Energy and Earth Science
Vol. 1, No. 1, 2018
www.scholink.org/ojs/index.php/ees
ISSN 2578-1359 (Print) ISSN 2578-1367 (Online)

Original Paper

Systems Design for Energy Demand by Optimal Utilization of Renewable Energy in Robust Aquaponic Systems

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Received: October 12, 2018 Accepted: November 8, 2018 Online Published: November 21, 2018
doi:10.22158/ees.v1n1p33 URL: http://dx.doi.org/10.22158/ees.v1n1p33

Abstract

In a debate with other reservoirs, ocean waves furnish an ample supply of clean, reliable, and decent energy, but this origin requires to be made a cost-effective fount for physical energy return. For this mission, the proposed membership functions are adopted and stabilization criterion of the closed-loop T-S fuzzy systems are obtained through a new parametrized LMI (linear matrix) inequality which is rearranged by machine learning membership functions.

Keywords

ocean waves, LMI, membership functions

1. Introduction

Wave energy can generate large amounts of clean, safe, reliable, and economical renewable energy, thus making it an attractive source to meet the rapidly growing demand for energy (Gericke, 1940). Although in its infancy, the wave energy industry is expected, similar to the offshore wind power industry, to become established in several Nordic countries because of the rapid growth in the past decade. Among the various renewable energy sources (such as solar, wind, and tidal power), wave energy has the highest power density and provides relatively continuous and reliable output, which is advantageous for the operation of the power grids (Klinger & Naylor, 2012). Some large devices are designed as shown in Fig. 1, which indicate the diversity of the practical applications in the ocean. The cost of tapping the wave energy has increased from the 1980s but gradually declined and is likely to further reduce with advances in the technology industry (Osmundsen, Almklov, & Tveterås, 2017). As energy costs from fossil fuels are exorbitant, wave energy could become economically feasible in the near future. Thus, policy-makers, the private sector, and the general public are interested in the conversion of wave energy into electrical energy. The two important steps in this process are (1) assessment of the ability of a site to produce electricity and (2) identification of surrounding ecosystems and the potential impacts and activities in support of electricity production (Read & Fernandes, 2003).

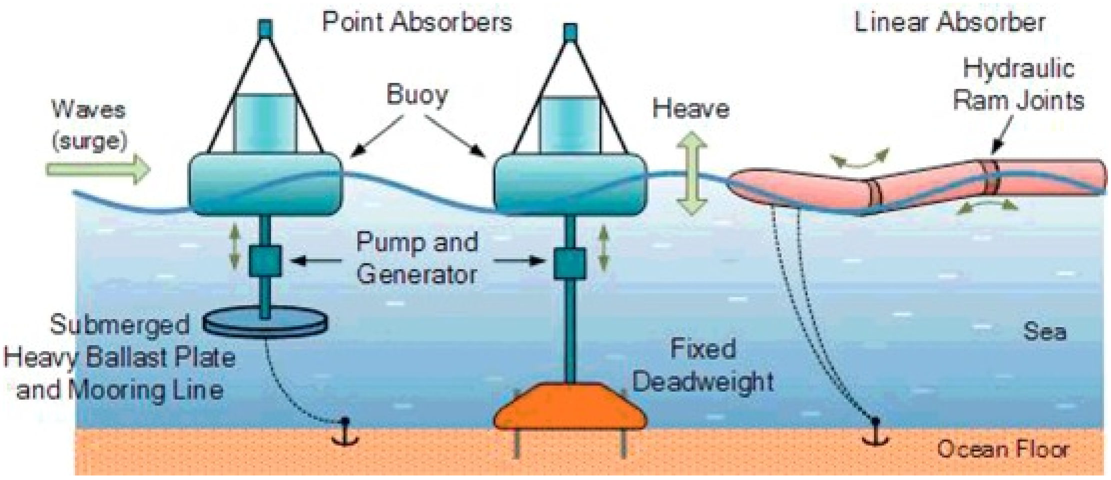

Figure 1. Wave Power Devices

While the waves may provide a source of clean and renewable energy, a wave energy conversion project may harm the protection of the marine species and habitats, and create a strategic conflict with the existing marine ecosystems. Wave energy conversion facilities and their potential impacts, including fishing, planktonic and benthic habitat; recreation; aesthetic point of view changes; hydrodynamic and wave environment; and navigational hazards were studied by (Bohl, 1977; Collins et al., 1975; Naegel, 1977). Many potential impacts are site specific, and the extent of these impacts on coastal and marine ecosystems is unclear, because the studies on the wave energy conversion projects are limited; hence, the concept is poorly understood. This knowledge gap hindered the development of practical equations to support wave energy projects related to marine spatial planning. An assessment of wave energy capacity of a site considers various factors such as wave energy resources, the characteristics of wave energy conversion device, the cost-effectiveness of energy conversion facility, locational constraints, and uses of the information on ecosystem properties or compatibility with others. Marine spatial planning is at a nascent stage in North America, and involves an interaction between the planners to consider the cumulative impact of the procedure on the coastal and marine space human activities (Sneed, Allen, & Ellis, 1975). Implementing the wave energy projects and efficient marine spatial planning requires a comprehensive framework that considers these various kinds of information. It is estimated that the wave power resources can help to identify potential sites of energy-rich areas and sustainable resources. Previous studies employed different scales to estimate the potential of wave power. For example, the global- and regional-scale studies have shown that the west coast of Europe (i.e., Ireland, Portugal, and Scotland), similar to the North American west coast (i.e., British Columbia, Washington, Oregon, and California), is the main area of wave energy projects because of its potential for abundant wave energy harvest, which can be used to meet the demands of high coastal population areas (Lewis, Yopp, & Schramm, 1978; Sutton & Lewis, 1982; Timmons & Ebeling, 2010). Previous research focused on a local scale to quantify near-shore wave energy resources and to identify hot spots in the field of wave energy (Mollison & Holmgren, 1981; Todd, 1980).

Different types of wave energy conversion device are used to extract energy from the waves, and various technologies are employed to calculate how much energy can be harvested as a function of the local wave condition change. For example, using a attenuator-type device (for example, sea snake, the Pelamis Wave Power, Edinburgh, Scotland) works more effectively in the Irish and Scottish region (Lewis, Yopp, & Schramm, 1978), where the wave height typically under high sea conditions aids in the estimation. In contrast, the terminator-type devices (for example, an oscillating water column device from Energetech Corporation, Utah, USA) work more efficiently on the west coast of North America (Zweig, 1986), where there is disposal of longer period waves (such as swelling).

In reality, a wave energy conversion efficiency of the device depends not only on the location of the potential energy to be harvested, but also on income and decisions related to the construction and operating costs of the facility. The economic value of the harvested wave energy facilitates to identify the specific location of energy conversion facility and to evaluate the potential tradeoff between the cost positioning factors related to the installation location, maintenance, and operation of the facility. While the ability to develop the harvest wave energy method is explored in (Lewis, Yopp, & Schramm, 1978; Sutton & Lewis, 1982; Zweig, 1986; McMurtry, Nelson, & Sanders, 1990), harvest wave energy does not provide explicit spatial information to assess the cost of wave site energy generation or the other associated estimates.

This study developed a wave energy conversion device to identify a potential site, which provides decision support equations for the policy-makers to respond to the challenges of wave energy projects related to integrated coastal and marine spatial planning. First, the study developed a model of wave energy as ecosystem services, and the tradeoffs (investment) equation (McMurtry, 1992) is a part of an integrated assessment (Rakocy 1984; Watten & Busch, 1984). The wave energy model by using ecosystem services is based on the framework of Talese and other researchers (Rakocy, 2012) and consists of three parts: (1) the model was based on wave conditions ("supply measures"), (2) the model used a wave energy conversion device to quantify the potential of wave power evaluation ("service standards") consisting certain technical information in harvesting energy, and (3) the utility of the model was evaluated as capital investment ("value index") to assess the economic value of wave energy conversion facilities. Second, the study conducted a compatibility analysis to determine the optimum compatibility between the wave energy conversion device and the existing uses of the oceans. Investment in an ecosystem service model, including wave energy in the model, is described here. This equation is used in many other coastal and marine spatial planning processes, and can be used for a variety of related marine renewable energy projects to support marine spatial planning (Rakocy, Masser, & Losordo, 2006).

2. Evaluation of the Formulas

The mathematical models of many physical and engineering systems are frequently of high dimension, or possessing interacting dynamic phenomena. The information processing and requirements to experiment with these models for control purposes are usually excessive. It is therefore natural to seek techniques that can reduce the computational effort. The methodologies of large-scale systems provide such techniques through the manipulation of system structure in some way. Thus, there has been considerable interest in the research area of modeling, analysis, optimization and control of large-scale systems (Mahmoud, Hassan, & Darwish, 1985). Recently, many approaches have been used to investigate the stability and stabilization of large-scale systems, as proposed in the literature (Routledge, 2015; Deutsch, Csordas, Sun, & Jarnuczak, 2017).

During the past several years, fuzzy-rule-based modeling has become an active research field because of its unique merits in solving complex nonlinear system identification and control problems. This approach can obtain more flexibility and more effective capability of handling and processing uncertainties in complicated and ill-defined systems. Unlike conventional modeling, fuzzy rule-based modeling is essentially a multimodel approach in which individual rules are combined to describe the global behavior of the system (Mei, Grossberg, Ng, Navarro, & Ellmore, 2017).

In this paper, we consider a fuzzy large-scale system composed of J subsystems with interconnections and each subsystem is represented by the so-called Takagi-Sugeno fuzzy model. One critical property of control systems is stability and considerable reports have been issued in the literature on the stability problem of fuzzy dynamic systems. However, a literature survey indicates that the stability problem of fuzzy large-scale systems has not yet been resolved. Hence, a stability criterion in terms of Lyapunov's direct method is proposed to guarantee the asymptotic stability of fuzzy large-scale systems.

3. System Description and Stability Analysis

Consider a fuzzy large-scale system F which consists of J interconnected fuzzy subsystems $F_j,\ j=1,2,\cdots,J.$ The jth fuzzy subsystem F_j is of the following form:

$$F_j : \begin{cases} x_j(k+1) = \sum_{i=1}^{r_j} h_{ij}(k) A_{ij} x_j(k) + \phi_j(k) & (1a) \\ \phi_j(k) = \sum_{\substack{n=1 \\ n \neq j}}^{J} C_{nj} x_n(k), & (1b) \end{cases}$$

where A_{ij} is a constant matrix with appropriate dimensions, $x_j(k)$ is the state vector, C_{nj} is the interconnection between the nth and jth subsystems, r_j is the number of fuzzy implications and $h_{ij}(k)$ is the normalized weight. Each isolated subsystem (i.e., $C_{nj} = 0$) of F is represented by a Takagi-Sugeno fuzzy model composed of a set of fuzzy implications and the final output of this fuzzy model is described as (Laurens, Batlolona, Batlolona, & Leasa, 2018)

$$x_j(k+1) = \sum_{i=1}^{r_j} h_{ij}(k) A_{ij} x_j(k). \tag{2}$$

Lemma 1 (Bohl, 1977): The jth isolated subsystem (2) is asymptotically stable if there exists a common positive definite matrix P_j such that

$$Q_{ij} \equiv A_{ij}^{\ T} P_j A_{ij} - P_j < 0 \quad \text{for} \quad i = 1, 2, \cdots, r_j. \tag{3}$$

Based on Lemma 1, a stability criterion is derived below to guarantee the asymptotic stability of the fuzzy large-scale system F.

Theorem 1: The fuzzy large-scale system F is asymptotically stable, if each isolated subsystem of F is asymptotically stable and the following inequality is fulfilled (Warsito & Herman, 2018; Wardono, Mariani, & Candra, 2016; Yuanita & Zakaria, 2016; Mulbar & Zaki, 2018; Meika, Suryadi, & Darhim, 2018):

$$\sum_{i=1}^{r_j} h_{ij}^2(k)\lambda_M(Q_{ij}) + \sum_{i<f}^{r_j} h_{ij}(k)h_{fj}(k)[\lambda_M(Q_{ij}) + \lambda_M(Q_{fj})] + \sum_{\substack{n=1 \\ n\neq j}}^{J}[\sum_{i=1}^{r_j} h_{ij}(k)m_{ijn} + \sum_{i=1}^{r_j} h_{in}(k)m_{inj}$$

$$+ (J-1)\lambda_M(P_n)\|C_{jn}\|^2] < 0 \quad \text{for} \quad 1 \le i < f \le r_j, \quad j = 1, 2, \cdots, J, \tag{4}$$

where f is a positive integral, $\lambda_M(Q_{ij})$ is the maximal eigenvalue of Q_{ij} defined in Eq. (3) and

$$m_{ijn} \equiv \left\|A_{ij}^T P_j C_{nj}\right\| + \left\|C_{nj}^T P_j A_{ij}\right\|, \quad m_{inj} \equiv \left\|A_{in}^T P_n C_{jn}\right\| + \left\|C_{jn}^T P_n A_{in}\right\|.$$

Proof: Let the Lyapunov function for the fuzzy large-scale system F be defined as

$$V(k)=\sum_{j=1}^{J}V_j(k)=\sum_{j=1}^{J}x_j(k)P_jx_j(k) \tag{5}$$

where P_j is the solution of Eq. (3). Taking the backward difference of V(k), we have

$$\Delta V(k)=V(k+1)-V(k)$$

$$=\sum_{j=1}^{J}\{[\sum_{i=1}^{r_j}h_{ij}(k)A_{ij}x_j(k)+\phi_j(k)]^T P_j[\sum_{f=1}^{r_j}h_{fj}(k)A_{fj}x_j(k)+\phi_j(k)]-x_j^T(k)P_jx_j(k)\}$$

$$=\sum_{j=1}^{J}\sum_{i=f=1}^{r_j}h_{ij}^2(k)x_j^T(k)(A_{ij}^TP_jA_{ij}-P_j)x_j(k)+\sum_{j=1}^{J}\sum_{i\neq f}^{r_j}h_{ij}(k)h_{fj}(k)x_j^T(k)(A_{ij}^TP_jA_{fj}-P_j)x_j(k)$$

$$+\sum_{j=1}^{J}\sum_{i=1}^{r_j}h_{ij}(k)x_j^T(k)A_{ij}^TP_j\phi_j(k)+\sum_{j=1}^{J}\sum_{f=1}^{r_j}h_{fj}(k)\phi_j^T(k)P_jA_{fj}x_j(k)+\sum_{j=1}^{J}\phi_j^T(k)P_j\phi_j(k)$$

$$=m_1+m_2+m_3+m_4+m_5, \quad \text{where} \tag{6}$$

$$m_1\equiv\sum_{j=1}^{J}\sum_{i=f=1}^{r_j}h_{ij}^2(k)x_j^T(k)(A_{ij}^TP_jA_{ij}-P_j)x_j(k)\le\sum_{j=1}^{J}\sum_{i=1}^{r_j}h_{ij}^2(k)\lambda_M(Q_{ij})x_j^T(k)x_j(k), \tag{7}$$

$$m_2\equiv\sum_{j=1}^{J}\sum_{i\neq f}^{r_j}h_{ij}(k)h_{fj}(k)x_j^T(k)(A_{ij}^TP_jA_{fj}-P_j)x_j(k)$$

$$=\sum_{j=1}^{J}\sum_{i<f}^{r_j}h_{ij}(k)h_{fj}(k)x_j^T(k)(A_{ij}^TP_jA_{fj}+A_{fj}^TP_jA_{ij}-2P_j)x_j(k)$$

$$=\sum_{j=1}^{J}\sum_{i<f}^{r_j}h_{ij}(k)h_{fj}(k)x_j^T(k)\{-[(A_{ij}-A_{fj})^TP_j(A_{ij}-A_{fj})]$$

$$+[A_{ij}^TP_jA_{ij}+A_{fj}^TP_jA_{fj}-2P_j]\}x_j(k)$$

$$\le\sum_{j=1}^{J}\sum_{i<f}^{r_j}h_{ij}(k)h_{fj}(k)[\lambda_M(Q_{ij})+\lambda_M(Q_{fj})]x_j^T(k)x_j(k), \tag{8}$$

$$m_3\equiv\sum_{j=1}^{J}\sum_{i=1}^{r_j}\sum_{n\neq j}^{J}h_{ij}(k)x_j^T(k)A_{ij}^TP_jC_{nj}x_n(k)\le\sum_{j=1}^{J}\sum_{i=1}^{r_j}\sum_{n\neq j}^{J}h_{ij}(k)\|x_j(k)\|\|A_{ij}^TP_jC_{nj}\|\|x_n(k)\|, \tag{9}$$

$$m_4 \equiv \sum_{j=1}^{J}\sum_{i=1}^{r_j}\sum_{n\neq j}^{J} h_{ij}(k)x_n^T(k)C_{nj}^T P_j A_{ij} x_j(k) \leq \sum_{j=1}^{J}\sum_{i=1}^{r_j}\sum_{n\neq j}^{J} h_{ij}(k)\|x_n(k)\|\|C_{nj}^T P_j A_{ij}\|\|x_j(k)\|, \quad (10)$$

$$\begin{aligned} m_5 &\equiv \sum_{j=1}^{J} \phi_j^T(k)P_j\phi_j(k) = \sum_{j=1}^{J}\{[C_{1j}x_1(k)+C_{2j}x_2(k)+\cdots]^T P_j[C_{1j}x_1(k)+C_{2j}x_2(k)+\cdots]\} \\ &\leq \sum_{j=1}^{J}[(J-1)\lambda_M(P_j)\|C_{1j}x_1(k)\|^2+(J-1)\lambda_M(P_j)\|C_{2j}x_2(k)\|^2+\cdots] \\ &= \sum_{j=1}^{J}\sum_{n\neq j}^{J}[(J-1)\lambda_M(P_j)\|C_{nj}x_n(k)\|^2] \\ &= \sum_{j=1}^{J}\sum_{n\neq j}^{J}[(J-1)\lambda_M(P_n)\|C_{jn}x_j(k)\|^2] \leq \sum_{j=1}^{J}\sum_{n\neq j}^{J}(J-1)\lambda_M(P_n)\|C_{jn}\|^2\|x_j(k)\|^2. \quad (11) \end{aligned}$$

From Eqs. (9-10), we have

$$\begin{aligned} m_3+m_4 &\leq \sum_{j=1}^{J}\sum_{i=1}^{r_j}\sum_{n\neq j}^{J} h_{ij}(k)\|x_j(k)\|[\|A_{ij}^T P_j C_{nj}\|+\|C_{nj}^T P_j A_{ij}\|]\|x_n(k)\| \\ &\leq \sum_{j=1}^{J}\sum_{i=1}^{r_j}\sum_{n\neq j}^{J} h_{ij}(k)m_{ijn}[\|x_j(k)\|^2+\|x_n(k)\|^2] \\ &= \sum_{j=1}^{J}\sum_{i=1}^{r_j}\sum_{n\neq j}^{J} h_{ij}(k)m_{ijn}\|x_j(k)\|^2+\sum_{j=1}^{J}\sum_{i=1}^{r_j}\sum_{n\neq j}^{J} h_{in}(k)m_{inj}\|x_j(k)\|^2. \quad (12) \end{aligned}$$

Substituting Eqs. (7-12) into Eq. (6) yields

$$\begin{aligned} \Delta V(k) &\leq \sum_{j=1}^{J}x_j^T(k)\{\sum_{i=1}^{r_j}h_{ij}^2(k)\lambda_{\mathrm{M}}(Q_{ij})+\sum_{i<f}^{r_j}h_{ij}(k)h_{fj}(k)[\lambda_M(Q_{ij})+\lambda_M(Q_{fj})] \\ &+\sum_{n\neq j}^{J}[\sum_{i=1}^{r_j}h_{ij}(k)m_{ijn}+\sum_{i=1}^{r_j}h_{in}(k)m_{inj}+(J-1)\lambda_M(P_n)\|C_{jn}\|^2]\}x_j(k). \end{aligned}$$

4. Conclusions and Suggestions

This paper introduced a practical simulation model for renewable energy in aquaponic systems. The output current has harmonic component of both high order frequencies and dispersed harmonics. The characteristic is more close to the real electric arc furnace property. A flicker testing model is established to test the instantaneous flicker visual sensitivity S. Modulating waves of different frequencies and the same amplitude is introduced to test the correctness of the model. It can help to establish a more practical model to simulate a wide output range of harmonics. It would be more help full for harmonic-preventing sets such as active power filter to test their characteristics. The power system would be more reliable and Electro-insulating material will have a longer using life. The method is proved to be reasonable and realizable to reflect the real electric arc furnace property.

Developing future politics requires simple goals, which are beyond economic development and employment or the protection and environmental protection. The difficulty of the maritime market shows there are many opportunities to increase the pace of sustainable aquatic life and new perspectives that can be used through political support.

Funding Acknowledgement

This research was in part enlightened by the grant 106EFA0101550 of Ministry of Science and Technology, Taiwan.

References

Bohl, M. (1977). Some initial aquaculture experiments in recirculating water systems. *Aquaculture*, *11*, 323-328.

Collins, M. et al. (1975). Nitrification in an Aquatic Recirculating System. *Journal of the Fisheries Research Board of Canada*, *32*, 2025-2031.

Deutsch, E. W., Csordas, A., Sun, Z., & Jarnuczak, A. (2017). The ProteomeXchange consortium in 2017: Supporting the cultural change in proteomics public data deposition. *Nucleic Acids Res*, *45*, D1100-D1106.

Gericke, W. F (1940). *The Complete Guide to Soilless Gardening*. New York: Prentice-Hall Inc.

James, P. (2015). *Routledge, Taylor & Francis Group: Earthscan, from Routledge, Abingdon, Oxon*. New York, NY: Urban Sustainability in Theory and Practice: Circles of Sustainability.

Klinger, D. (2012). Naylor R. Searching for solutions in aquaculture: Charting a sustainable course. Annu. *Rev. Environ Resour*, *37*, 247-276.

Laurens, T, Batlolona, F. A., Batlolona, J. R., & Leasa, M. (2018). How Does Realistic Mathematics Education (RME) Improve Students' Mathematics Cognitive Achievement? *EURASIA Journal of Mathematics, Science and Technology Education*, *14*(2), 569-578.

Lewis, W. M., Yopp, J. H., & Schramm, J. H. L. (1978). Use of hydroponics to maintain quality of recirculated water in a fish culture system. *Transactions of the American Fisheries Society*, *107*, 92-99.

Mahmoud, M. S., Hassan, M. F., & Darwish, M. G. (1985). *Large-scale control systems*. New York: Marcel Dekker.

McMurtry, M. (1992). *Integrated Aquaculture-Olericulture System as Influenced by Component Ratio* (p. 78). Ph.D. Thesis.: North Carolina State University.

McMurtry, M. R., Nelson, P. V., & Sanders, D. C. (1990). Sand culture of vegetables using recirculated aquacultural effluents. *Applied Agricultural Research*, *5*, 280-284.

Mei, N., Grossberg, M. D., Ng, K., Navarro, K. T., & Ellmore, T. M. (2017). Identifying sleep spindles with multichannel EEG and classification optimization. *Comput. Biol. Med.*, *89*, 441-453.

Meika, Suryadi, D., & Darhim. (2018). Students' errors in solving combinatorics problems observed from the characteristics of RME modeling. *Journal of Physics: Conference Series*, *948*, 1-6.

Mollison, B., & Holmgren, D. (1981). *Permaculture One: A Perennial Agricultural System for Human*

Settlements. International Tree Crop Institute USA.

Mulbar, U., & Zaki, A. (2018). Design of Realistic Mathematics Education on Elementary School Students. *Journal of Physics: Conference Series*, *128*, 1-8.

Naegel, L. C. A. (1977). Combined production of fish and plants in recirculating water. *Aquaculture*, *10*, 17-24.

Osmundsen, T. C., Almklov, P., & Tveterås, R. (2017). Fish farmers and regulators coping with the wickedness of aquaculture. *Aquac. Econ. Manag*, 1-21.

Rakocy, J. E. (1984). A Recirculating System for Tilapia Culture and Vegetable Hydroponics. In D. Tave (Ed.), *Smitherman RO* (pp. 103-114). Auburn, AL.

Rakocy, J. E. (2012). *Aquaponics-Integrating Fish and Plant Culture* (pp. 344-386). Oxford, UK: Wiley-Blackwell.

Rakocy, J. E., Masser, M. P., & Losordo, T. M. (2006) *Recirculating aquaculture tank production systems: Aquaponics–integrating fish and plant culture* (p. 454). SRAC Publication.

Read, P., & Fernandes, T. (2003). Management of environmental impacts of marine aquaculture in Europe. *Aquaculture*, *226*, 139-163.

Sneed, K., Allen, K., & Ellis, J. (1975). Fish farming and hydroponics. *Aquaculture and the Fish Farmer*, *2*, 18-20.

Sutton, R. J., & Lewis, W. M. (1982). Further observations on a fish production system that incorporates hydroponically grown plants. *The Progressive Fish-Culturist*, *44*, 55-59.

Timmons, M., & Ebeling, J. (2010). *Recirculating Aquaculture*. Ithica, NY: Cayuga Aqua Ventures.

Todd, J. (1980). Dreaming in my own backyard. *The Journal of the New Alchemists*, *6*, 108-111.

Wardono, W. S. B., Mariani, S., & Candra, D. S. (2016). Mathematics literacy on problem based learning with indonesian realistic mathematics education approach assisted e-learning edmodo. *Journal of Physics: Conference Series*, *693*, 1-10.

Warsito, D., & Herman, T. (2018). Improving students' mathematical representational ability through RME-based progressive mathematization. *Journal of Physics: Conference Series*, *948*, 1-6.

Watten, B. J., & Busch RL (1984) Tropical production of tilapia (Sarotherodon aurea) and tomatoes (Lycopersicon esculentum) in a small-scale recirculating water system. *Aquaculture*, *41*, 271-283.

Yuanita, P., & Zakaria, E. (2016). The Effect of Realistic Mathematics Education (RME) Implementation to Mathematics Belief, Mathematics Representative and Mathematics Problem Solving. *Advanced Science Letters*, *22*(8), 1989-1992.

Zweig, R. D. (1986). An integrated fish culture hydroponic vegetableproduction system. *Aquaculture Magazine*, 34-40.