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Development and Validation of Sustainable Aquaculture Indicators: Case of Alborz Dam Basin, Mazandaran, Iran

Ehsan Gholifar [1], Enayat Abbasi [2], Gholamreza Pezeshki Rad [3], Hassan Salehi [4] and Abdolmotalleb Rezaei [5]*

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Abstract

The present study was conducted to examine the development and validation of sustainable indicators related to aquaculture as a social-ecological system. By reviewing the literature, it was found about 148 indicators related to sustainable aquaculture in economic (market-oriented and responsive aquaculture, capability of risk assessment and crisis management, and financial management in aquaculture), social (participation in food security and healthy food, the role of producer and non-governmental organizations, improving the image of aquaculture, and social responsibility), environment (minimizing the impacts of aquaculture at the national level, minimizing the impacts on the environmental conditions, and biodiversity), and institutional (local development and participation in decision-making) components. The extracted components were used in the form of a questionnaire with a five-point Likert type scale according to six criteria. Questionnaires were distributed among aquaculture experts in Alborz Dam Basin in Mazandaran Province, where 32 questionnaires were returned. Research results include ranking indicators based on a total of six criteria mentioned in methodology, and ranking components, as well as their associated indicators related to sustainable aquaculture using AHP. The findings further suggested that economic and environmental aspects also were placed as the first and second ranks among 10 sustainable aquaculture indicators. Accordingly, it is highly recommended that the agencies related to the country's aquaculture development paid attention to these identified dimensions and used them in their planning.

Keywords:
Alborz Dam, basin, development and validation, Iran, sustainable aquaculture indicators

[1] Ph.D. Candidate, Agricultural Extension and Education Department, Tarbiat Modares University, Iran
[2] Assistant Professor, Agricultural Extension and Education Department, Tarbiat Modares University, Iran
[3] Professor, Agricultural Extension and Education Department, Tarbiat Modares University, Iran
[4] Associate Professor, Iran Fisheries Organization, Tehran, Iran
[5] Assistant Professor, Agricultural Extension and Education Department, University of Tehran, Iran
* Corresponding author's email: enayat.abbasi@modares.ac.ir

INTRODUCTION

Aquaculture has been considered as one of the fastest growths in the field of food production (FAO, 1997). Given the disproportionate exploitation of marine fish resources in recent decades, there has been an increasingly explicit focus on aquaculture to ensure poverty reduction, food security and income generation (FAO, 1999). Developing responsive or sustainable aquaculture can, therefore, contribute significantly to food security and nutrition in the society, as well as a variety of incomes and livelihoods, mainly through the ways that can help to reduce vulnerability and further facilitating water and nutrients management as efficient as possible. Less-privileged groups such as women and workers, especially those having no land for farming, in poor communities can benefit dramatically from aquaculture development in terms of livelihood opportunities related to the processing and service sectors (Bunting, 2013).

Aquaculture has been faced with three main challenges, including sustainable economic growth, environmental considerations and equitable distribution of benefits. An effective response to these challenges requires a coherent interaction, accelerating private investments along with a facilitation role relating to public sectors. Through building partnerships and providing access to financial resources and other resources needed, developing countries can deal successfully with these challenges, revolving primarily around two pivotal aspects, e.g., appropriate management and production and dissemination of sustainability knowledge (World Bank, 2007).

Aquaculture development is considered as a viable source for providing a still increasing population in need for affordable food in Iran. Aquaculture generally is subsumed under agriculture sector as being associated considerably with agriculture where there is water for farming a peaceful coexistence can be established between them. Recent experiences have shown that aquaculture can expedite food security, especially in developing countries. Several past decades have witnessed aquaculture is quickly moving to achieve a growing and dynamic industry (Jafarian, 2006). In Iran, the rapid development of aquaculture breeding (Table 1) clearly supports the rapid growth relating to aquaculture production observed over the last decade. For instance, the amount of aquaculture production reached in 2001 about 73 thousand and 645 tons. In 2011, 10 years later, this level of output reached 285 thousand and 351 tons. Table 1 indicates the development trend of aquaculture and reduction in fishing in the Mazandaran Province as one of pioneer provinces in the field of aquaculture (Statistical Yearbook of the Iranian Fisheries Organization, 2010).

Despite the rapid increase in the development of aquaculture in Iran, given the limited access to natural resources this rapid growth requires a move toward a more sustainable development. Compared to other production systems aquaculture is under more pressure to be sustainable, principally because of using natural resources, such as natural sweet water resources, wetlands, coastal areas, and hunting marine fish to feed farmed fishes. Along with the rapid growth of food production in the world, modern aquaculture has been growing as well. This growth is combined with a shift from focusing solely on production technology development to an emphasis on the economic and environmental aspects of sustainability in aquaculture activities (Stickney, 2002).

The sustainability of aquaculture activities depends on a combination of two groups of internal and external factors. Internal factors include water quality, breeding techniques, operational and location facilities, source of fish eggs, species properties, and natural or artificial access to food resources, while external factors encompass national policies, natural hazards, weather and water change, pollution, market, introduction of foreign species, social and cultural conditions, fish production sites and legal supervision and control. All of these factors influence fish farming operations, marketing products, and distribution of economic and social benefits. The repugnant impacts of internal factors related to the environment and sustainability aspects of aquaculture production can be resolved through the planning and on-farm appropriate management. Most external or off-farm factors require appropriate government policies and management

Table 1
Statistics Associated to Aquaculture and Fishing Activities in the Period of Ten Years in Mazandaran

The fish catches in the Mazandaran Province in the years 2001-2011 (tons)											
Description	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Bony fishes	4837	5280	7983.5	6046.5	8316	11025	10244	9987.1	8500	7360	7251
Sturgeon	350	272	173	170	152	129	87	61.2	54	32	32
Kilka	14785	10200	8025	10260	13859	13538	10301	12260	20741	21216	15856
Total	19972	15752	16181.5	16476.5	22327	24692	20632	22308.3	29295	28608	23139
Level of water resources withdrawal in the Mazandaran province in the years 2001-2011 (in tons)											
Years	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Mazandaran	134	80	240	121	120	165	180	120	206	185	124
Level of growing cold-water fish in the Mazandaran province in the years 2001-2011 (in tons)											
Years	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Mazandaran	1195	1713	3187	4074	4662	6864	8097	9169	10514	12456	13294
Level of growing warm-water fish (carp fish and caviar) in the Mazandaran province in the years 2001-2011 (in tons)											
Years	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Mazandaran	2766	20844	22233	22825	24648	22959	30610	29140	35950	38391	41690

of government interventions to tackle related problems based on source or an assigned area, planning in the exploitation of land and water, technical aids, information services, supervision and legal controls, and coordination with other industries. The effect of combining internal and external factors can cause aquaculture to be considered crucial when relating to all its system resources (Mokhtari Abkenari et al., 2004).

In this study, to integrate these two groups of internal and external factors and extract indicators, we draw upon social-ecological systems theory introduced by (Ostrom, 2009). This theory includes following sub-systems: the source system (for example, coastal fishing), the source units (for example, marine fish), users (such as fisherman), and government and management systems (including organizations and rules of the coastal fishing). These sub-systems are rather distinct from each another, but in social-ecological systems these sub-systems have to interact with each other to produce the desired result, in which, in turn, these sub-systems and their related components are under the effect of smaller or larger social-ecological systems. To maintain the sustainability of the social-ecological systems, we need the scientific knowledge directed toward studies that consider these systems as a whole and not a separate one, mainly in the form of ecological and social sciences as well as integrated units. In the present study, we also consider a combination of these two groups of variables and their interaction to develop and validate sustainable aquaculture indicators in the Alborz Dam Basin, Mazandaran Province.

MATERIALS AND METHODS

To achieve development and validation of sustainable indicators related to aquaculture as a social-ecological system, we reviewed the literature (Costa-Pierce & page, 2010, FAO, 2011, 2013, Nunes et al., 2011, Ting et al., 2015) and found about 148 indicators in relation to sustainable aquaculture in economic (market-oriented and responsive aquaculture, capability of risk assessment and crisis management, and financial management in aquaculture), social (participation in food security and healthy food, the role of producer and non-governmental organizations, improving the image of aquaculture, and social responsibility), the environment (minimizing the impacts of aquaculture at the national

Table 2

Indicators of Sustainable Aquaculture and Their Sub-indicators

Indicators	The average of total of criteria	SD	CV
Market-oriented and responsive aquaculture			
1. The ratio of marketing costs to the total value of sales.	21.43	3.90	1.201
2. The percentage of high value-added products.	20.37	3.18	0.997
3. The difference in price due to product quality.	19.90	3.56	1.293
4. The existence of a clear marketing plan.	19.34	3.43	1.342
5. Include the tastes of consumers in selecting a product type.	18.50	3.53	1.390
6. The existence of a product tracking system.	19.96	3.59	1.499
7. The existence of a quality certificate plan.	19.03	3.09	1.352
8. Innovation capability in products annually.	20.81	3.12	1.453
9. The existence of a unique label to aquaculture.	21.65	2.78	1.385
Capability of risk assessment and crisis management			
10. Market's geographic diversity (number and share of each market from total sales).	3.43	1.10	0.322
11. The number of products (species, size, class, value-added).	3.84	1.32	0.344
12. The cost of insurance to total sales.	3.68	1.28	0.348
13. The proportion of the cost of receiving professional advice to total sales.	3.25	1.19	0.366
14. The number of domestic feed suppliers (also, the percentage of imports).	3.75	1.39	0.370
15. The number of domestic hatcheries (percentage of imported baby).	3.78	1.40	0.372
16. The time scale of aquaculture farm lease.	3.78	1.43	0.378
17. Type of ownership in aquaculture farm.	3.62	1.38	0.382
18. Integration of aquaculture with complementary activities (ecotourism, restaurant, recreational fishing).	3.25	1.27	0.390
19. Supply and product sales, directly or in the contract.	3.31	1.22	0.392
20. The share of each consumer in total sales.	3.43	1.36	0.398
21. The number of renewals in aquaculture farm lease, annually.	3.59	1.43	0.399
22. Use standard ISO 14000 (or other standards).	3.25	1.50	0.462
23. Membership in the cooperatives or organizations for the sale of products.	3.15	1.48	0.470
24. The existence of a law on the disposal of biological wastes.	3.00	1.45	0.486
25. The existence of biosecurity system.	2.75	1.36	0.497
26. The existence of farm health management plans (vaccination plan).	3.25	1.54	0.515
Financial management in aquaculture			
27. The financial costs per kg of fish produced (and percentage of total cost in kg).	4.15	1.11	0.267
28. Debt rate (loan) divided by assets (total farm debts divide by total farm assets).	3.68	0.99	0.270
29. Aquaculture unit production costs (total fixed and variable costs divide by kg of fish produced, and finally divide by executive costs).	4.18	1.17	0.281
30. The energy costs per kg of fish produced (and percentage of total cost in kg).	3.75	1.07	0.287
31. The feed cost per kg of fish produced (and percentage of total cost in kg).	4.12	1.21	0.293
32. The current rate (total current farm assets divide by total current farm liabilities).	3.96	1.17	0.297
33. The rate of farm assets return.	3.84	1.16	0.303
34. Baby fish cost per kilogram of fish produced (and percentage of total cost in kg).	3.96	1.20	0.304
35. Percentage of the net sales (gross profit to revenue * 100).	3.96	1.23	0.310
36. The labor costs per kg of fish produced (and percentage of total cost in kg).	4.00	1.29	0.323
37. Transportation costs per kg of fish produced (and percentage of total cost in kg).	3.78	1.38	0.366
38. The debt rate (loan) divided by capital (total farm debts divide by total farm capitals).	3.43	1.34	0.391
39. Financial support from the government to start aquaculture (land, subsidies, loan).	3.34	1.33	0.399
40. The existence of savings for emergency and unprecedented issues.	3.18	1.30	0.410
41. Costs of environmental monitoring divide by per kg of fish produced (as a percentage of the total cost divided by kg).	3.12	1.31	0.420
42. The existence of training programs for staff and workers related to environmental aspects of their activities.	3.12	1.36	0.436
43. The existence of a plan for managing crisis situations.	2.90	1.27	0.441
44. The existence of training programs for staff related to financial aspects of their activities.	2.93	1.36	0.466
45. Receiving incentives, directly or indirectly, for environmental protection activities.	2.78	1.38	0.498
46. Financial investment for environmental protection divide by per kg of fish produced (as a percentage of the total cost divided by kg).	2.93	1.54	0.526

Indicators	The average of total of criteria	SD	CV
Participation in food security and healthy food			
47. The price of fish in contrast to the national minimum wage.	3.78	1.06	0.282
48. Annual aquaculture production.	4.18	1.20	0.287
49. The rate of production for the local markets (Self-consumption).	3.84	1.39	0.362
50. Percentage of innovation in products, annually.	3.15	1.34	0.427
The role of producer and non-governmental organizations and improving the image of aquaculture			
51. The minimum wage of staff and workers against the national minimum wage.	3.43	1.13	0.330
52. Percentage of trained staff and workers with specialized certification.	3.50	1.27	0.362
53. Membership in farmers' organizations and cooperatives (in number).	3.31	1.20	0.363
54. The existence of ecological labels and product specifications.	3.06	1.41	0.461
55. The existence of a strong social base among the other aquaculture growers.	2.84	1.46	0.514
Social responsibility			
56. The number of work hours by the aquaculture workers.	3.93	1.24	0.316
57. The number of work-related accidents.	3.31	1.14	0.346
58. Percentage of high-quality fish produced.	3.40	1.18	0.349
59. Percentage of women workers	3.37	1.28	0.382
60. The number of identified pathology.	3.03	1.20	0.397
61. The percentage of membership in workers' unions.	3.28	1.32	0.403
62. The rate of visiting relevant agencies and gaining information from them.	2.78	1.18	0.425
63. The rate of unsaleable fishes produced.	3.12	1.38	0.443
Minimizing the impacts of aquaculture at the national level			
64. The feed conversion ratio (kg feed / kg fish).	4.15	1.13	0.274
65. The existence of the hatchery with the masses of indigenous babies.	3.25	0.91	0.281
66. Algal growth and blooms (number of cells per milliliter).	3.68	1.11	0.304
67. Depth (m).	3.84	1.22	0.317
68. The percentage of space used for aquaculture.	3.62	1.15	0.319
69. The number of species introduced in aquaculture.	3.90	1.35	0.346
70. Water volume occupied by per kg of product (kg / m^3).	3.46	1.24	0.359
71. Exchange with the open sea (coastline part): distance in meters.	3.50	1.31	0.376
72. Increasing fishing activity around the farm cages.	2.96	1.14	0.388
73. Oxygen saturation (percent).	3.46	1.34	0.388
74. Consumption of marine fish (tons per year).	3.50	1.36	0.390
75. Loss of nursery and spawning habitat.	3.25	1.29	0.398
76. Vegetable consumption (tons per year).	3.40	1.38	0.407
77. Turbidity / clarity (sushi disc).	3.56	1.45	0.409
78. The microbiological indexes (coliforms).	3.40	1.49	0.440
79. Rehabilitation index and the spawning mass (biomass).	3.37	1.49	0.444
80. Carrying and storage capacity of the ecosystem.	2.93	1.41	0.481
81. Supervision on the quality of fish larvae produced in hatcheries.	3	1.50	0.500
82. Modified catching of target species in the area (monitoring of fishing activities).	2.96	1.15	0.525
Minimizing the impacts of aquaculture at the national level			
83. Total Phosphorus (kg).	4.02	0.98	0.244
84. Accumulation of heavy metals (one millionth gram).	3.96	1.14	0.290
85. Oxidation-reduction potential (PH).	3.81	1.14	0.301
86. Antiphrastic kg per ton of fish produced (kg).	3.78	1.15	0.305
87. The use of non-indigenous species.	3.71	1.22	0.329
88. Use GMO species.	3.31	1.09	0.329
89. Turbidity (sushi disc).	3.78	1.26	0.334
90. Use locally-based production sources.	3.71	1.25	0.336

Indicators	The average of total of criteria	SD	CV
91. Antibiotic kg per ton of fish produced (kg).	3.84	1.29	0.337
92. Chlorophyll (mg / m³).	3.65	1.23	0.338
93. Use food nutrients along with chemical antioxidants.	3.50	1.21	0.348
94. The level of nutrients lost to total (percentage).	3.31	1.17	0.355
95. Disinfectants kg per ton of fish produced (kg).	3.71	1.39	0.376
96. Total particulate organic matter (mg / M³).	3.62	1.38	0.382
97. Total organic carbon (organic) (TOC, mg / m³).	3.56	1.38	0.390
98. Total dissolved organic matter (mg / M³).	3.62	1.45	0.401
99. Stool sedimentation rate (grams per day).	3.18	1.33	0.418
100. Use antifouling biocides in aquaculture.	3.40	1.43	0.421
101. The level of nutrient balances (kg).	3.21	1.40	0.438
102. Use certified organic fish feed.	3.15	1.41	0.449
103. The level of farm's disseminated pathogens in other farms.	2.96	1.40	0.472
Local development			
104. The number of reports related to the environmental crises over the last five	3.50	1.13	0.324
years.	3.25	1.19	0.366
105. Percentage of the seasonal workers in aquaculture in comparison to seasonal	3.62	1.33	0.369
workers with supplement activities.	3.06	1.13	0.370
106. The number of staff and workers (both direct and indirect).	3.62	1.36	0.375
107. Receiving subsidies for ecological services.	3.50	1.31	0.376
108. Percentage of full-time and permanent workers.	3.15	1.32	0.419
109. Percentage of seasonal workers.	2.81	1.40	0.498
110. The rate of participation with local policy-making organizations and institutions (Dehyari, Gubernatorial).			
Participation in decision making by aquaculture growers			
112. Percentage of the workers and technicians familiar with the rules.	3.43	1.24	0.362
113. The number of participating in advisory sessions.	3.25	1.16	0.357
114. The number of constructed measures in partnership relationships.	2.75	1.19	0.433
115. The number of disputes resolved at the local level.	2.78	1.12	0.405
116. Effective participation in local decision-making processes.	2.90	1.27	0.441

level, minimizing the impacts on the environmental conditions and biodiversity), and institutional (local development and participation in decision-making) components. The extracted components were used in the form of a questionnaire with a five-point Likert type scale according to six criteria: (a) measurement capability: is the indicator quantifiable and measurable? is there data to measure it?; (b) scientific relevance: to what extent indicator is scientifically valid?; (c) policy relevance: is whether indicator related to the country's strategic and important issues for management and decision making or not?; (d) sensitive to changes: to what extent is sensitive to changes in its encompassing environment and react to it?; (e) simplicity: is indicator understandable for people without specialized knowledge?; and (f) economic justification: is collection and calculation of data in a time and cost framework possible? Questionnaires were distributed among aquaculture experts which were selected purposively, where 32 questionnaires were returned. Respondents were experts in National Fisheries Organization (n=15), National Institute of Research and Science for Fisheries (n=8), Faculty Members of Fisheries in University of Tehran (n=1), Sari's Fisheries Organization (n=4), Academic Center for Education, Culture and Research (n=2), and Faculty members at the Sari University (n=2). Next, the opinions of respondents were received, where most important indicators ranked using the Coefficient of Variation (CV) and the mean. The Analytic Hierarchy Process

(AHP) was applied to determine the weight and importance of each of the indicators in their corresponding components. The multi-criteria decision-making methods primarily draw upon the several criteria instead of using a measure of optimality. Available models in this area are categorized in two models,, that is, multi-objective and multi-criteria. Multi-objective models intend to design objectives; however, multi-attribute models are used to select the top priority option. The decision space for the first method is continuous while the later benefit from the discrete space used for the decision-making.

AHP method is considered as one of the most common methods for Multi-Criteria Decision Making or MCDM, used primarily to solve unstructured problems in different areas of the study. This method is used mainly in two settings: (a) finding the weight or relative importance of the indicators that have been used in a given study, and (b) rankings options in relation to several indicators. In this study, we draw upon the first application of AHP method, where paired comparisons between indicators are established. After obtaining the relative weight of each of the indicators, the Inconsistency Rate (IR) is calculated. To this end, first, we should calculate the vector of the weighted sum in which the paired comparison matrix will be multiplied by the vector of relative weight, resulting in a matrix so-called the vector of the weighted sum. Finally, the consistency vector will be obtained through dividing the elements of the vector of the weighted sum to relative weights.

RESULTS

In this section, findings are presented in two sub-sections (a) ranking indicators based on a total of six criteria outlined in methodology, and (b) ranking components and their associated indicators relating to sustainable aquaculture using AHP.

Ranking indicators based on a total of six criteria

The average of the total of six criteria (0-5 for each criteria), (measurement capability; scientific relevance; policy relevance; sensitive to changes; simplicity; and economic justification) in relation to each variable was calculated and presented in Table 2.

Ranking components and their associated indicators related to sustainable aquaculture using AHP

In order to study sustainable aquaculture indicators, we first should culminate in paired comparisons from utilizing questionnaires completed by 32 experts. After norming the pairwise comparison matrices, the indicators were ranked, mainly through obtaining the arithmetic mean of each row of the matrix and multiplying the relative weights in the obtained mean. The next step is to calculate the largest eigenvalues of pairwise comparisons matrix in order to come to indicators and the IR. For the paired comparisons in the present study, IR was close to 1.0, showing that the obtained relative weights are the valid and reliable collective opinions. Figures 1, 2 , and 3shows the relative weight of dimensions and their associated indicators related to sustainable aquaculture, respectively

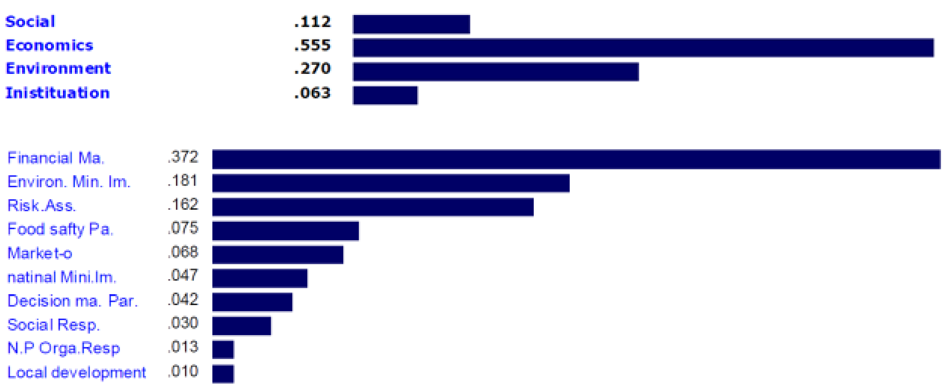

Figure 2. The relative weight of each indicator of sustainable aquaculture

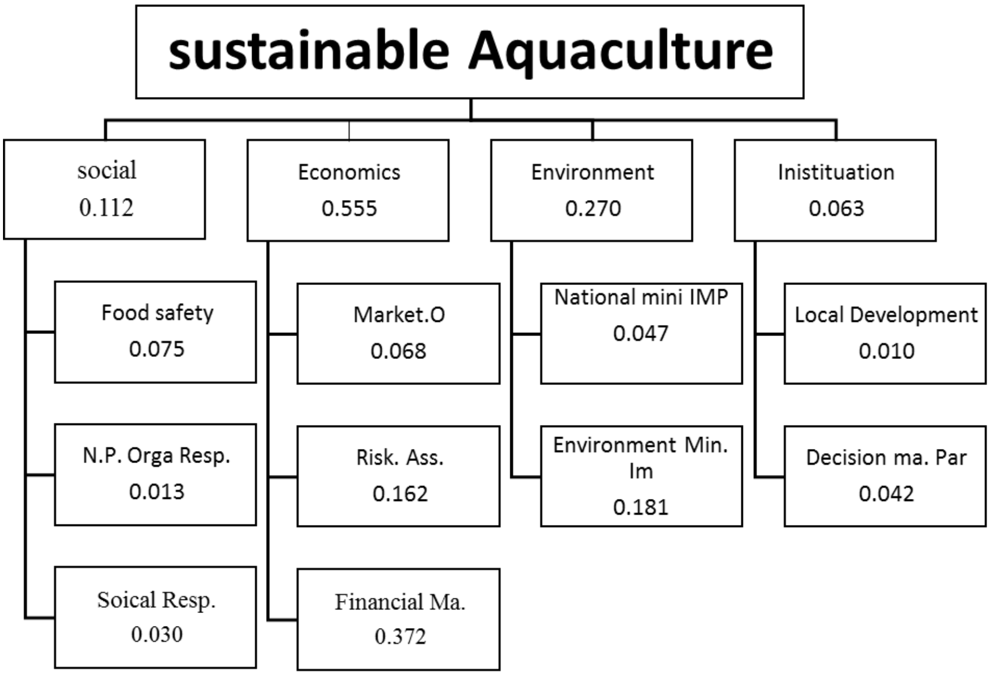

Figure 2. Hierarchal map of each indicator of sustainable aquaculture

CONCLUSION AND RECOMMENDATIONS

The loss of potential water resources, forests, and fisheries has been a critical problem around the world. Understanding the processes that lead to the improvement or exacerbation of natural resources are frustratingly limited, mainly because of the various languages and concepts used in scientific disciplines to describe complex socio-ecological systems. There is no ability to access multidisciplinary knowledge without having a common framework to organize the findings (Ostrom, 2009). In this way, the principles of "systematic approach to managing the sustainability of aquaculture" has been developed by (Bunting, 2013). Components or features that interact in an aquaculture system include moral, cultural, social-political, economic, climatic, agricultural- environmental, water and weather, production, resource utilization, mass balance, and biological.

Generally, the stages of using a system-based approach include the definition of cultural practices under investigation and the determination of the scope and boundaries of the system based on the physical area occupied, as well as the comprehensive environmental impact assessments or zero assessment to 100 products, including input, by products, and waste disposal. The next steps in this approach include studying the relationships between the components within the system, evaluating the context, describing the system, checking performance, controlling system behaviour, describing the practical implications, and the effects of the system output. The subsequent combination of these components should lead to a better understanding of the context of the overall system, making it possible to sort different components of the system and provide more details about the choices made, as well as the required predictions related to the outcomes and consequences of the system (Bunting, 2013). In the light of such a systemic view, the present study aimed to develop and validate indicators of sustainable aquaculture in the Alborz Dam Basin, Mazandaran Province. One hundred and sixteen sub-indicators (four components and 10 indicators) were identified and ranked. The ranked priorities were: economic, environmental, social, and institutional components. What is certain is that since most of aquaculture growers in the study area were holding small-scale aquaculture, it is necessary to give more attention to economic aspects and provide financial facilities for them to use modern methods related to aquaculture in accordance with the environmental considerations, a finding supported by experts' opinions.

The findings further indicated that economic and environmental aspects also were placed in the first and second ranks among 10 sustainable aquaculture indicators. Therefore, it is highly recommended that attention to these identified dimensions and planning according to their corresponding indicators should be the focus of agencies related to developing the country's aquaculture development agenda, where developing a comprehensive plan for sustainable aquaculture development based on these identified priorities can accelerate the growth of sustainable aquaculture in the country to provide healthy products for the consumer along with taking into account all environmental effects it matters.

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