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Sustainable livelihood alternatives among Nile perch (*Lates niloticus*) fishers in Lake Victoria Tanzania: analytical hierarchy process (AHP) approach

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Abstract

Sustainable livelihood has been a focal point in many development initiatives by private and public sectors in most African countries. However artisanal fishers in the main lakes of Africa are faced with several alternative decisions to improve their livelihood sustainably. Several studies which have been conducted in Africa offered various options using different models such as sustainable livelihood approach/framework (SLA). This study provides different decision-making alternatives using multi-criteria decision model known as analytical hierarchy process (AHP) to assess the most economical and sustainable livelihood options for Nile perch fishers in Lake Victoria Tanzania. Using structured questionnaires and key informant interviews, different strategic criteria such as environment, economic, social and technology were analyzed and the study found that, important factor in the strategic criteria is environment. Moreover, different livelihood alternatives which include livelihood diversification, fisheries co-management and promotion of aquaculture were analyzed. The study found that livelihood diversification which implies diversifying income-generating activities was identified as the best alternative model for sustainable livelihood development. The study recommends proper income diversification interventions and environment management for the sustainability of Nile perch fishers' livelihood and fishery resources in Lake Victoria.

Keywords: Analytical hierarchy process (AHP), Nile perch fishers, Sustainable livelihood

1 Introduction

Small-scale fisheries play an essential role as a source of livelihoods, food security and income for millions of people around the world in both developed and developing countries (Allison and Ellis 2001; Berkes et al. 2001; Purcell and Pomeroy 2015). Over 90% of fishers in the world are employed in small-scale fishing operations particularly in developing countries (FAO 2012). Small-scale fisheries are often not well-managed and are under extensive pressure both on local and global scales (Berkes et al. 2001; Smith et al. 2010; Kittinger et al. 2013). Consequently, households around fisheries resources are

faced with a high level of poverty, food insecurity and insufficient livelihood alternatives (Silva 2006; Béné et al. 2007; Wallner-Hahn et al. 2016). Additionally, the growing population around fisheries resources has influenced environmental stresses and overfishing due to the fishing pressure exerted in the nearshore fisheries (Pomeroy et al. 2016).

Lake Victoria is the world's second-largest freshwater and the largest tropical lake, with a total surface area of 68,800 km^2 (Witte and van Densen 1995). The lake's surface areas are shared by three countries which are Tanzania (51%), Uganda (43%) and Kenya (6%). It supports the largest inland fishery and livelihood of communities, but also accounts for about 1% of the world's capture production (World Bank 2012). It recently has changed from a multi-species to single-specie fishery that is dominated by the introduced Nile perch (*Lates niloticus*) (Linnaeus, 1758) (Aloo et al. 2017). Nile perch, is a predatory fish of high commercial and recreational value supporting a multimillion-dollar export industry that offers the three East African countries an average of US $350 million in export earnings annually (Marshall and Mkumbo 2012; Njiru et al. 2014; Aloo et al. 2017). As a consequence, catch and effort continued to expand in Lake Victoria in the last decades causing overfishing of Nile perch despite the introduction of the fisheries management practices (Van der Knaap et al. 2002; Kolding et al. 2008; Obiero et al. 2015). Over-exploitation of fishery resources has become the main challenge not only to users of the resource, but also the society at large, which is likely to affect the livelihood of Nile perch fishers in the future (Tetteh 2010). This calls for an understanding of different livelihood strategies that can sustain the livelihood of Nile perch fishers at the same time conserving the fishery resources.

The sustainable livelihoods framework (SLF/SLA) has been widely used in the assessment of livelihoods of communities around natural resource. For instance, Ferrol-Schulte et al. (2013) focusing on sustainable livelihoods approach (SLA) as a framework for understanding and guiding policy-making in coastal and marine social-ecological systems. Other studies employed SLA to understand the impact of fishers mobility, climate change and poverty on fishers livelihood (Badjeck et al. 2010; Nunan 2010). Some of the methodologies that have been used to assess the livelihood strategies of artisanal fishers includes, ecosystem approach to fisheries, management for resilience, social-ecological systems and a meta-analysis methodology (FAO 2003; Garcia et al. 2003; Carpenter et al. 2001; Carpenter et al. 2005; Walker et al. 2004; Berkes et al. 2003; Evans et al. 2011; Pomeroy et al. 2016).

These methods were specific to one particular aspect of analysis and failed to integrate different complex aspects of livelihood together. Also, there are insufficient studies conducted to assess various optimum alternatives for artisanal fishers livelihood using the multi-criteria cluster analysis such as analytical hierarchical processing (AHP) model. Unlike other models, the analytical hierarchical processing (AHP) model is an effective model that helps to deal with complex decision-making by reducing complex decisions to a series of pairwise comparisons, and then synthesizing the results. In addition, it helps to capture both subjective and objective aspects of a decision. Furthermore, the AHP includes a useful technique for checking the consistency of the decision-maker's evaluations, thus reducing the bias in the decision-making process (Saaty 1990, 2010; Adamus and Florkowski 2016). Therefore, this study aims to contribute to the existing literature and provide optimal and priority strategies for enhancing Nile perch

fishers' livelihood in Lake Victoria Tanzania by using the multi-criteria cluster analysis approach, specifically analytical hierarchical processing (AHP) model.

2 Theoretical and conceptual framework

The livelihood theory has been well hinged under the sustainable livelihood framework approach in explaining the livelihood and practice. A livelihood involves different aspects such as capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from shocks and stresses and maintain and enhance its capabilities and assets both now and in the future, whilst not undermining the natural resource base (Chambers and Conway 1992; Morse et al. 2009). Identifying what livelihood resources (or combinations of 'assets') are required for different livelihood strategy combinations is a key step in the process of analysis (Scoones 1998). There have been different models for sustainable livelihood framework put forward by several studies, which focused on five capitals of sustainable livelihood that are natural, social, human, physical and economic capital (Chambers and Conway 1992; Scoones 1998; Carney et al. 1999). In the different models of SLA according to various institutions such as Care International and UNDP integrated all the five capitals (assets), but with different approaches and some models use few or more assets and outcomes (Solesbury 2003; Small 2007). This study focused on the most recent model by DFID, which among all, integrated the assets with the distinguished feature of underlying principles[1] and a variety of sustainable livelihood analysis of strengths and micro–macro links, it also builds upon the existing experience and lessons and offers a practical way forward in a complex environment (Chambers and Conway 1988; Carney et al. 1999).

In building the sustainable livelihood framework for Nile perch fishers in Lake Victoria Tanzania, this study conceptualized that Lake Victoria is endowed with potential livelihood assets. These assets are natural resources including abundant fish species (Nile tilapia, sardines, different haplochromines and highly commercial value Nile perch fish). However, other livelihood assets such as human capital (skilled labor), physical capital (improved infrastructures) and financial capital (financial services such as credits) remain a challenge. Sithole (2006) pointed that some major limitations for artisanal fishers development in Africa are, access to credits because artisanal fishers are perceived as high risk, smaller credit size, lack of collateral, information gap, and quality of business propositions. Furthermore, Jentoft et al. (2010) indicated that fisher's access to finance as a livelihood financial asset was hindered by inadequate collateral and land assets. Moreover, other available livelihood assets in Lake Victoria are cross-cutting since one asset would influence the other, for instance, access to finance could be influenced by skilled labor (human capital), communication and improved fishing gear (physical capital).

This study gleaned the empirical literature on fishers sustainable livelihood (Finkbeiner and Basurto 2015; Nunan et al. 2015; Matera 2016; Torell et al. 2017) in an attempt to improve the Nile perch fisher's livelihood through the transforming structures and processes under the context of vulnerability. Various livelihood strategic criteria and

[1] According to DFID's Sustainable Livelihood Principles, poverty-focused development activity should be people centered, responsive and partipatory, multi-level, conducted partnership, sustainable and dynamic.

alternatives were used which are livelihood diversification, fisheries co-management and promotion of aquaculture. These strategic criteria are hypothesized to improve Nile perch fishers' livelihood outcome such as increased income, increased wellbeing, reduced vulnerability, improved food security and more sustainable use of the lake fisheries resources.

3 Methodology

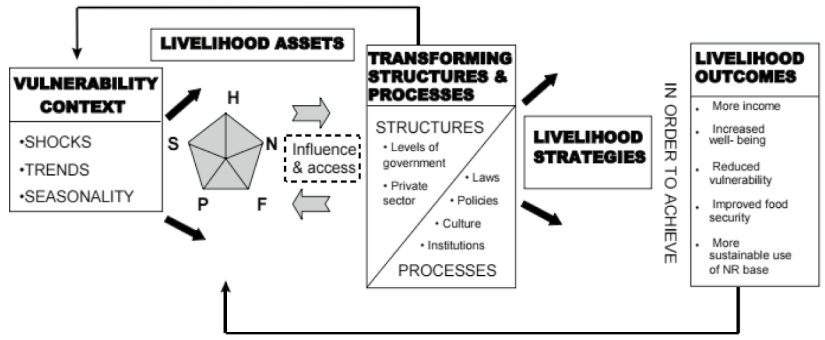
3.1 Multi-criteria analysis—analytic hierarchy process (AHP)

Multi-criteria analysis methods are mainly used to structure a complex decision problem. They are used when multi-objectives or multiple criteria need to be considered and when there are heterogeneous sets of criteria and conflicting objectives. They are also used to compare different management alternatives, and to conduct a more rational, transparent and comprehensive analysis, which could be both qualitative and quantitative data in the decision model (Wolfslehner et al. 2005). Some of the mostly used multi-criteria analysis methods in empirical studies are the analytic network process (ANP); artificial neural networks (ANN); multi-criterion analysis of preferences by means pairwise actions and criterion comparisons (MAPPACC); preference ranking organization method for enrichment evaluating (PROMETHEE version I to VI); technique for ordinal multi-attribute sorting and ordering (TOMASO); technique for order preference by similarity to ideal solution (TOPSIS); utilities additives (UTA methods); verbal analysis decisions (VDA) and analytic hierarchy process (AHP).

In order to evaluate decision alternatives for the Nile perch fisher's livelihood in Lake Victoria Tanzania (Fig. 2), the analytical hierarchy process (AHP) was applied (Wind and Saaty 1980; Saaty 1986, 1994). The AHP is a widely applied and discussed multi-criteria decision-making technique, which decomposes a complex problem into a hierarchy, in which each level is composed of specific elements (Kangas and Kangas 2004; Adamus et al. 2011). The AHP model differs from other multi-criteria decision-making methods in a number of aspects in that it presents the problem structure in a hierarchical form, with the overall goal at the top of the hierarchy and the criteria, sub-criteria and decision alternatives are on descending levels of this hierarchy (see Fig. 1). The AHP also conducts pairwise comparisons of elements at each level of the hierarchical structure using the Saaty's preference scale (see Table 1). In addition, it introduces a relative assessment scale (priorities) for quantitative and qualitative comparisons (Alphonce 1997; Bascetin 2007).

The significance and preferences of the various decision elements are linked in pairs with reference to the element that is immediately above in the hierarchy. Based on these comparisons, local and global priorities are compared. Local priorities determine the relative importance of decision elements at each level of the hierarchical structure. They constitute a basis for the calculation of global priorities, which represent the share of each decision element from the various levels in the accomplishment of the main goal. The alternative with highest priority value is deemed the best and recommended for implementation in practice. All calculations have been done with aid of Super Decisions© software (Adamus 2011).

The differences in scales, as well as measurement units, are not a barrier in the application of AHP since the method is based on direct significance degree comparisons as



H represents human capital: the skills, knowledge, and ability to labor and good health important to the ability to pursue different livelihood strategies;

P represents physical capital: the basic infrastructure (transport, shelter, water, energy and communications) and the production equipment and means that enable people to pursue livelihoods;

S represents social capital: the social resources (networks, membership of groups, relationships of trust, access to wider institutions of society) upon which people draw in pursuit of livelihoods;

F represents financial capital: the financial resources which are available to people (whether savings, supplies of credit or regular remittances or pensions) and which provide them with different livelihood options;

N represents natural capital: the natural resource stocks from which resource flows useful for livelihoods are derived (e.g. land, water, wildlife, biodiversity, environmental resources).

Fig. 1 Sustainable livelihood framework (Source: Carney et al. (1999))

Table 1 Saaty's fundamental comparison scale (1–9). Source: Saaty (2004)

Scale	Definition	Explanation
1	*Equal importance/preference/likelihood*	Two elements contribute equally to the goal/parent element
3	*Weak dominance*	Experience or judgment slightly favors one element over another
5	*Strong dominance*	Experience or judgment strongly favors one element over another
7	*Demonstrated (very strong) dominance*	Experience or judgment strongly very strongly favors one element over another (an element's dominance is demonstrated in practice)
9	*Absolute dominance*	The evidence favoring an element over another is affirmed to the highest possible order
2, 4, 6, 8	*Intermediate values*	Further subdivision or compromise is needed
Reciprocals of the above	If activity *i* has one of the above nonzero numbers assigned to it when compared with activity *j*, then *j* has reciprocal value when compared with *i*	i.e., If *x* is 5 times *y*, then $y = x/5$
Rationals	Rations arising from the scale	If consistency were to be forced by obtaining *n* numerical values to span the matrix

well as preferences of each decision elements pair without using physical units. This is why AHP is also used with reference to analyzing both quantitative as well as qualitative variables.

Extensive literature review in related databases such as Scopus, Science Direct, Emerald Intelligence, Google scholar was used to formulate major criteria and sub-criteria affecting the effectiveness of *Nile perch fishers' livelihood improvement (NPFLI)* in Lake Victoria (Fig. 2). Initial research into the literature review was conducted in order

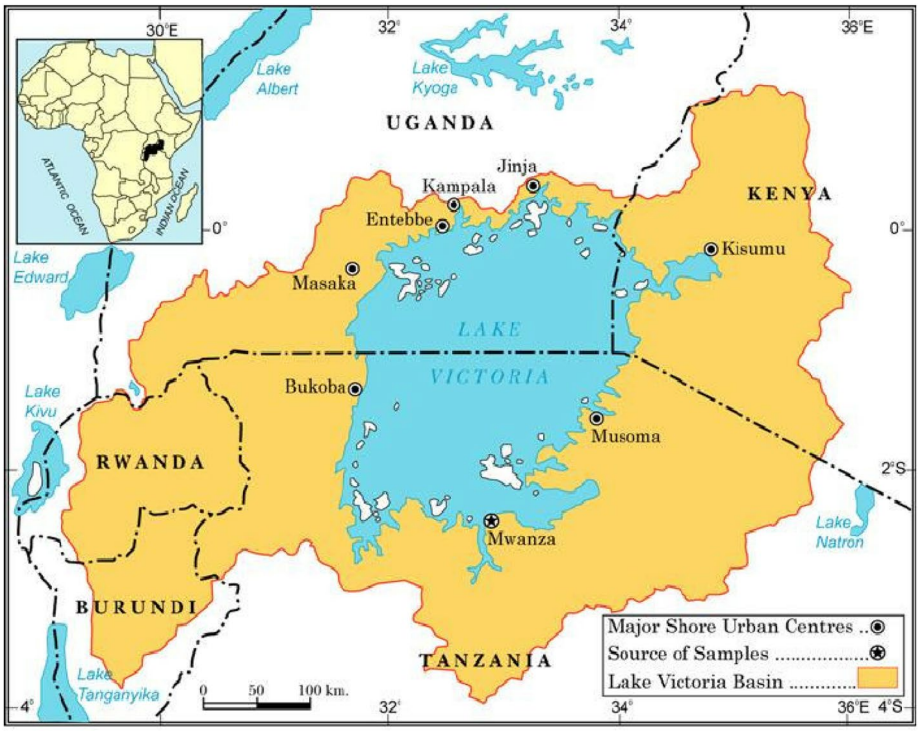


Fig. 2 The map of Lake Victoria (Source: Gumisiriza et al. (2009))

to select keywords, which were utilized for further research. Preparation of questionnaire used in AHP approach was designed to elicit and refine judgments from a panel of experts. AHP questionnaire allowed the experts to identify and elaborate factors they consider important. Questionnaires were filled in during face-to-face and Skype meetings. Selection of the expert group taking part in AHP evaluation of *NPFLI* largely depended on the quality of the participants/experts, therefore, the nomination of people who would be taking part in a study was very precise and carefully thought out. This study was conducted among Tanzania's experts involved in the fishery sector with 100 sample size of respondents who were purposively selected for an interview which was conducted using different means such as Video Skype, face-to-face and phone call.

Moreover, the majority of experts were top-quality experts from academic institutions that involved 10 professors in fishery studies, 10 senior researchers from fishery research institutions, 20 fishery extension officers with at least two from 10 districts visited in Mwanza region and 50 owners of small and medium fishery enterprises who have at least secondary education. In addition, a collection of expert's opinions/ideas/judgments about *NPFLI* was conducted to prioritize the livelihood strategies. At this phase of the study, a pairwise comparison questionnaire of the success factors identified in previous phases was developed and used to collect pairwise comparison data. By the pairwise comparison data, the priority and ranking of each criteria and sub-criteria in terms of effective and successful *NPFLI* was obtained (filled in questionnaires) and formulation of the hierarchical structure of the identified critical factors. Construction of the *NPFLI*

evaluation and monitoring framework based on identified *NPFLI* was done by through pilot studies with selected experts.

3.2 Application of AHP method for identification of Nile perch fishers' livelihood improvement

In order to determine the critical success factors of cluster initiatives management using AHP model the following steps (stages) were adopted for the assessment of significant factors that influence *Nile perch fishers' livelihood improvement*:

1. The positioning of the problem—determination of factors affecting *Nile perch fishers' livelihood improvement*;
2. Identification of the main goal *Nile perch fishers' livelihood improvement*;
3. Identification of *Nile perch fishers' livelihood improvement* literature review;
4. The construction of the multi-level structure of the problem in the form of a hierarchy tree, the main goal, strategic criteria and sub-criteria (a) presentation of the problem structure in hierarchical form, with the overall goal at the top of the hierarchy as well as decision alternatives at its lowest level (see Fig. 3).
5. Defining in the framework of the hierarchical structure the dominance (prevalence) of the main criteria by making pairwise comparisons (for each against all others) of their importance (verbal opinions) in relation to the factors, which determine the Nile perch fishers' livelihood improvement on the fundamental preference scale of T. Saaty. Evaluators of the criteria (experts) were expected to answer a series of questions, such as which of the criteria rank is more important in relation to other criteria and which of the sub-criteria are more important in relation to the given criterion as well as to what degree they are more important in the scale from equally important (1) to absolute dominance (9). The evaluator's task was to mark in the pairwise comparison table the dominance of one criterion above another on the verbal scale from weak to absolute (extreme) dominance. If one criterion did not outweigh another in relation to the respective goal of comparison, i.e., in the case of equivalence of both criteria in the expert's opinion, the evaluators (experts) marked equal dominance of the criteria (the lack of preference for one above the other).
6. Defining in the framework of the hierarchical structure, the preferences for sub-criteria (intensity level) by pairwise comparison of the importance in relation to the value of each main criterion using the fundamental preference scale of T. Saaty.
7. Quantification of verbal opinions about the comparative importance of the main criteria based on the fundamental preference scale of T. Saaty (by converting verbal assessments into numerical scores).
8. Quantification of verbal opinions about the comparative importance of sub-criteria.
9. Computation of priorities (weights), from the interval $[>0, <1]$ for each criterion and sub-criterion by normalizing eigenvectors for the comparison matrix. Computed weights for the criteria show their dominance/influence ranking.
10. Finally, the decision scenarios for of Nile perch fishers' livelihood improvement (under some conditions inseparably related to the aim of the research) achieved the highest rank.

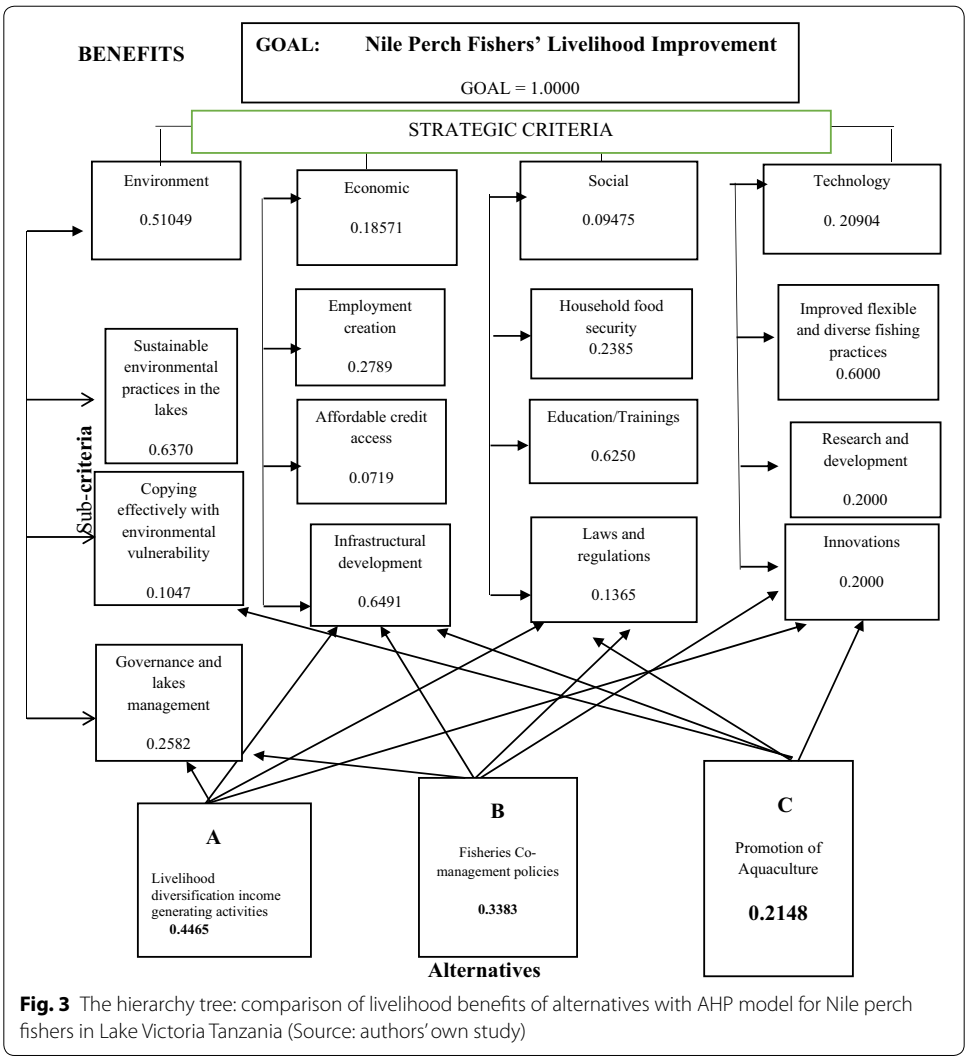


Fig. 3 The hierarchy tree: comparison of livelihood benefits of alternatives with AHP model for Nile perch fishers in Lake Victoria Tanzania (Source: authors' own study)

4 Results

The magnitude of the global priority determines the percent of 'contribution' of the given sub-criteria for overall Nile perch fishers' livelihood improvement. In order to compute the exact influence of each sub-criteria on the whole process of *Nile perch fishers' livelihood improvement* for each sub-criteria its global priority was estimated. The global priority means the individual influence of each sub-criteria on the process of cluster initiatives management. To obtain it, the local priority of the main criterion was multiplied by the local priority of the given sub-criteria according to the following formula: global weight (priority) of the *j*th sub-criteria with regard to the ith main criterion = [weight (priority) of the ith criterion] × [local weight (priority) of the *j*th sub-criterion with regard to the ith criterion]. Thus, for example, the global priority for "Governance and Lake's management" was a result of the multiplication of the normalized local priority

Table 2 Main criteria and global criteria. Source: authors' own study

Main criteria	Global priority
Environment	0.51049

Table 3 Global priorities of the main (strategic) criteria (goal: Nile perch fishers' livelihood improvement). Source: authors' own study

Criteria	Scores
Economic	0.18571
Social	0.09475
Technology	0.20904
$\Sigma =$	1.00000

for 'Environment ($P=0.51049$) by the normalized local priority of "Governance and Lake's management" ($P=0.2582$).

The calculated global priority is thus equal to $P_g = P_e + P_l$, $P_g = 0.51049 \times 0.2582 = 0.1318$.

4.1 Alternatives

Model A Livelihood diversification income-generating activities
Model B Fisheries co-management policies
Model C Promotion of aquaculture

5 Discussion and conclusion

Relative weights of criteria are the result of pairwise comparison of each criteria against one another. AHP model included 16 criteria including environmental, economic, technological and social factors determining Nile perch fishers' livelihood improvement. The most important factor in the strategic criteria is the environment since it scored a high value as compared to other criteria (see Tables 2, 3, 4, 5, 6, 7 and Fig. 4). Because of prioritization (see the summary in Table 8), math formula gives the results for Model A: livelihood diversification income-generating activities, as the best alternative as it scored high compared to other alternatives. However, sensitivity analysis can slightly change the values of priorities for analyzed alternatives, but that requires taking extreme assumptions for prioritization. In order to develop sustainable livelihood mechanism for Nile perch fishers' livelihood, proper interventions and policy should be focusing on environmental management and diversify income-generating activities apart from Nile perch fishing. Diversification of income sources has always been put forward to minimize income variability and to ensure a minimum level of income (Abdulai and Rees 2001). Livelihood diversification means, attempts by individuals and households to undertake diverse income-generating activities over

Table 4 Sub-criteria-normalized local priorities (goal: Nile perch fishers' livelihood improvement). Source: authors' own study

Strategic criteria	Sub-criteria	Normalized criteria
Environment	Sustainable environmental practices in the lakes	0.6370
	Coping effectively with environmental vulnerability	0.1047
	Governance and lakes management	0.2582
	$\Sigma =$	1.0000
Economic	Employment creation	0.2789
	Affordable credit access	0.0719
	Infrastructural development	0.6491
	$\Sigma =$	1.0000
Social	Household food security	0.2385
	Education/training	0.6250
	Laws and regulations	0.1365
	$\Sigma =$	1.0000
Technology	Improved flexible and diverse fishing practices	0.6000
	Research and development	0.2000
	Innovations	0.2000
	$\Sigma =$	1.0000

Table 5 Sub-criteria global priorities (goal: Nile perch fishers' livelihood improvement). Source: authors' own study

Strategic criteria	Sub-criteria	Global priority
Environment	Sustainable environmental practices in the lakes	0.3252
	Coping effectively with environmental vulnerability	0.0534
	Governance and lakes management	0.1318
Economic	Employment creation	0.0518
	Affordable credit access	0.0133
	Infrastructural development	0.1205
Social	Household food security	0.0226
	Education/training	0.0592
	Laws and regulations	0.0129
Technology	Improved flexible and diverse fishing practices	0.1254
	Research and development	0.0418
	Innovations	0.0418
	$\Sigma =$	1.0000

time to secure survival and improve standards of living (Ellis 2000). Additionally, it aimed at reducing risk, vulnerability, and poverty, increasing income, enhancing security and increasing wealth (Yaro 2006).

Table 6 Sub-criteria-normalized local priorities across alternatives (goal: Nile perch fishers' livelihood improvement). Source: authors' own study

Strategic criteria	Sub-criteria	Global priority	Alternatives		
			A	B	C
			Local priority		
			Livelihood diversification income-generating activities	Fisheries co-management policies	Promotion of aquaculture
Environment	Sustainable environmental practices in the lakes	0.3252	0.5815	0.1094	0.3090
	Coping effectively with environmental vulnerability	0.0534	0.7172	0.1947	0.0881
	Governance and lakes management	0.1318	0.1865	0.6870	0.1265
Economic	Employment creation	0.0518	0.2789	0.6491	0.0719
	Affordable credit access	0.0133	0.2797	0.6270	0.0936
	Infrastructural development	0.1205	0.2377	0.6072	0.1551
Social	Household food security	0.0226	0.4286	0.4286	0.1428
	Education/training	0.0592	0.2684	0.6144	0.1172
	Laws and regulations	0.129	0.7088	0.1786	0.1125
Technology	Improved flexible and diverse fishing practices	0.1254	0.6694	0.0879	0.2426
	Research and development	0.0418	0.5584	0.3196	0.1220
	Innovations	0.0418	0.1396	0.3325	0.5278
	$\Sigma =$	1.0000			

Table 7 Sub-criteria-normalized global priorities across alternatives (goal: Nile perch fishers' livelihood improvement). Source: authors' own study

Strategic criteria	Sub-criteria	Global priority	Alternatives		
			A	B	C
			Global priority		
			Livelihood diversification income-generating activities	Fisheries co-management policies	Promotion of aquaculture
Environment	Sustainable environmental practices in the lakes	0.3252	0.1891	0.0356	0.1005
	Coping effectively with environmental vulnerability	0.0534	0.0383	0.0104	0.0047
	Governance and lakes management	0.1318	0.0245	0.0905	0.0167
Economic	Employment creation	0.0518	0.0145	0.0336	0.0037
	Affordable credit access	0.0133	0.0037	0.0083	0.0013
	Infrastructural development	0.1205	0.0286	0.0732	0.0187
Social	Household food security	0.0226	0.0097	0.0097	0.0032
	Education/training	0.0596	0.0159	0.0364	0.0069
	Laws and regulations	0.0129	0.0091	0.0023	0.0015
Technology	Improved flexible and diverse fishing practices	0.1254	0.0840	0.0110	0.0304
	Research and development	0.0418	0.0233	0.0134	0.0051
	Innovations	0.0418	0.0058	0.0139	0.0221
		$\Sigma =$	0.4465	0.3383	0.2148

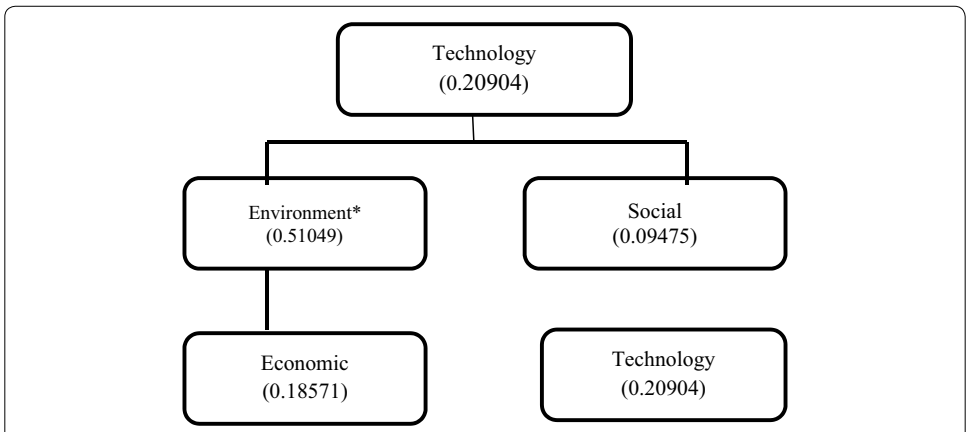


Fig. 4 Priorities of the strategic criteria. *In this criterion the experts paid the greatest attention to Environment (0.51049) (Source: authors' own study)

Table 8 Summary statement of Nile perch fishers' livelihood improvement. Source: authors' own study

Strategic criteria	Sub-criteria	Local priority	Global priority	Alternatives		
				A	B	C
				Global priority		
				Livelihood diversification income-generating activities	Fisheries co-management policies	Promotion of aquaculture
Environment	Sustainable environmental practices in the lakes	0.6370	*0.3252*	0.5815	0.1024	0.3090
				0.1891	*0.0356*	*0.1005*
	Coping effectively with environmental vulnerability	0.1047	*0.0534*	0.7172	0.1947	0.0881
				0.0383	*0.0104*	*0.0047*
	Governance and lakes management	0.25822	*0.1318*	0.1865	0.6870	0.1265
				0.0245	*0.0905*	*0.0167*
		$\Sigma = 1.0000$	$\Sigma = 0.5105$			
Economic	Employment creation	0.2789	*0.0518*	0.2789	0.6491	0.0719
				0.0145	*0.0336*	*0.0037*
	Affordable credit access	0.0719	*0.0133*	0.2797	0.6270	0.0936
				0.0037	*0.0083*	*0.0013*
	Infrastructural development	0.6491	*0.1205*	0.2377	0.6072	0.1551
				0.0286	*0.0732*	*0.0187*
		$\Sigma = 1.0000$	$\Sigma = 0.1857$			
Social	Household food security	0.2385	*0.0226*	0.4286	0.4286	0.1428
				0.0097	*0.0097*	*0.0032*
	Education/training		0.6250	*0.0592*	0.2684	0.6144
					0.0159	*0.0364*
	Laws and regulations	0.1365	*0.0129*	0.7088	0.1786	0.1125
				0.0091	*0.0023*	*0.0015*
		$\Sigma = 1.0000$	$\Sigma = 0.1857$			
Technology	Improved flexible and diverse fishing practices	0.6000	*0.1254*	0.6694	0.0879	0.2426
				0.0840	*0.0110*	*0.0304*
	Research and development	0.2000	*0.0418*	0.5584	0.3196	0.1220
				0.0233	*0.0134*	*0.0051*
	Innovations	0.2000	*0.0418*	0.1396	0.3325	0.5278
				0.0058	*0.0139*	*0.0221*

Table 8 (continued)

Strategic criteria	Sub-criteria	Local priority	Global priority	Alternatives		
				A	B	C
				Global priority		
				Livelihood diversification income-generating activities	Fisheries co-management policies	Promotion of aquaculture
		$\Sigma = 1.0000$	$\Sigma = 0.2090$			
			$\Sigma\Sigma = 1.0000$	*0.4465*	*0.3383*	*0.2148*

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Authors' contributions
EM prepared the manuscript and interpreted the data while WA performed the data analysis and LB provided suggestions/comments and proof-read the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials
The datasets generated and/or analyzed during the current study are not publicly available due confidentiality of respondents, but are available from the corresponding author on reasonable request.

Competing interests
The authors declare that they have no competing interests.

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Appendix

See Table 9.

Table 9 Definitions of criteria and sub-criteria in the AHP model. Source: authors' own study

Strategic criteria	Sub-criteria	Descriptions of the criteria
Environment	Sustainable environmental practices in the lakes	This is defined as the rates of renewable resource harvest which is fish in this case, that can be continued indefinitely in Lake Victoria
	Coping effectively with environmental vulnerability	In this case it refers to the ability (of a system or a unit) to withstand the effects of a hostile environment which may affect the fishing activities in the lake
	Governance and lakes management	Governance refers to the structures, functions, processes, and organizational behaviors that have been put in place with respect to fishing activities in the lakes. Management here refers to the day-to-day operation of the fishing activities with respect to strategies, policies, processes, and procedures that have been established by the governments in Tanzania
Economic	Employment creation	It refers to the process of providing new jobs, especially for people who are unemployed around the lakes
	Affordable credit access	This refers to the ability to access affordable credit by artisanal through private sector-led growth or public sector to grow and expand their fishing businesses
	Infrastructural development	In this study, fishing infrastructure is the basic physical system which can support the fishing activities to take place smoothly; it involves transportation, communication, sewage, water and electric systems for artisanal to store and add value of their fish catch
Social	Household food security	FAO (2017) defined food security [as] a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. In this study it refers to the system in which fishery sector can support the food security of Nile perch fishers
	Education/training	Gorur (2015) defined education and training refers to all organized, systematic education and training activities in which people take part in order to obtain knowledge and/or learn new skills for current job. In this case, artisanal fishers require proper education and training to improve their fishing practices
	Laws and regulations	These are rules of order having the force of law, prescribed by a government in Tanzania, relating to the actions under the control and sustainability of fishing activities in the lakes

Table 9 (continued)

Strategic criteria	Sub-criteria	Descriptions of the criteria
Technology	Improved flexible and diverse fishing practices	This refers to improved fishing techniques for catching more and sustainable fish in Lake Victoria
	Research and development	In this study, it refers to the investigative fishing activities to improve existing fishing practices in Lake Victoria Tanzania
	Innovations	Refers to the process of translating an idea or invention into a good sustainable fishing practices that create value for the livelihood of the Nile perch fishers

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