American Journal of Operations Research, 2022, 12, 94-110
https://www.scirp.org/journal/ajor
ISSN Online: 2160-8849
ISSN Print: 2160-8830

Modeling of Catfish Farm Using Lexicographic Linear Goal Programming

Ukamaka Cynthia Orumie[1], Egenti Francis Nzerem[1], Chekwube Bartholomew Desmond[2]*

[1]Department of Mathematics and Statistics, University of Port Harcourt, Port Harcourt, Nigeria
[2]Department of Statistics, Federal University of Technology Owerri, Owerri, Nigeria
Email: ukamaka.orumie@uniport.edu.ng, *desmond.bartholomew@futo.edu.ng

How to cite this paper: Orumie, U.C., Nzerem, E.F. and Desmond, C.B. (2022) Modeling of Catfish Farm Using Lexicographic Linear Goal Programming. *American Journal of Operations Research*, **12**, 94-110.
https://doi.org/10.4236/ajor.2022.123006

Received: March 21, 2022
Accepted: May 17, 2022
Published: May 20, 2022

Copyright © 2022 by author(s) and Scientific Research Publishing Inc.
This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).
http://creativecommons.org/licenses/by/4.0/
Open Access

Abstract

In this paper, a fish farm was modeled using the Lexicographic linear goal programming approach due to incommensurability in objectives. The study considered the fish farming plan with two sizes of catfish from stocking to harvesting at four-month intervals. The multi-objective goals developed are required raw materials feed, water, light (resource utilization), sales revenue, profit realized, labor utilization, production costs, and pond utilization. The developed model was tested using related data collected from the farm records with the use of TORA 2007 software. The compromised solution from the results showed that the developed model is an efficient tool for decision-making process in the fish farm business organization.

Keywords

Goal Programming, Incommensurability, Lexicographic, Multi-Objective, Compromised Solution

1. Introduction

Quality products increase revenue (sales) and profits; the profit in turn also depends on the cost of production and resources utilization for the production process. This process involves the optimization of several objectives, at the same time. Thus, goal programming technique is one of the multi-objective optimization techniques used to address a problem with multiple objective functions by minimizing deviations from the target of each objective. Fish consumption is increasing daily with an increase in population growth, especially in Nigeria and Catfish is one of the most consumed fish species due to the fact that it can easily be purchased in all markets and the price is relatively cheaper than sea fish. Catfish farming is spread in several cities in Nigeria with two major stages—the nursery and the grow-out pond operation stages.

Several works of literature exist on fish farming across the globe which motivated this study. Some of the literatures are reviewed thus. Sophia and Irine [1] developed a weighted Multiple Objective Goal Programming (MOGP) model that considered three types of dominant fishes namely Catla, Rohu, and Mrigal in a small area with maximization of production profit, stocking density and minimization of seed costs as conflicting objectives. The MOGP model developed was an efficient tool that assisted the management in solving a series of linear programs and thus obtained a compromised solution. Sadiq *et al.* [2] examined resource optimization in small-scale fish using a response approach with the help of a multi-stage sampling technique in data selection. The regression results indicated that feeds, fingerlings, water, depreciation on capital items and labour were significant determinants of output in fish production. According to them, in Niang & Jubrin [3] Aquaculture, the farming of aquatic organisms, including fish, molluscs, crustaceans and aquatic plants has always been one of the ways of reliably expanding food production and animal protein intake in Nigeria is below 8g per person in one day, which is far below Food and Agricultural recommendation (FAO) minimum recommendation. Anene [4] posited that cattle, goats, sheep, poultry and fish constitute the major animal protein sources in the country out of which fish and fish products provide above 60% of the total protein consumption. Ugwumba & Chukwuji [5] argued that catfish farming is an alternative means of boosting fish production and thereby moving the country towards self-sufficiency in fish production is by embarking on fish farming especially catfish farming. The fulfillment of fish consumption needs depend on its productivity and this productivity depends on the area of the pond. The greater the land area, the more catfish can be produced. However, farmers are restricted by the size of ponds due to capital, thus limiting the amount of catfish harvest.

In this study, the Lexicographic goal programming model will be developed to generate the most important objectives relating to the fish farming production plan. In this regard, the management is to make a decision that will achieve these objectives as close as possible. According to Fatkhur *et al.* [6], these important multi objectives are maximizing profits, minimizing capital, minimizing production costs. Thus, this research wants to develop and model BEST4 fish farm using Lexicographic Linear Goal programming. The remaining part of this study is divided into six sections: section two comprises the brief history of BEST4 Fish farm and its operations; Section 3 comprises the development of multiple objectives with modeled goals and goal priority structures attached. The fish farm management combinations, the goal programming modeling, and its applications are presented in Section 4. Then, Analysis and Results output, summary and interpretation, and conclusion are presented in Sections 5, 6, and 7 respectively.

2. BEST4 Fish Farm and Its Management Operations

BEST4 fish farm is found in Omuokiri, Aluu, Rivers State; the fish ponds were constructed in 2020 with the aim of supplying the inhabitants of the environment with fish at an affordable price. It is a commercial farm run by a local fish farmer with the aim of making a profit as well as creating small-scale job opportunities for a few people. It started with 10 fish ponds constructed with tarpaulin and four manual laborers (unemployed youth) for managing the farm. It trains two sizes of catfish from stocking till 4 months: fingerlings and post fingerlings.

Based on previous sales and experience, the farmer wants to expand his fish farm in order to make more sales and make more profit, minimize costs of production, maximize resource utilization, provide fish farming knowledge to other interested local farmers, establish proper fish harvesting, and management measures.

3. Goal Programming and Multiple Objective Functions in the Farm

Reorganizing that deviations from goals will exist in unsolvable Linear programming problems (LPPs) like an infeasible LPP, Charnes, and Cooper [7] showed how such derivation could be reduced by placing them in an achievement function. This allows multiple and sometimes conflicting goals to be expressed in a model that will allow a solution to be found.

Charnes and Cooper [7], Lee [8], Ignizio [9], and many other researchers were the first to develop the Goal programming (GP) technique: an optimization technique that can take care of several and sometimes conflicting objective functions at the same time by minimizing its deviation from the target which ordinary linear programming (lp) could not handle. It provides a satisfying solution [10].

Goal programming establishes a specific numeric goal for each of the objectives, formulates an objective function for each objective, and then seeks a solution that minimizes the weighted sum of deviations of these objective functions from their respective goals.

GP formulation must include:

1) Define the decision variable
2) State the constraint
3) Determine the preemptive priority if need be
4) Determine the relative weight
5) State the achievement function
6) State the non-negative requirement

According to Orumie and Ebong [11], a frequently applied generalized GP model is that of Arthur and Ravindran [12] and it is stated thus:

$$\text{Min } z = \sum_{i=1}^{n} w_i p_i \left(d_{ik}^{+} + d_{ik}^{-} \right) \tag{1}$$

s.t

$$\sum_{i=1}^{n} \left(x_{ij} + d_i^{-} + d_i^{-} \right) = b_i \tag{2}$$

$$x_{ij}, d_i^-, d_i^+ > 0 \tag{3}$$

where

p_i is the preemptive factor/priority level assigned to each objective in rank order.

w_i is the non-negative constant representing the relative weights assigned with priority level to the deviational variable d_i^+ and d_i^- for each j^{th} corresponding goal b_i.

x_{ij} is the decision variable, whereas a_{ij} means the decision variable coefficient.

While equation:

1) Represents the objective function, which minimizes the weighted sum of the deviation variable.

2) Represents the goal constraints relating the decision variable (x_{ij}) to target (b_j).

3) Represents standard non-negativity restrictions on all variables.

However, the management of the BEST4 investment Farm wants to know which size of the catfish production process can provide the maximum profit with the lowest possible production, labor and, capital costs. The objective function in the goal programming model is to minimize deviations from the target values for each of the developed multiple objectives or targeted goals in the farm, and then set and test the priority structure using data obtained from the farm record. The objective function in this research is formulated below.

3.1. Multi-Objectives in a Farm Formulation

Since there are varied interests, Farmers often do have many objectives, which are aimed at satisfying them. It is obvious that farmers however will want to grow, survive, and be secured within their operating system.

Therefore, we consider multiple (different) objectives of the farmer, using the farm's already existing facilities. The management wants to avoid underutilization of labour, resources and at the same time minimize costs, as well as maximize sales revenue and profit.

Details of variables and the objective functions representing the various performance criteria are presented as follows:

3.2. Parameters and Variable Notations with Objective Functions

i = The fish stock type ($i = 1, \cdots, n$)

p_i = The unit profit from i^{th} product

P = Total profit (Target Profit)

l = The labour type ($l = 1, \cdots, m$)

L = Total available labour

L_k = The labour capacity required for i^{th} product

f = The feed type ($f = 1, \cdots, F$)

F = Total available feed

D = Pond capacity resources

d_i = Pond available for i^{th} fish type resources

f_k = The feed available required for i^{th} fish stocked resources

C_k = Production/growing cost of i^{th} fish type

R_i = Sales revenue from unit of i^{th} fish sold

X_i = Quantity of fish type i [No. of fish i] harvested per period

a_k = Amount of resource (materials) needed for i^{th} fish (feed, water, light)

A = Resource (materials) available

S = Total sales (Target)

Variable X_i = The fish type to harvest per period

The following criteria are included in the model

- Required raw materials feed, water, and light (resource utilization)
- Fish type
- Cost of farming from stock to harvest
- Sales revenue
- Profit realized
- Labour utilization

These important criteria are thus,

Minimize production cost

Minimize resource utilization

Maximize labour utilization

Maximize fish pond utilization

Maximize sales revenue

Maximize profit

The above are formulated thus:

3.2.1. Minimize Cost of Production and Purchase Cost

The cost here is considered as the overall expenditure involved in growing a given set of fish to the harvesting stage. It is obtained when the unit cost of growing a fish (stocking) is multiplied by the total quantity of a commodity produced derives it. The total cost here comprises the cost of stocking the fishes, feed costs, supplement cost (booster), labour costs, maintenance and management costs, cost of resources, wages and salaries.

The Formulated cost objective equation is:

$$\sum_{i}^{n} c_i x_i = C \tag{4}$$

3.2.2. Maximize Revenue

Here, Revenue is defined as the money generated by the farmer from sales of his fishes. It is calculated by multiplying the total quantity sold by the unit price.

Sales maximization objectives aim at improving the cash inflow of the organization (company) while profit maximization does not place much premium on cash flow but on the high rate of return. Sales are maximized when marginal revenue is zero, whereas profit is maximized when marginal revenue is equal to marginal cost and since the marginal cost cannot be equal to zero, sales maximization will not guarantee profit maximization. This implies that the two objectives are important to the organization in the attempt to establish a competitive advantage in the market. The Formulated revenue objective equation is:

$$\sum_{i}^{n} R_i x_i = S \tag{5}$$

3.2.3. Resource Utilization (Fish Feed)

Each fish type has a different feed from starting to finish. The quantity of feed mix needed to grow one unit of each fish type to harvest period is required. The feed requirement and availability is estimated based on the quantity needed for growing one unit of fish type. The average amount of feed mix is denoted by a_i. The average feed quantity for each fish i is obtained from the farmer's process plan. The manager of the farm provides the amount of feed available in the planning horizon and the objective function is thus:

$$\sum_{i}^{n} a_i x_i = A \tag{6}$$

The management also wants to maximize the utilization of the available unit of pond d_i for each fish given that the available pond is D. The objective is

$$\sum_{i}^{n} d_i x_i = D \tag{7}$$

3.2.4. Labour Utilization

The availability of labour and their capacity is estimated based on the time of growing to harvest time of one unit of fish type. This is denoted by l_i. This is derived from the farm plan. The manager of the farm provides the capacity available in the planning horizon for each labour. This could be man or machine. The objective function becomes:

$$\sum_{i}^{n} l_i x_i = L \tag{8}$$

3.2.5. Maximize Profit

The total profit is estimated as the difference between the total revenue and the total cost. The unit profit contribution from each fish type is estimated by using the profit data as provided by the management profile. In view of past records, the management feels that the profit goal should be P naira, which depend on the sale and the total expenditure. This objective is denoted by

$$\sum_{i}^{n} p_i x_i = P \tag{9}$$

Therefore, Equations (4) to (9) are the relationship between the fish types i (decision variable) and the various activities in the farming processes (the farmer). The total cost of fish production per product is represented as $C_i \cdot X_i$ in Equation (4). C_i is the unit cost of production of i^{th} product. The revenue generated and resource utilization is represented in (5) and (6). The objective of availability of fish pond is formulated through Equation (7), which is represented as $d_i\, X_I$ for the i^{th} fish type, and Equation (8) is the availability of labour $l_i X_i$, whereas that of profit generated is in Equation (9). All other objectives are channelled towards having a favorable level of return on investment. It is obvious that some of the above objectives are conflicting and incommensurable and the decision of evaluating their trade-off is challenging. As such, the management activities should be handled properly to incorporate the managements target on various objectives into the planning process. Goal programming approach is capable of handling conflicting ‘objectives.

3.3. Model Formulation (GP Model) for the Above Equations

Problem with Rigid constraint should be constructed as a goal such that it is being minimized and placed at the achievement function with top priority.

Reorganizing that deviations from goals will exist in unsolvable LPPs like an infeasible LPP, Charnes and Cooper (1961) showed how such derivation could be reduced by placing them in an achievement function. This allows multiple and sometimes conflicting goals to be expressed in a model that will allow a solution to be found.

To formulate the model, the parameters used for input to the GP model in each priority structure should be given or else estimated by the management. Therefore the management is involved and takes a major part in GP formulation. All model parameters are assumed to be deterministic and constant. The goals are formulated thus:

3.3.1. Minimize Cost of Production

This includes costs during the process of raising catfish in a pond to the time of harvest. Mathematically, the goal constraints of production costs:

$$\sum_{i}^{n} C_i x + d_1^- - d_1^+ = C \tag{10}$$

Every business organization will like to minimize the cost of production. This implies the minimization of positive deviation from the target. The goal of minimizing the production cost for the i^{th} fish type is represented as

$$\text{Min } d_1^+$$

s.t

$$\sum_{i}^{n} C_i x + d_1^- - d_1^+ = C \tag{11}$$

where

d_1^- is underspending in production cost goal.

d_1^+ is overspending in production cost goal.

3.3.2. Maximize Sales Revenue

Large revenue from sales is a target that any profit oriented firm will love to meet. Thus the goal is to minimize underachievement of the target, and it is represented thus:

$$\text{Max } d_2^{\mp}$$

s.t

$$\sum_{i}^{n} S_i x_i - d_2^- + d_2^+ = S \tag{12}$$

where

d_2^- is underachievement of the sales revenue goal

d_2^+ is over achievement of the sales revenue goal.

However, the over-achievement of sales is accepted and hence positive deviation from the goal is eliminated from the objective function. S is the sales revenue goal fixed by the management.

3.3.3. Maximize Resource Utilization (Feed Requirement)

Feed required from growing to harvesting should not exceed the target and must not be less. So that the growth of fish is not altered. Thus, both deviations from the goal will be included in the objective function. The goal of both underutilizing and over utilizing of feed can be represented as

$$\text{Min } \left(d_3^- + d_3^+\right)$$

s.t

$$\sum_{k}^{n} a_k Y_k + d_3^- + d_3^+ = A \tag{13}$$

where,

d_3^- is underutilization of feed.

d_3^+ is overutilization of resources.

3.3.4. Maximizing Pond Utilization

This goal is to ensure that the number of catfish in a pond must not exceed the specified capacity limit. The goal of minimizing the underutilization of the pond can be represented as:

$$\text{Min } d_4^+$$

s.t

$$\sum_{k}^{n} d_k x_k + d_4^- - d_4^+ = D \tag{14}$$

where

D is availab1e capacity of ponds (goal).

d_4^- is underutilization of ponds.

d_4^+ is overutilization of ponds.

3.3.5. Minimize Labour Requirement

This goal is to ensure that the amount of labour will not be underutilized. The goal of minimizing the overutilization of the labour can be represented as:

$$\text{Min } d_5^+$$

s.t

$$\sum_{k}^{n} l_i x_i + d_5^- - d_5^+ = L \tag{15}$$

where

L is available Labour.

d_5^- is underutilization of Labour.

d_5^+ is overutilization of Labour.

3.3.6. Maximize Profit

However, the over-achievement of profits goal is accepted and hence positive deviation from the goal is eliminated from the objective function. This goal can be represented as

$$\text{Min } d_6^-$$

s.t

$$\sum_{k}^{n} p_i x_k + d_6^+ - d_6^- = P \tag{16}$$

where

d_6^+ is overachievement on the profit target.

d_6^- is underachievement on the profit target.

Equations (10) to (16) represent the Farmers goal.

3.4. Goal Priority Structure

In 1977, [13] observed that the Goal programming (GP) model can allow movement completely away from weighting deviational variables towards an absolute priority structure when each of the functions or goals was given a separate priority. However, Ignazio [14] advised that the issues of incommensurability in goal programming constraints are better addressed using preemptive GP (lexicographically).

The impact of the incommensurability issues in GP modeling can be minimized in different ways such as normalization by Romero (1991) [15], and prioritization.

[1] considered finance, site, fish stock, harvesting as very crucial factors a prospective fish farmer should consider before venturing into fish farming. They modeled MOLP by minimizing weighted sum of deviations from goals, and solved problem by using Lingo software.

Thus weighted, non-preemptive suffer from issue of incommensurability, and requires normalization.

(That is element in z being measured in different units), Tamiz and Jones [16]. But non-weighted preemptive priority or lexicographic GP does not suffer it. This is because each of its goals is separated at a different priority level. However, priority levels should not exceed 5 [5]. GP solution is referred to as satisficing, instead of optimizing a single objective [17].

Whether goals are attainable or not objective may then be stated in which optimization gives a result that comes as close as possible to the indicated goals.

In a real sense, some of the goals above conflict. As a result the management of the farm resort to prioritizing their objectives in order to settle the conflict with a clear definition of which of the objectives are more important to them and thus arranged with the most important one coming first.

A good priority structure is a hierarchical representation of the goal priorities that reflect management's preferences. Problem with rigid constraint should be constructed as a goal such that it is being minimized and placed at the achievement function with top priority.

However, a goal priority structure is to be formulated based on the preferences that the management listed and they are defined below:

P_1 ensures that the production cost is minimized.

P_2 ensure that underutilization of resources, pond, and idle labour are minimized.

P_3 ensures that sales target is met and that under-achievement of profit is minimized.

P_4 ensure that feed requirement is not violated.

Thus, Lexicographic structure of the objective of the farm model becomes to minimize deviations from various goals imposed by the management. Thus;

Min.

$$Z = P_1 d_1^+, P_2\left(d_4^+ + d_5^+\right), P_3\left(d_2^- + d_6^-\right), P_4\left(d_3^- + d_3^+\right)$$

S.t

Equations (10) to (15) holds. *i.e.*

$$\sum_i^n C_i X + d_1^- - d_1^+ = C \tag{10}$$

$$\sum_k^n S_i X_i + d_2^- - d_2^+ = S \tag{11}$$

$$\sum_k^n a_K Y_k + d_3^- - d_3^- = A \tag{12}$$

$$\sum_k^n d_K X_k + d_4^- - d_4^+ = D \tag{13}$$

S.t

$$\sum_k^n l_i X_i + d_5^- - d_5^+ = L \tag{14}$$

$$\sum_k^n p_i X_k + d_6^- - d_6^+ = P \tag{15}$$

All variables are non-negative.

4. The Fish Farm Management Combinations and the Goal Programming Modeling

4.1. Data Collection Analysis

The modeling considers the problem of planning a fish farming system with two sizes of fishes namely fingerlings and post finger. The fish feeds are allaqua, blue crown, and top feed. The table below summarizes the requirements, resource allocation in each growing phase of the fish, quantity of fish stocked at a time; number of fingerlings and postfingers, criteria along the production lines (costs). In Table 1, row 1, column 1 shows the number of fingerlings stocked per period with its unit price of ₦15 per fingerlings as shown in row 1 of column 2 of the same table. This gives the total amount of ₦180,000 for the 12,000 fingerlings stocked as shown in row 1, column 3 of the same table. On the same Table, the quantity stocked, the price per unit, and the total price of postfingerlings are shown in row1, columns 4, 5, and 6 respectively etc. The fish farm considered in the study has only half plot of land.

4.2. Fish Farm GP Model and Its Application

From Tables 1-3, the developed LGPM model becomes

Min.

$$Z = P_1 d_1^+, P_2\left(d_4^+ + d_5^+\right), P_3\left(d_2^- + d_6^-\right), P_4\left(d_3^- + d_3^+\right)$$

Table 1. Description of activities in the farm.

Requirements	Fingerlings			Postfingerlings			Availability Or Target
	Qnty (Units)	Unit Price ₦	Total Price ₦	Qnty (Units)	Unit Price ₦	Total Price ₦	
Fish Cost (Seed)	12,000	15	180,000	10,000	30	300,000	370,000
Feed Cost With Booster	65	12,000	780,000	95	12,000	1,144,000	1,924,000
	1	2000	2000	1	2000	2000	
Pond	5	-	-	5	-	-	10
Resource Utilization (L/W)	4	10,000	40,000	4	10,000	40,000	120,000
Maintenance Plumbing etc	4	5000	20,000	4	5000	20,000	
Fish Cost (Seed)	65	12,000	780,000	95	12,000	1,144,000	
Labour cost	1 (4)	20,000	80,000	1 (4)	20,000	80,000	190,000
Management (transport/harvest)	11,500	-	15,000	9610	15,000	30,000	
TOTAL COST	-	-	**1,117,000**	-	-	**1,616,000**	**2,733,000**
Sales (Revenue)	11,500	400	4,600,000	9610	700	6,727,000	11,327,000
Profit	11,500	302.86	3.483,000	9610	531.84	5,111,000	8,594,000
ACTUAL COST PER FISH	-	-	97	-	-	168.16	265.168
ACTUAL PROFIT PER FISH	-	-	302.86	-	-	531.84	834.7
Actual pond space per fish	5	0.00043	5	0.00052			
Actual feed per fish	65	0.0057	95	0.0099			
Actual labour utilization per fish	4	0.00035	4	0.00042			

Table 2. Description of activities in the farm continues.

	Fingerlings		Prolings		Availability Or Target
REQUIREMENTS	Qnty (Units)	Unit fish	Qnty (Units)	Unit fish	
Actual pond space per fish	5	0.00043	5	0.00052	10
Actual feed per fish	65	0.0057	95	0.0099	160
Actual labour utilization per fish	4	0.00035	4	0.00042	8

Table 3. Summary of the goal targets for each of the multiple objectives.

	x_1	x_2	Target	Deviational Var to Min
Cost goal	97	168.16	2,733,000	d_1^+
Sales (Revenue)	400	700	11,327,000	d_2^-
Resource utilization goal	0.0057	0.0099	160	$d_3^- + d_3^+$
Pond goal	0.00043	0.00052	10	d_4^+
Labour goal	0.00035	0.00042	8	d_5^+
Profit goal	302.86	531.84	8,574,000	d_6^-

S.t

$$97x_1 + 168.16x_2 + d_1^- - d_1^+ = 2733000 \quad \text{(cost goal (₦))}$$

$$400x_1 + 700x_2 + d_2^- - d_2^+ = 11327000 \quad \text{(sales goal (₦))}$$

$$0.0057x_1 + 0.0099x_2 + d_3^- - d_3^+ = 160 \quad \text{(resource goal (bags))}$$

$$0.00043x_1 + 0.00052x_2 + d_4^- - d_4^+ = 10 \quad \text{(pond goal per trampoline)}$$

$$0.00035x_1 + 0.00043x_2 + d_5^- - d_5^+ = 8 \quad \text{(labour goal (person))}$$

$$302.86 + 531.84x_2 + d_6^- - d_6^+ = 8594000 \quad \text{(profit goal (₦))}$$

Deciding an optimal solution for MOGPP will be unrealistic since the objectives conflict and it is impossible to achieve one goal without violating the attainment of the next goal. To achieve this, GP technique is employed to minimize the deviation from the target.

5. Analysis and Results Output

The results from the model developed using Tora 2007 software are as shown in figures below

Min $P_1 d_1^+$

S.t

$$97x_1 + 168.16x_2 + d_1^- - d_1^+ = 2733000$$

$$400x_1 + 700x_2 + d_2^- - d_2^+ = 11327000$$

$$0.0057x_1 + 0.0099x_2 + d_3^- - d_3^+ = 160$$

$$0.00043x_1 + 0.00052x_2 + d_4^- - d_4^+ = 10$$

$$0.00035x_1 + 0.00043x_2 + d_5^- - d_5^+ = 8$$

$$302.86 + 531.84x_2 + d_6^- - d_6^+ = 8594000$$

Thus

Min d_5^+

s.t

$$d_1^+ = 0$$

$$d_4^+ = 0$$

$$97x_1 + 168.16x_2 + d_1^- - d_1^+ = 2733000$$

$$400x_1 + 700x_2 + d_2^- - d_2^+ = 11327000$$

$$0.0057x_1 + 0.0099x_2 + d_3^- - d_3^+ = 160$$

$$0.00043x_1 + 0.00052x_2 + d_4^- - d_4^+ = 10$$

$$0.00035x_1 + 0.00043x_2 + d_5^- - d_5^+ = 8$$

$$302.86 + 531.84x_2 + d_6^- - d_6^+ = 8594000$$

Thus

Min d_2^-

s.t

$$d_1^+ = 0$$

$$d_4^+ = 0$$

$$d_5^+ = 0$$

$$d_6^+ = 0$$

$$97x_1 + 168.16x_2 + d_1^- - d_1^+ = 2733000$$

$$400x_1 + 700x_2 + d_2^- - d_2^+ = 11327000$$

$$0.0057x_1 + 0.0099x_2 + d_3^- - d_3^+ = 160$$

$$0.00043x_1 + 0.00052x_2 + d_4^- - d_4^+ = 10$$

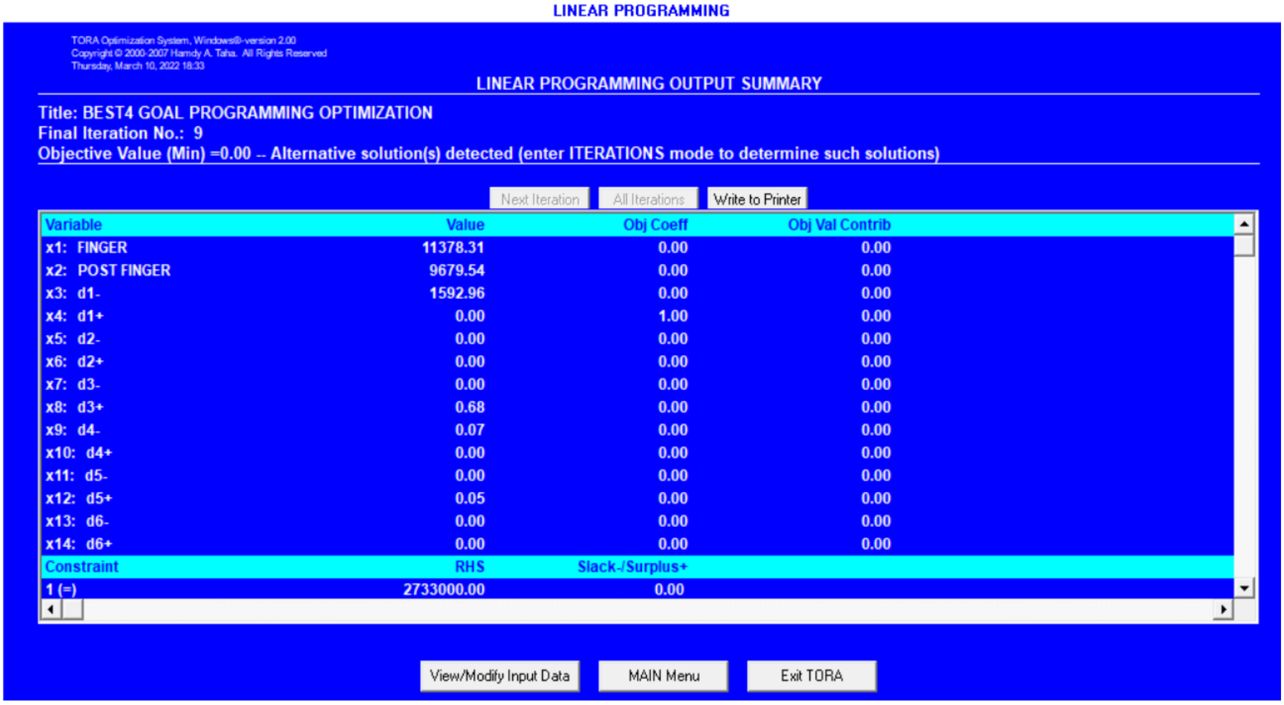
$$0.00035x_1 + 0.00043x_2 + d_5^- - d_5^+ = 8$$

$$302.86 + 531.84x_2 + d_6^- - d_6^+ = 8594000$$

P4 d3+

6. Result Summary and Interpretations

The result output from **Figures 1-3** was generated by solving the MOGP developed using TORA 2007 software. **Figure 1** shows that the first priority goal has been attained by minimizing d_1^+ to zero. Furthermore, Priority 2, $P_2\left(d_4^+\right)$ is also minimized to zero. But (d_5^+) was not satisfied since the value is 0.05. So we



LINEAR PROGRAMMING

TORA Optimization System, Windows®-version 2.00
Copyright © 2000-2007 Hamdy A. Taha. All Rights Reserved
Thursday, March 10, 2022 18:33

LINEAR PROGRAMMING OUTPUT SUMMARY

Title: BEST4 GOAL PROGRAMMING OPTIMIZATION
Final Iteration No.: 9
Objective Value (Min) =0.00 -- Alternative solution(s) detected (enter ITERATIONS mode to determine such solutions)

Next Iteration | All Iterations | Write to Printer

Variable	Value	Obj Coeff	Obj Val Contrib
x1: FINGER	11378.31	0.00	0.00
x2: POST FINGER	9679.54	0.00	0.00
x3: d1-	1592.96	0.00	0.00
x4: d1+	0.00	1.00	0.00
x5: d2-	0.00	0.00	0.00
x6: d2+	0.00	0.00	0.00
x7: d3-	0.00	0.00	0.00
x8: d3+	0.68	0.00	0.00
x9: d4-	0.07	0.00	0.00
x10: d4+	0.00	0.00	0.00
x11: d5-	0.00	0.00	0.00
x12: d5+	0.05	0.00	0.00
x13: d6-	0.00	0.00	0.00
x14: d6+	0.00	0.00	0.00
Constraint	**RHS**	**Slack-/Surplus+**	
1 (=)	2733000.00	0.00	

View/Modify Input Data | MAIN Menu | Exit TORA

Figure 1. Result output for the first priority.

LINEAR PROGRAMMING

TORA Optimization System, Windows®-version 2.00
Copyright © 2000-2007 Hamdy A. Taha. All Rights Reserved
Thursday, March 10, 2022 18:56

LINEAR PROGRAMMING OUTPUT SUMMARY

Title: BEST4 GOAL PROGRAMMING OPTIMIZATION
Final Iteration No.: 10
Objective Value (Min) =0.00 -- Alternative solution(s) detected (enter ITERATIONS mode to determine such solutions)

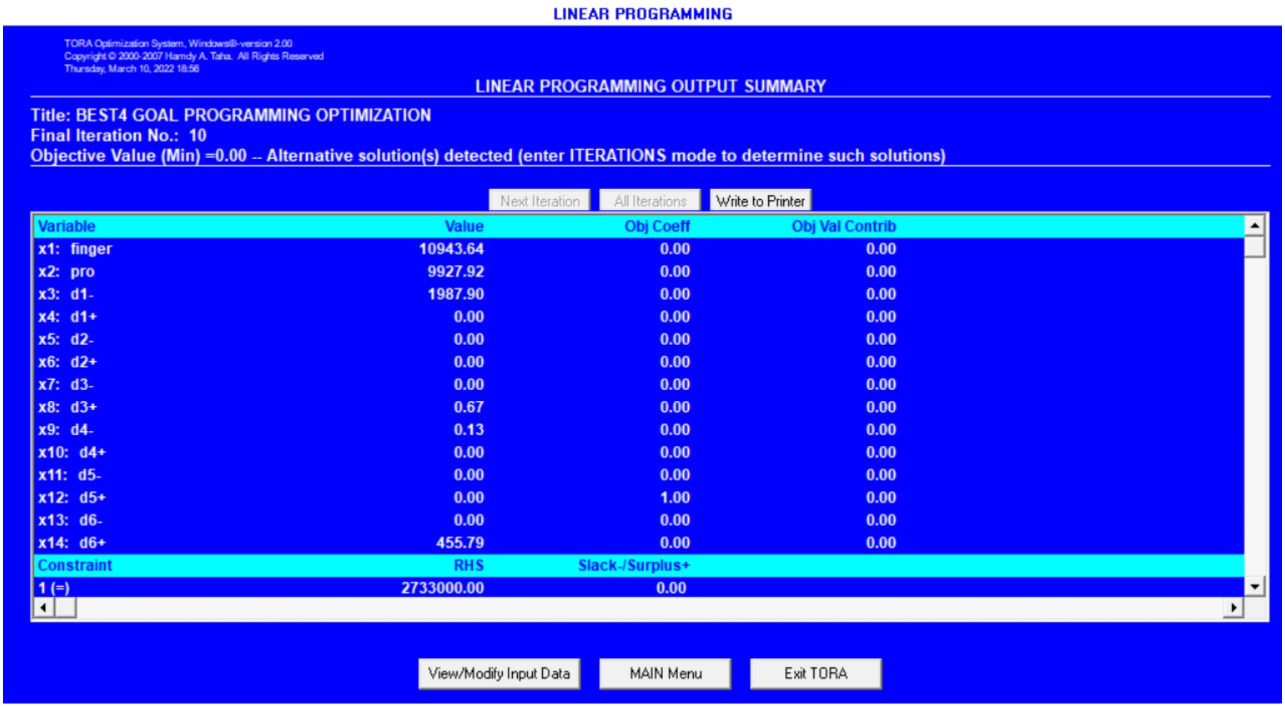
Next Iteration | All Iterations | Write to Printer

Variable	Value	Obj Coeff	Obj Val Contrib
x1: finger	10943.64	0.00	0.00
x2: pro	9927.92	0.00	0.00
x3: d1-	1987.90	0.00	0.00
x4: d1+	0.00	0.00	0.00
x5: d2-	0.00	0.00	0.00
x6: d2+	0.00	0.00	0.00
x7: d3-	0.00	0.00	0.00
x8: d3+	0.67	0.00	0.00
x9: d4-	0.13	0.00	0.00
x10: d4+	0.00	0.00	0.00
x11: d5-	0.00	0.00	0.00
x12: d5+	0.00	1.00	0.00
x13: d6-	0.00	0.00	0.00
x14: d6+	455.79	0.00	0.00
Constraint	**RHS**	**Slack-/Surplus+**	
1 (=)	2733000.00	0.00	

View/Modify Input Data | MAIN Menu | Exit TORA

Figure 2. Result output for the 2nd priority given that the first has been achieved.

proceed to Min the second priority (d_5^+) such that higher or equal priorities already achieved are not violated. That is minimizing (d_5^+) such that all the constraints holds given that $d_1^+ = d_4^+ = 0$. Repeating the same procedure yields the result output in Figure 2.


LINEAR PROGRAMMING

TORA Optimization System, Windows®-version 2.00
Copyright © 2000-2007 Hamdy A. Taha. All Rights Reserved
Thursday, March 10, 2022 18:56

LINEAR PROGRAMMING OUTPUT SUMMARY

Title: BEST4 GOAL PROGRAMMING OPTIMIZATION
Final Iteration No.: 10
Objective Value (Min) =0.00 -- Alternative solution(s) detected (enter ITERATIONS mode to determine such solutions)

Next Iteration | All Iterations | Write to Printer

Variable	Value	Obj Coeff	Obj Val Contrib
x1: finger	10943.64	0.00	0.00
x2: pro	9927.92	0.00	0.00
x3: d1-	1987.90	0.00	0.00
x4: d1+	0.00	0.00	0.00
x5: d2-	0.00	0.00	0.00
x6: d2+	0.00	0.00	0.00
x7: d3-	0.00	0.00	0.00
x8: d3+	0.67	0.00	0.00
x9: d4-	0.13	0.00	0.00
x10: d4+	0.00	0.00	0.00
x11: d5-	0.00	0.00	0.00
x12: d5+	0.00	1.00	0.00
x13: d6-	0.00	0.00	0.00
x14: d6+	455.79	0.00	0.00
Constraint	RHS	Slack-/Surplus+	
1 (=)	2733000.00	0.00	

View/Modify Input Data | MAIN Menu | Exit TORA

Figure 3. Result output for the 3rd priority given that the first and priorities have been achieved.

Figure 2 result shows that the 2nd priority has been attained without violating priority 1. *i.e.* $P_1 d_1^+ = P_2 \left(d_4^+ + d_5^+ \right) = 0$. It also indicates that Priority 3 is partially satisfied. Thus $d_6^- = 0$ but ($d_2^- = 0.05$). (d_2^-) was not satisfied since the value is 2.5. So we proceed to Minimize (d_2^-) such that higher or equal priorities already achieved are not violated. That is Min (d_2^-), given the existing constraints equations, given that $d_1^+ = d_4^+ = d_5^+ = d_6^+ = 0$. Solving these resulted problems lead to the result output in **Figure 3**.

The result output in **Figure 3** above shows that the 3rd priority has been attained without violating priority 1, 2, and 3. *i.e.* $P_1 d_1^+ = P_2 \left(d_4^+ + d_5^+ \right) = P_3 \left(d_2^- + d_6^- \right) = 0$. Priority 4 is partially satisfied. Thus $d_3^- = 0$ but ($d_3^+ = 0.67$). (d_3^+) was not satisfied, but cannot be optimized further since any attempt will violate top priorities.

Thus the deviational variable ($d_3^+ = 0.67$) implies that the number of bags of feed exceeds the target value of 160 bags by 0.65. This means that the management should budget for 161bags. This does not matter since the negative deviational variable $d_1^- = 1987.9$. This implies that the overall costs of production are reduced by ₦18,879 which is more than one the cost of extra bag of feed (12,000). **Figure 3** also shows that $d_4^- = 10.13$. This means that the number of fish pond can be reduced by 1.3. In other words, more fishes can still be accommodated using the same available ponds and this means more money for the farmer. Also $d_6^+ = 455.79$, indicating that the profit goal is overachieved with ₦455.79, increasing the total profit to ₦8,459,445.5 which is a credit to the farmer. x_1 and x_2 in **Figure 3** is the number of fingerlings and post-fingerlings that the farmer will stock in order to achieve the maximum results (profit).

7. Conclusions

The result shows that the compromised solution is reached, and thus the model developed is good for fish farm with multiple objective function as it minimizes costs of investment and improves sales revenue which in turn improves profit. It is also hoped that the interpretation above will guide the management in their decisions in expanding the business.

However, the developed model can be used by other farmers with multiple resources utilization such as machines and equipment, and different types of fishes in their farm management in order to meet market demand.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Sophia, R. and Irine, J. (2018) Multi-Objective Linear Programming Model for Small-Scalefish Farmers in Polyculture Fish Farming. *International Journal of Pure and Applied Mathematics*, **119**, 361-369.

[2] Sadiq, M.S., Singh, I.P. and Kolo, M.D. (2015) Resource Optimization in Small-Scalefish Farming in Minna Agricultural Zone of Niger State, Nigeria. *International Journal of Innovative Research and Development*, **4**, 123-128.

[3] Niang, T. and Jubrin, S. (2001) Fish Farming in the Tropics: A Functional Approach. *Quarterly Newsletter of the Nigeria Agriculture Question and Answer Service*, **1**, 1-7.

[4] Anene, A. (2004) Issues on Sustainable Fish Production in Nigeria. In: Anene, A. and Nwaigbo, L.C., Eds., *Issues in Sustainable Agriculture in Nigeria*, Osprey Publishers, Owerri, 141-149.

[5] Ugwumba, C.O.A. and Chukwuji, C.O. (2010) The Economics of Catfish Production in Anambra State, Nigeria: A Profit Function Approach. *Journal of Agriculture and Social Sciences*, **6**, 105-109.

[6] Rohman, F., Singgih, M.L. and Ciptomulyon, U. (2020) Goal Programming Model for Optimizing the Management of Brackish Water Milkfish Ponds in Gresik. *The 6th International Seminar on Science and Technology*, 526-532. https://doi.org/10.12962/j23546026.y2020i6.11154

[7] Charmes, A. and Cooper, W.W. (1961) Management Models and Industrial Application of Linear Programming. Vol. 1, Wiley, New York.

[8] Lee, S.M. (1972) Goal Programming for Decision Analysis. *Auerbach*, *Philadelphia Mathematics*, **119**, 361-369.

[9] Ignizio, J.P. (1976) Goal Programming and Extensions. Lexington Books, Lexington.

[10] Orumie, U.C. and Ebong, D.W. (2014) A Glorious Literature on Linear Goal Programming Algorithms. *American Journal of Operations Research*, **4**, 59-71. https://doi.org/10.4236/ajor.2014.42007

[11] Orumie, U.C. and Ebong, D.W. (2013) An Efficient Method of Solving Lexicographic Linear Goal Programming Problem. *International Journal of Scientific and Research Publications*, **3**, 1-8.

[12] Arthur, J.L. and Ravindran, A. (1978) An Efficient Goal Programming Algorithm Using Constraint Partitioning and Variable Elimination. *Management Science*, **24**, 867-886. https://doi.org/10.1287/mnsc.24.8.867

[13] Charnes, A. and Cooper, W.W. (1977) Goal Programming and Multi-Objective Optimization. *European Journal of Operational Research*, **1**, 39-54. https://doi.org/10.1016/S0377-2217(77)81007-2

[14] Ignizio, J.P. (1985) An Algorithm for Solving the Linear Goal-Programming Problem by Solving Its Dual. *Journal of operational Research Society*, **36**, 507-515. https://doi.org/10.2307/2582823

[15] Romero, C. (1991) Handbook of Critical Issues in Goal Programming. Pergamon Press, Oxford.

[16] Tamiz, M., Jones, D.F. and El-Darzin, E. (1995) A Review of Goal Programming and Its Applications. *Annals of Operation Research*, **58**, 39-53. https://doi.org/10.1007/BF02032309

[17] Schniederjans, M.J. (1984) A Glorious Literature on Linear Goal Programming Algorithms. *American Journal of Operations Research*, **4**, 59-71. https://doi.org/10.4236/ajor.2014.42007