponds field conditions. Mechanically aerated ponds managed by this DSS showed an increase in the fish production by 3.3%, besides saving 61.80% of water exchanged in ponds compared to non-mechanically aerated ponds. For testing the control system ability to run the load of aerator for a certain calculated time, a laboratory test was conducted based on simulation field data. The assumed data was a vertical pump aerator type working in 1 ha pond, 1.5 m depth with 4 mg l^{-1} DO_{in}, 10 mg l^{-1} salinity, and 15℃ water temperature with inlet water supply at zero, and 0.02 m^3 s^{-1} flow rates. The feeding daily amount was assumed 150 kg d^{-1}. The calculated time of the control system was compared to the motor rotation time to evaluate the accuracy of the control system to operate the load for a certain time.

3 Results

3.1 Farm area planning

A farm of 50 ha was assumed to check the DSS accuracy for the total farm area planning. Table 5 shows the results of the DSS calculations for the simulated 50 ha area. Parents, incubation, fattening, and breeding ponds' areas act 10, 20, 30, and 40% of the total assumed area.

Table 5 DSS calculation results for a 50 ha area planning

Pond type	Area / ha
A_{PP}	5
A_{IP}	10
A_{FP}	15
A_{BP}	20

3.2 Water environment evaluation

Values for DO_{in}, pH, T, S, NH_3 and transparency were entered to the DSS to check the system response for evaluating different values for the previously mentioned water quality parameters. Random values 6, 8.5, 30, 10, 4, and 11 considering measuring units were entered respectively to simulate the water environment evaluation parameters as is shown in Figure 2. The Data listed in Table 6 shows the program response for evaluating the parameters of water environment quality. There was a different evaluation for all parameters according to the recommended value for each type of fish. There was an agreement between the control unit evaluation and recommendations of (Kaoud, 2003).

Table 6 Water environment parameters values evaluation by the control system

Parameters	Value	Mullet	Tilapia	Carp
Dissolved Oxygen / mg l^{-1}	6	Good	Low	Good
pH	8.5	High	Good	Good
Temperature /℃	30	High	Good	High
Salinity /mg l^{-1}	10	Good	High	High
Ammonia /mg l^{-1}	4	Good	Good	Good
Transparency	11	Good	Good	Good

3.3 Aerator management

Table 7 shows the results obtained from the DSS for the simulated cases under mg l^{-1} DO_{in}. Correction factor resulted value was 0.55 in these case studies for the DO_{in}, 4 mg l^{-1} and 15℃ water temperature. Calculations showed that there was a response from the system to the change of external water supply flow rate. There was a decrease in power requirement by the existence of external water feeding into assumed pond conditions. The decrease in power requirement led to an increase in operation time. The motor rotation time started by the control system was identical to the system calculations.

Table 7 Calculated operation time and motor operation time resulted from the simulation of vertical pump aerator

Flow rate /m^3 s^{-1}	Power requirement /kW ha^{-1}	No. of Units	Aeration time/ min	Motor operation time/ min
0.0	3.72	1	400	400
0.02	3.60	1	413	413

4 Discussion

The results of farm area planning showed an agreement with the area planning recommended by (Kaoud, 2003). The water environment evaluation showed a response for changing the values of parameters of water environment for DO_{in}, pH, NH_3, T, S, and water transparency for the different types of fish Tilapia, Mullet, and Carp. The parameters values evaluation agreed with the optimal ranges for these parameters recommended by Kaoud (2003). El Nemr et al. (2012) checked the validation of this DSS for mechanical aeration management with a field study that was in agreement with reference data. The obtained c.f values in their study showed a variation of 2-4% of the c.f values showed by Boyd (1998) and Boyd (2010). There was also an agreement with (Boyd, 1998; Boyd and Tucker, 1998; and Tucker, 2005) in power requirement calculations. The field experiments conducted by (El Nemr et al., 2012) showed an increase of 3.3% in Tilapia fish production using a paddle wheel aerator managed by this DSS compared to a non-mechanically aerated pond. The control system succeeded to operate the load for a time that was identical to the calculated one. The increase in time of aerator operation in the case of external water supply, resulted from the decrease of power required due to the external oxygen supplement (Equation (5), Equation (6), Equation (7), and Equation (8)). The obtained results show that this DSS introduces a utility based on Microsoft Excel spreadsheets. This software does not need the experience of programing or complicated data processing in consistent with the recommendation of Halachmi, 2005 to introduce such features in DSS. The portability of MS-Excel across devices and platforms such as computers, websites and mobile phones may give this DSS the advantage of using widely spread software supported with the friendly user interface. The DSS also goes through particular management that does not go through different management scenarios but depending mainly on the real farm data in agreement with Seginer and Halachmi (2008) recommendation besides considering data simplicity. The success of the Microcontroller based control system to operate the load as decided for a certain time, may help the farmers specially callow ones to manage one of the most important aquaculture practices which directly affects fish production (Loyacano, 1974; Rapport and

Sarig, 1975; Parker, 1979; Plemmons, 1980; Holerman and Boyd, 1980; Boyd, 1998; Peterson and Walker, 2002). Using micro controller based control system will help in the reduction of power required for aeration process in addition to the low cost (Kaur, 2010). This means that the control system may help to operate different types of aerators in an economic way.

5 Conclusion

Interactive Microsoft Excel 2007 spreadsheets were successfully designed and developed to create a DSS. This DSS worked as a utility for different management purposes of fish farms, which included farm area planning, water environment evaluation, and mechanical aeration management. Microcontroller based control system was created for mechanical aeration operation purpose. The software and hardware were designed to be compatible with the environmental conditions of Tilapia, Mullett, and Carp fish types. The DSS worked successfully to suggest farm area distribution according to the different farming purposes consistently with the recommended planning. The system showed a response for different water environment parameters, which included water temperature, salinity, ammonia, acidity, dissolved oxygen, and transparency. The system gave a right evaluation for water environment based on the recommended optimal ranges for the mentioned different types of fish. A case study was assumed in order to test the ability of the control system to operate the aerator load that was act by a 1 hp 3-phase induction motor. The system operated the load identically with the calculated time. Need of some economic studies may appear to evaluate the economic impact of using such system on fish production profitability. In addition, it may be important to carry out other studies on energy consumption with the control system. It may be recommended to depend on the created DSS and the control system for farm area planning, water environment evaluation, and mechanical aeration management. There should be also tries and studies to develop the system to be a real-time system especially with water quality parameters that do not vary rapidly to give a continuous evaluation for the farmer about his farm needs.

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