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TECHNICAL NOTE TEKNİK NOT

Using of the computer software for the sustainable rainbow trout cage culture: A case study in Gökçekaya Dam Lake (Ankara, Turkey)

Ağ kafeslerde gökkuşağı alabalığı yetiştiriciliğinin sürdürülebilirliği için bir bilgisayar yazılımının kullanımı: Gökçekaya Baraj Gölü (Ankara, Türkiye)

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Özet: Bu araştırmanın amacı, ağ kafeslerde sürdürülebilir yetiştiricilik için geliştirilen ve -Ağ Kafeslerde Yetiştiriciliğe İlişkin Karar Destek Sistemi- olarak adlandırılan bilgisayar yazılımını Gökçekaya Baraj Gölü'nde ağ kafeslerde gökkuşağı alabalığı yetiştiriciliği yapan yüksek kapasiteli (950 ton yıl^{-1}) bir işletmede kullanmaktır. Bilgisayar yazılımının modülleri olan: i) alan sınıflandırması, ii) alan seçimi, iii) taşıma yoğunluğu-taşıma kapasitesi ve iv) ekonomik değerlendirme, seçilen ağ kafes işletmesinde uygulanmıştır. Ağ kafes işletmesi, alan sınıflandırması ve alan seçimi modüllerini oluşturan kriter (su- sediment kalitesi, hidrometeoroloji ve sosyoekonomi) ve alt kriterler bağlamında - kötü, orta ve iyi olarak sınıflandırılmıştır. Bir diğer bilgisayar yazılım modülü olan ağ kafeslerde taşıma yoğunluğu değeri, yüksek kapasiteli işletme için 17,72 kg m^{-3} olarak saptanmıştır. Baraj gölünün taşıma kapasitesi ise, ağ kafes işletmesi verilerine göre 2.056 ton yıl^{-1} olarak tahmin edilmiştir. Ekonomik değerlendirme modülünde, taşıma yoğunluğu ve bazı ekonomik parametrelere göre sermayenin geri dönüş oranı ≅ %127 olarak hesaplanmıştır. Gökçekaya Baraj Gölü örneğinde kullanımı önerilen programın, hızlı ve kolay uygulanabilir olması nedeniyle, Türkiye'de farklı ekosistemlerde dağılım gösteren ağ kafes işletmelerinin yönetimi ve yetiştiriciliğin çevresel etkilerinin izlenmesi konusunda anahtar rol oynayacağı düşünülmektedir.

Anahtar kelimeler: Ağ kafeslerde yetiştiricilik, Taşıma kapasitesi, Bilgisayar yazılımı, Baraj gölü, MOM, CADS_TOOL, *Oncorhynchus mykiss*.

Abstract: The aim of this research is application of a computer software for the developing sustainable cage aquaculture named -Cage Aquaculture Decision Support Tool- on high capacity (950 tons year^{-1}) rainbow trout cage farm in Gökçekaya Dam Lake. The modules of the computer software program: i) site classification, ii) site selection, iii) holding density-carrying capacity and iv) economic appraisal is applied at selected cage farm. The cage farm is classified into three categories - poor, medium, and good- according to set of criteria (water- substrate qualities, hydrometeorology and socioeconomic) and sub-criteria of site classification and site selection modules. Holding density which is the other computer software module is determined in cage farm as 17,72 kg m^{-3}. Carrying capacity of the dam lake is estimated in cage farm's inputs as 2.056 tons year^{-1}. In the economical appraisal module; return on investment are calculated as ≅ 127% using cage-holding density and some economic parameters. Being a fast and easily applicable, the programme proposed to be used as a case study of the Gökcekaya Dam Lake, is thought to play a key role in the subject of the management of different cage farms in distinct ecological areas and monitoring of the environmental impacts of fish farming in Turkey.

Keywords: Cage culture, Carrying capacity, Computer software, Dam lake, MOM, CADS_TOOL, *Oncorhynchus mykiss*.

INTRODUCTION

In the recent years, a world-wide substantial increase in the intensive aquaculture caused an increase of awareness in the environmental impacts of fish farming and sustainable farming to become important. The environmental impact of the fish farming in inland water can be more dangerous than marine fish farming. While the most common changes in water quality are characterized by differences in nitrogen and phosphorus concentrations, changes in sediment quality also include differences in total nitrogen, total phosphorus, total carbon, organic matter and redox potential (Demir *et al.*, 2001, Alpaslan and Pulatsu, 2008).

The importance of sustainable aquaculture, new models are developing or existent models are calibrating with the new technological and culture techniques. For example, observation programs are used by governments in many countries to monitor aquaculture's environmental impact. Additionally, simulation models have been developed to estimate the effects of organic waste and wastewater from aquaculture mixing with the local waters. However, in order to prevent overuse of any single receiving environment and optimize the use of shore resources, systems are needed which combine modelling and observation programs with environmental quality standards. The MOM system (Modelling-Ongrowing Fish Farms-Monitoring) is one such system (Ervik *et al.*, 1997; Hansen *et al.*, 2001; Stigebrandt *et al.*, 2004).

The -Cage Aquaculture Decision Support Tool (CADS_TOOL)- is a computer program based on the MOM

system and developed in recent years in parallel with the increase in studies and the importance of this topic. This program comprises four modules and it was created by the Southeast Asian aquaculture industry to promote sustainable cage aquaculture, and is available for free download on the Australian Institute of Marine Science website (http://data.aims.gov.au/cads). The practical advantages of this program are that each module can be easily applied and that it can be used on any computer running Java (Halide *et al.*, 2009).

Because of the cage aquaculture in the dam lakes and in the reservoirs, there can be some differences at the nutrient levels. In Turkey's inland waters there are 1.587 licensed aquaculture facilities, with a total capacity of 160.933 tons year^{-1}. Gökçekaya Reservoir is one of Turkey's reservoirs that in recent years have begun to experience an increase in cage aquaculture. It is located on the Sakarya River on the border of Nallıhan County (Ankara Province) and was constructed for power production. It is reported that there are six approved and operational aquaculture projects with a capacity of 3.858 tons/year, and an additional 17 pre-approved facilities with a capacity of 13.200 tons/year in the reservoir (interview, Head of Department of Aquaculture, General Directorate of Fishing and Water Products, 2011).

In Turkey, there are limited researches about sustainable cage farming in inland water (Pulatsü, 2003; Verep *et al.*, 2003; Anonymous, 2005; Buyukcapar and Alp, 2006; Buhan *et al.*, 2010; Polat and Özmen, 2011). But for the sustainable farming, there's a necessity of a model which can give reliable results in a short time and has technological information about cage aquaculture. The programme proposed in the scope of the present research, has not been used in our country and in a dam lake in the context of sustainable aquaculture. For this purpose, - a decision support system for the sustainable cage aquaculture developing programme –shortly CADS_TOOL is used at rainbow trout cage farm with 950 tons year^{-1} capacity in Gokcekaya Dam Lake. In this context, study is focused on:

- Identification of criteria and sub-criteria particular to site classification in accordance with data obtained from field and laboratory studies in context with the first module;
- Evaluation of suitable site selection using the second module of the above-mentioned program;
- Calculation of the holding density of the cages and estimation of the carrying capacity of Gökçekaya Reservoir based on the criteria of the third module;

Implementing economic evaluations of the systems considering the criteria of the fourth module.

MATERIALS AND METHODS

Study Site

Built with the aim of providing electricity to Eskişehir Province, Gökçekaya Dam Lake is located on the Sakarya River between Sarıyar and Yenice Reservoirs. The water from Gökçekaya Reservoir empties into Yenice Reservoir. In a study conducted in Gökçekaya Reservoir between the years 2005-2006, the reservoir's physicochemical water quality properties were determined and chlorophyll-a and algae species were detected; the reservoir's nutrient level was reported as mesotrophic (Akın *et al.*, 2008). This research was conducted on high capacity (950 tons year^{-1}) cage farm producing portion-sized rainbow trout (*Oncorhynchus mykiss* Walbaum, 1792) in the dam lake.

Sampling

Water and sediment samples were taken in May and October 2011 in selected rainbow trout cage farm in Gökçekaya Dam Lake.

Application of the Cage Aquaculture Decision Support Tool (CADS_TOOL)

Data extrusion methods are presented below for the four modules (site classification, site selection, holding density, carrying capacity and economic appraisal) of the CADS_TOOL computer program developed by Halide *et al.* (2009) to promote sustainable cage aquaculture.

Site classification

Water quality: Lake water samples were collected from surface and filtered through a Whatman GF/C membrane filter and analyzed for ammonium. It was measured with nesslerization method (Anonymous, 1995). Dissolved oxygen (mg L^{-1}) and Secchi depth (m) were measured by oxygen meter and Secchi Disc in situ, respectively.

Substrat quality: Sediment samples were collected at cage bottom and then air-dried, homogenized by grinding, and finally passed through a 1.0-mm sieve for the texture analyzes in laboratory conditions. Redox potential (mV) was measured by pHmeter in situ. Organic matter (%) was determined by the loss of weight during ignition at 550°C for 2 h (Kacar, 1995).

Hydrometeorology: Current (cm s^{-1}) was measured using current meter in situ. Significant wave height (m)- the average height of the one-third highest wave in a continuous wave time series- was determined according to Halide *et al.* (2009). Water depth was mesured dropping a weighted line marked with depth increments and observing the total line required to reach the bottom.

Socioeconomic: All sub criteria were determined according to Halide *et al.* (2009). Proximity to market should be scored as "near" if the fish can reach the market fresh without requiring special infrastructure e.g. freezers.

Infrastructure should be scored as "available" if all means that keep the fish in fresh condition are available, such as appropriate transportation, freezers, etc. Regulations should be scored as "available" if laws preventing poaching and conflicts in coastal zone usage are in place, or that appropriate zoning laws are in place.

Site selection

In the computer program, the values produced by the site classification module are automatically transferred to the site selection module. Site selection, which is the second module of CADS_TOOL, is calculated using four different criteria. Predictions of relative importance (RI) values were assigned to the criteria and sub-criteria so that the total equaled 100. Using the predictive approach, the variable range specified by the criteria during the study and possible positive-negative contributions to aquaculture were considered. After the values were entered, site selection was determined automatically by the program.

Estimation of holding density

Simplified MOM method was used to determine holding density of the cage farm. Surface current is measured using a current meter. Critical oxygen- ammonium concentration (mg L^{-1}) in cage and critical bottom oxygen (mg L^{-1}) were determined according to Çelikkale (1994) and Halide *et al.* (2009), respectively. Food conversion ratio (FCR= Dry weight of feed consumed (g) / wet weight of gain (g)) was calculated according to Laird and Needham (1987). The length of the farm (L_f) was estimated according to Stigebrandt *et al.* (2004) and the equation is given below:

"L_f= The number of pens/The number of pens in rows x (Pen length + The distance between the pens) - The distance between the pens (m))"

where pen length (L), for non-square pens L is taken as equal to the square root of the pen area.

Estimation of carrying capacity

In order to estimate Gökçekaya Reservoir's carrying capacity, the phosphorus budget model was used, which is based on data related to phosphorus consumption in inland water. Total-P concentration (mg m^{-3}) is measured according to the ascorbic acid method outlined in Anonymous (1995). 60 mg m^{-3} is chosen as the value for maximum acceptable [P] in temperature inland water bodies used for the culture of rainbow trout (Dillon and Rigler, 1974). Phosphorus content of fish (%) was determined according to Aşır and Pulatsü (2008). Morphometric and hydrologic characteristics of lake were obtained from Anonymous (2011).

Economic appraisal

The equations used for the economic appraisal module developed by Halide *et al.* (2009) are presented in Table 1.

Table 1. Input variables required for the economic appraisal (Halide *et al.* 2009)

Input variables	Economic appraisal formulae
Total weight of fish	Holding density (kg/m) x Cage volume (m^3)
Total fish biomass	Total weight of fish / Mean fish weight at harvest (kg)
Total number of seed	Total fish biomass / Survival rate of fish seed (%)
Fed needed to produce biomass at harvest	FCR x Total weight of fish
Total costs for seed	Seed cost x Total number of seed
Total costs for fed	Feed cost x Fed needed to produce biomass at harvest
Total cost	(Total costs for seed + Total costs for fed + Cage cost) (1 + Interest rate)
Break-even price	Total cost / Total weight of fish
Reveneu	Fish price x Total weight of fish
Profit	Reveneu - Total cost
Return on investment (%)	100 x (Profit / Total cost)

RESULTS

Results from the application of the four modules that constitute the CADS_TOOL computer program in Gökçekaya Reservoir are presented below (Figure 1-5). The average values for measurements taken at the operations in May and October were used in the modules of the computer program.

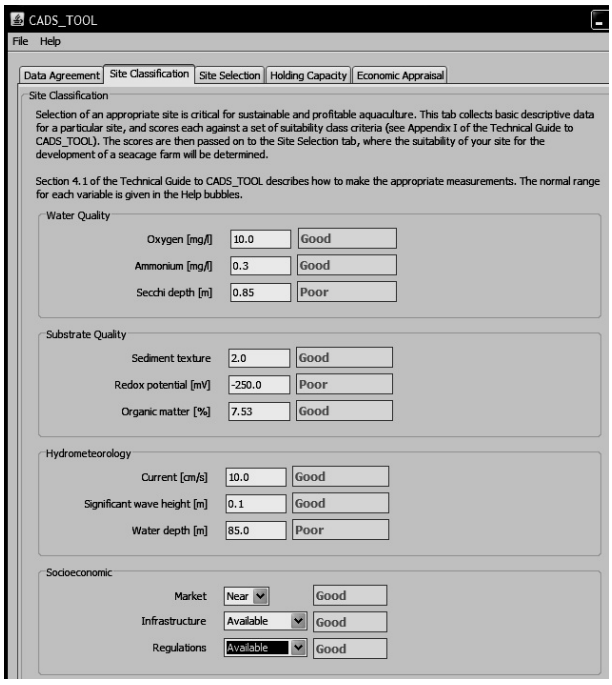

Figure 1. Site classification of a rainbow trout farm

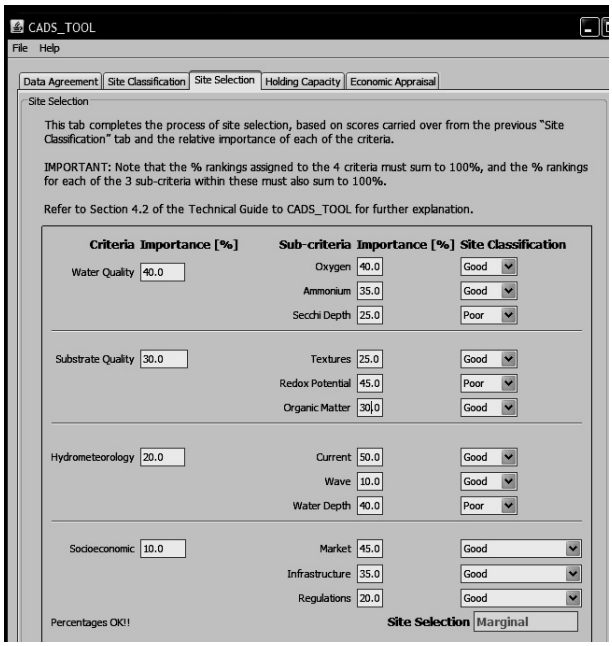

Figure 2. Site selection of a rainbow trout farm

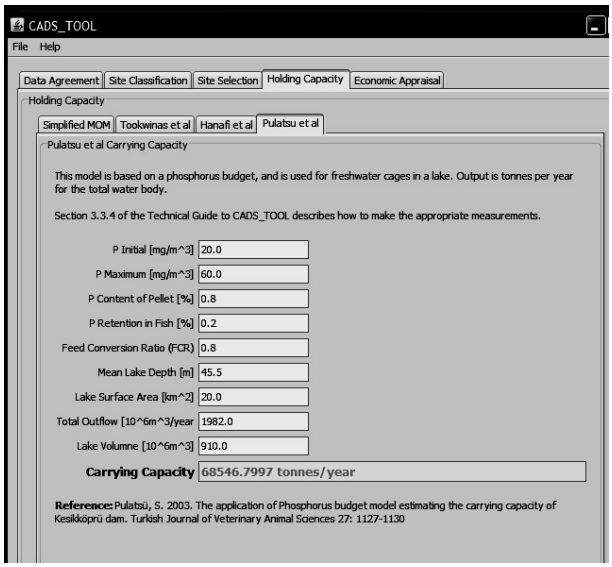

Figure 4. Carrying capacity of a rainbow trout cage farm determined by the phosphorus budget model

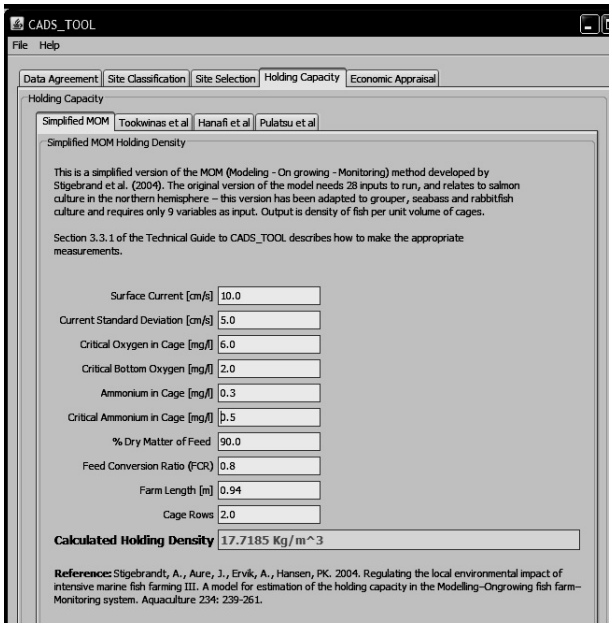

Figure 3. Holding density of a rainbow trout cage farm determined by the simplified MOM model

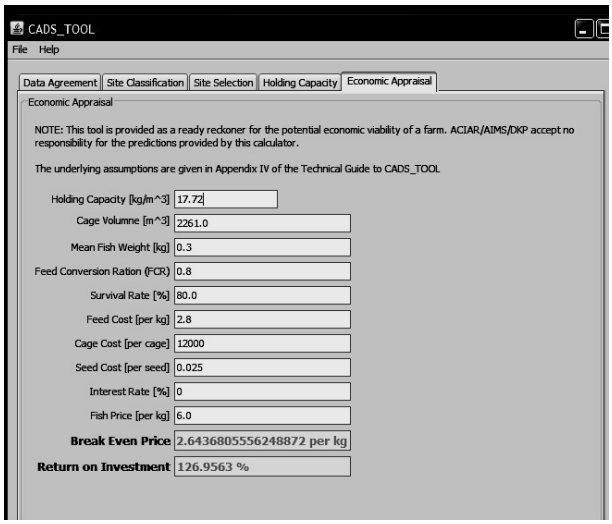

Figure 5. Economic appraisal of a rainbow trout farm

DISCUSSION

In the scope of the research, possibility of using the computer software, not applied before to the sustainable cage aquaculture in our country, was investigated in the case of Gökçekaya Dam Lake. Moreover, the program proposed for the sustainable aquaculture – modules of site classification, site selection, holding density and economic appraisal- was applied to the inland water ecosystem for the first time with the exception of marine ecosystems.

As a result of intensive aquaculture in reservoirs, several changes in the nutrient level of the lake can occur. Water column parameters are recognized as an important component in the observation of sustainable cage aquaculture. Since dissolved oxygen concentration is one of the especially important criteria for breeding fish in cage aquaculture, it is recommended that this criterion be observed separately from the others (Hansen *et al.*, 2001). The most criterion for the site classification in this study is water quality, and the selected sub-criteria show suitability with the site. Even though the criteria and sub-criteria of CADS_TOOL's site classification module proved suitable and adequate in the case of Gökçekaya Reservoir, potential modifications should be allowed for this module in order to adjust for various receiving environments, as stressed by Halide *et al.* (2009). In other words, the criteria chosen in this module should be able to reflect differences particular to the site and/or the sub-criteria should be adjustable.

CADS_TOOL's site selection module contains four different criteria, each with three sub-criteria. In this study, the levels of importance of some of the sub-criteria, taking into account the probability of environmentally-based threats to the receiving environment in the coming years, were accepted as water quality -40%, substrate quality -30%, hydrometeorology criterion -20%, and socio-economics criterion -10%. As in site classification, the user of CADS_TOOL must make decisions regarding relative importance values of the criteria and also regarding classification of the receiving environment in accordance with the importance of the criteria.

Stigebrandt *et al.* (2004) indicate that holding density in cage aquaculture systems is related with the size of the cage farm, characterized by the critical cage oxygen-ammonium concentration, the feed conversion ratio and number of rows of cages/cage length. Because it was thought that these parameters would also be important and sufficient in estimating the holding density of the active cage aquaculture operations in Gökçekaya Reservoir, the simplified MOM method was chosen to estimate holding density in this study.

Results related with the carrying capacity of Turkey's reservoirs make it possible to determine production levels that will not damage water quality or create a risk of eutrophication, giving direction to reservoir cage aquaculture operations. Studies exist which apply the phosphorus budget model (Dillon and Rigler, 1974) to various receiving environments in Turkey (Pulatsü, 2003; Verep *et al.*, 2003; Anonymous, 2005; Buyukcapar and Alp, 2006; Buhan *et al.*, 2010; Polat and Özmen, 2011). Applying the carrrying capacity module of CADS_TOOL, the carrying capacity of the reservoir, taking as a basis the total area of the lake and the acceptable (maximum) total phosphorus concentration of 60 mg m^{-3}, was estimated for the high capacity aquaculture operation values as 68.547 tons $year^{-1}$. However, it was stated in the 'Protocol of the General Directorate of State Water Operations for Reservoirs with Proprietorship or in Possession of Planned Aquaculture', signed in 2004 (Anonymous, 2004) between the General Directorates of State Water Operations Agricultural Production and Development, that the area set aside for aquaculture must not exceed 3% of the reservoir's area at minimum water level. For this reason, the carrying capacity value for Gökçekaya Reservoir, according to high capacity operation values, should be only 2.056 tons $year^{-1}$.

The total capacity of the approved operational and pre-approved aquaculture sites in Gökçekaya Reservoir, the venue of this study, is approximately 17.058 tons, and hence it appears that the values delineated above for estimated carrying capacity have been greatly exceeded. It can be said that Gökçekaya Dam Lake has a high degree of use, and that the environmental impact of its cage aquaculture operations has exceeded its carrying capacity. In order to prevent excessive use of the receiving environment or to limit increasing use, monitoring levels should be chosen contingent on the degree of environmental impact. In addition, some components for disease control can also be integrated into the monitoring program if necessary. When economic evaluation, the final module of the CADS_TOOL program, was applied the capital return on investment was determined as $\cong$ 127%.

The outputs of the computer program named CADS_TOOL recommended for use on selected cage farm in Gökçekaya Reservoir will provide basic data for monitoring the local impact of future aquaculture operations in the reservoir. Within the scope of this research, a suitable stocking level, proper feeding, a suitable flow rate and water depth were determined as criteria positively affecting water quality, and these components were in agreement with the results from CADS_TOOL. The criteria and sub-criteria for the modules of CADS_TOOL, constituting the basis of this study, can be developed by modifying them to reflect variations in the receiving environment's morphometric-hydrologic properties and the characteristic properties of cage aquaculture. Because the program is quick and easy to use, it is believed that it will play a key role in the management of cage aquaculture systems distributed among different ecosystems in Turkey and in monitoring aquaculture's environmental impact there.

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