Human resources development in farming and fisheries for food security

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Abstract. The article delves into the issues of providing food security in the Maldives, a nation that regularly faces adverse weather conditions and natural disasters. These challenges include tsunamis, heavy rainfall, and strong winds that damage infrastructure, fishing vessels, agricultural land, contaminate freshwater resources and wash away entire islands during the monsoon season. The research purpose was to support workforce development to compensate for shortage of natural and technical resources in farming and fisheries. The explored data was collected from Maldives Bureau of Statistics. The applied statistical and clustering methods proved that training in farming should share knowledge of cutting-edge technologies like Hydroponics and Pest control, benefit female farmers, involve the youth in local agriculture and be evenly distributed among the Atolls. The study findings based on ranking and trend analysis argue that unstable employment is the paramount problem in fisheries. It is recommended to optimize a number of fishermen per vessel by Atolls and promote acquiring skills of advanced eco-friendly fishing. Overall research results created a reliable foundation for systematic development of qualified human resources in farming and fisheries that are crucial for strengthening food security in a risky environment.

1 Introduction

The climate crisis is causing increasingly frequent and severe extreme weather events, impacting 1.7 billion people through disasters such as hurricanes, cyclones, and droughts. These events are exacerbating severe hunger and threatening to undo progress made in reducing undernourishment, which affected nearly 800 million people. Abrupt climatic changes directly affect food security by causing loss of rural livelihoods, degradation of ecosystems, and collapse of food systems. The risk of severe climate impacts is expected to rise after 2050. Nations already facing food insecurity and poverty, especially arid, semi-arid, landlocked, and small island developing states, are particularly vulnerable. Similarly, farming in developed countries also need to address increased temperatures and reduced precipitation [1].

Countries in the southern hemisphere, including Bangladesh, Sri Lanka, India, Pakistan, Nepal, and the Maldives, are among the most impoverished and particularly vulnerable to natural calamities. Disasters in these regions have indirect effects on agriculture, fisheries, and livestock, which are key for their economic stability and food security. Every year, millions of Bangladeshis suffer from the destruction of homes, farmlands, and fishing vessels due to heavy rain, flooding, and landslides. In India, several districts have experienced a 60 percent decrease in farmers' yearly income due to droughts and flooding. Populations residing in coastal areas of India are also facing long-term chronic malnutrition in children due to the negative impact on fishing activities [2].

The Maldives is one of the smallest island states in the South Asia consisting of 20 administrative atolls including North Thiladhunmathi (HA), South Thiladhunmathi (HDh), North Miladhunmadulu (Sh), South Miladhunmadulu (N), North Maalhosmadulu (R), South Maalhosmadulu (B), Faadhippolhu (Lh), Male' Atoll (K), North Ari Atoll (AA), South Ari Atoll (ADh), Felidhu Atoll (V), Mulakatholhu (M), North Nilandhe Atoll (F), South Nilandhe Atoll (Dh), Kolhumadulu (Th), Hadhdhunmathi (L), North Huvadhu Atoll (GA), South Huvadhu Atoll (GDh), Fuvahmulah (Gn) and Addu Atoll (S). The Maldives depends on agriculture and fisheries, as its fundamental economic activity food and security. The country as a whole is significantly affected by coastal vulnerabilities such as high waves, erosion, and flooding from heavy rainfall [3]. The nation's susceptibility to climatic conditions and its impact on food and nutrient security further exacerbated by the challenges faced in skilled labor force. Despite these challenges, the country has seen rapid economic growth and achieved full employment in recent years. However, the tourism sector struggles with a shortage of skilled labor, while the fisheries sector remains underutilized, leading to a substantial influx of expatriate workers to fill these gaps. Local workers in these sectors often face marginalization due to limited educational and vocational training opportunities, with women in remote island communities

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particularly disadvantaged compared to their urban counterparts [4].

Labor shortages in the agriculture and fisheries sectors hinder their development and sustainability, necessitating institutional reforms to harness untapped labor potential and enhance economic resilience [4]. While gender discrimination in education and employment rights is relatively low in the Maldives, women in small island communities encounter significant barriers to education and vocational training [5]. Addressing these challenges is vital as they pose threats to national food security, export revenues, and the livelihoods of those dependent on these sectors.

Focusing specifically on the agricultural sector of the Maldives, which mainly consists of small farming communities operating within remote islands, there are challenges in accessing information and support from local extension services, compounded by a lack of capable extension officers. According to human capital and human resource theories, high-quality agricultural extension agents enhance farmer productivity by improving problem-solving abilities, risk mitigation planning, communication skills, ethics, discipline, and overall competence [6]. Empowering women farmers in the Maldivian agriculture sector involves building their capacity to mitigate climate conditions, disaster preparedness and address gender-specific risk, time, and social preferences that influence resource allocation [7].

The Maldives also faces broader labor force challenges including an aging workforce, lack of skilled labor, economic diversification, climatic vulnerability, and migration trends towards urbanization. Scholars attribute the reluctance of the young population to enter the agricultural sector to factors such as lack of strategic planning, sales, and managerial skills, compounded by difficulties in finding qualified workers [8]. This situation mirrors observations among Maldivian youth who perceive limited access to agricultural education, technology, and financial support as barriers to entering the agricultural field. Additionally, there is a critical need for skills in climate change adaptation, which are essential for maintaining food and nutrient security. Without these skills, young farmers struggle to implement effective strategies to cope with changing climatic conditions, which further undermines the stability of food production and nutrient availability.

Despite the prevalence of traditional farming methods among Maldivian communities, there are significant challenges. These communities often lack the knowledge and skills needed to address adverse climatic conditions. Additionally, they face financial constraints that hinder improvements in production efficiency. Studies on hydroponic technology suggest that a comprehensive curriculum and diverse training can make a difference. Implementing such educational programs can provide farmers with essential tools and knowledge. This shift from traditional practices to more efficient hydroponic methods can help reduce the negative impact of climate change on food production and nutrient security. Such education not only facilitates the adoption of advanced technologies but also enhances production efficiency while minimizing environmental impact [9, 10].

The fisheries sector in the Maldives, crucial for protein and nutrient security, faces challenges such as shortages in skilled labor and technological resources [11]. Adverse climate conditions, including rising sea temperatures, ocean acidification, and unpredictable weather patterns, further exacerbate these challenges by affecting fish populations and disrupting fishing activities. Research into factors influencing fishermen's incomes underscores the importance of enhancing practical experience and optimizing working hours to improve income levels in this vital sector [12]. Addressing these issues is vital for maintaining food and nutrient security, as climate change impacts can reduce fish stocks and compromise the availability of essential protein sources for local populations.

Given the scarcity of natural resources such as arable land and fresh water, implementing resilient measures is imperative to strengthen food security in the Maldives. Continued reliance on traditional farming and fishing methods is insufficient to meet increasing demands for food and nutrients amidst environmental volatility and limited resources [4]. The recent COVID-19 pandemic and conflicts like the Ukraine-Russia war have underscored the vulnerability of national food and nutrient security to external shocks. Scholars emphasize the importance of understanding farmers' needs to formulate targeted policies that support food production and supply chain resilience [13].

The climate crisis poses severe implications for agriculture, fisheries, and labor forces, especially in vulnerable regions like the Maldives. As extreme weather events become more frequent and intense, the risk to food systems globally intensifies, undermining progress made in reducing hunger and malnutrition. Countries like the Maldives, which heavily rely on agriculture and fisheries, need to implement climate adaptation strategies and improve labor and technological capacities. This includes investing in education and training, promoting sustainable practices, and supporting economic diversification to mitigate the adverse effects of climate change and ensure a stable and nutritious food supply for future generations.

2 Literature review

In the context of global population growth, achieving the sustainable development goal of zero hunger requires robust support for the agricultural sectors, which are the backbone of global food production. Despite small scale farmers contributing 50-70% of global food output, many face food insecurity, particularly in less developed and developing countries. Sub-Saharan Africa exemplifies this challenge, where agriculture remains a primary source of employment and food security amidst significant population growth. However, these farmers are caught in a cycle of limited land availability, inadequate finance, and poor productivity [14].

To break this cycle, substantial investments are essential to build a resilient workforce, advance technological capabilities, and diversify into higher-value crops. Similar challenges are observed in Asian countries, where farmers also struggle with food insecurity,

hindering substantial economic growth potential [14]. Indonesia, susceptible to climate change and natural disasters like cyclones causing extensive damage to farmlands and crops, underscores the need for a resilient workforce capable of effective disaster mitigation and management strategies [15].

Access to timely information and skill development is key for enhancing the productivity of smallholder farmers and strengthening their food security [16]. Research focused on identifying agricultural skills using the European Skills/Competences, Qualifications and Occupations (ESCO) classification highlights the importance of aligning training programs and policies with evolving industry needs [17]. Financial literacy among the agricultural workforce is equally critical for scaling up business operations [18].

In Vanuatu, a Pacific island nation prone to cyclones that devastate its fisheries sector, there is a pressing need to enhance disaster preparedness and integrate it into rural development services to promote sectoral resilience and sustainable development amidst climate challenges [19]. Effective fisheries management, vital under UN SDG 14, plays a pivotal role in conserving ocean resources and optimizing productivity. Incorporating traditional ecological knowledge into policy frameworks is essential for promoting sustainable practices among artisanal fishing communities, enhancing environmental stewardship, and preserving natural resources [20].

Investing in modern technologies such as GPS and mechanized fishing gears is crucial for enhancing the capacity and efficiency of fisheries communities [21]. In Indonesia, the fisheries sector faces challenges due to a lack of skilled labor, necessitating alignment of competency standards and curriculum development to equip professionals with necessary knowledge, skills, and attitudes [22].

Countries like Ukraine link university performance metrics to educational outcomes, aiming to improve program quality and graduate readiness for the labor market [23, 24]. Indonesia's fisheries sector growth is hindered not only by labor shortages but also by inadequate infrastructure in fishing provinces, highlighting the need for support in vessel provision and sectoral advancements [25].

Bangladesh, reliant on its fisheries sector for food security, employment, and economic growth similar to the Maldives, identifies deficiencies in human resource management. Addressing these gaps, including recruitment, salary issues, and training, is vital for enhancing sectoral growth and broader economic contributions [26].

The fisheries sectors in India and the Maldives share economic importance, challenges, and labor development needs. Both face significant skilled labor shortages, with fishermen often relying on traditional, informal vocational training, and both grapple with climate change impacts and gender disparities in access to formal education. India has addressed these issues through initiatives like the National Skill Development Mission, the MUDRA scheme, and Digital India, which focus on inclusive skill training and technological innovation. Similarly, India's agriculture sector suffers from labor shortages, decreasing output and altering cropping patterns, paralleling the Maldives' reliance on food imports due to limited agricultural capacity. To combat these challenges, India has implemented robust skill development policies and educational programs to build a capable workforce, particularly for women and disadvantaged groups [27].

As a whole the development of a skilled labor force is vital for enhancing food and nutrition security in both the agricultural and fisheries sectors globally. Farmers and fisherfolk play pivotal roles in producing food and sustaining livelihoods in both developing and developed nations, yet they often face significant challenges such as climate change impacts, limited resources, and technological barriers. Investment in labor development, including training in advanced agricultural practices, reforming and revising national education curriculum and aligning it with the sectoral competency requirement, financial literacy, and disaster management, is essential to overcoming these obstacles.

3 Results

3.1 Development of human resources in farming

Unfortunately, at present there are no educational courses on farming at colleges and universities in the Maldives. But when it comes to food security farmers are those who can make a difference.

With the severe scarcity of natural resources accompanied by high risks of natural disasters, the Maldivian farmers need advanced training to address the discussed issues not to mention that special retention efforts are necessary to empower female farmers and involve the young in farming. Agricultural extension officers make a huge contribution to providing food security in the Maldives through sharing contemporary knowledge on innovative farming. The national agriculture is making progress to mitigate dependency on food imports that endanger food security in the Maldives which is also at risk of negative consequences of ongoing climate change. However, the observed results are far from optimistic expectations. That is why it makes sense to find some weak spots that should be avoided in the future.

The analyzed data on conducted training for 2018-2024 incorporated 82 programs encompassing farmers from all of 20 Atolls listed in the Introduction [28]. Fig. 1 illustrates distribution (in %) of these training programs by 4 topics including Pest Control, Home Gardening, Agricultural Basics, and Hydroponics. On the one hand, Fig. 1 shows that those projects comprised really urgent agricultural issues. On the other hand, the cutting-edge options on Hydroponics and Pest Control were least discussed. It means that major programs made no difference to retention of the youth in farming. In other words, young farmers were mostly disadvantaged. But it is they who might be a powerful driving force to provide food security despite high risks of natural disasters in the Maldives.

Moreover, as it can be seen in Fig. 2, training programs were unevenly assigned to Atolls. Consequently, AA, V, F, Dh, and S Atolls (listed in the Introduction) remained the least aware of effective practices of resilient agriculture.

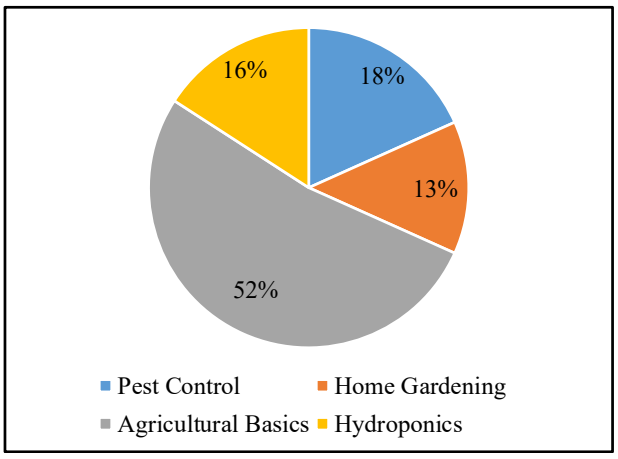

Fig. 1. Shares of training topics on farming in 2018-2024.

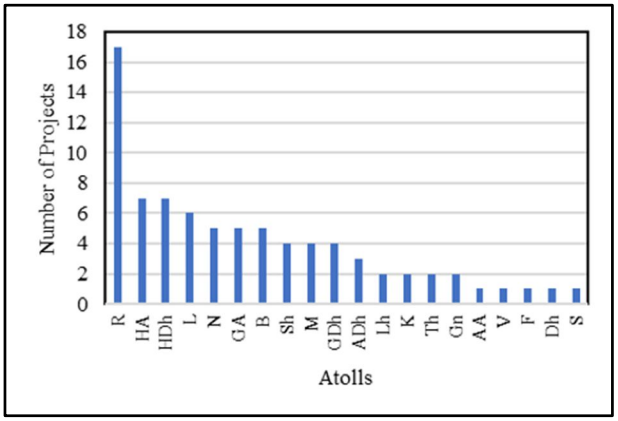

Fig. 2. Distribution of training programs on farming by Atolls in 2018-2024.

In order to assess quality work of agricultural extension officers in dynamics, all projects were characterized by three key parameters, such as

- a total number of trained participants (T, people),
- a share of women-farmers who were instructed by advisers (F, %),
- a program duration (D, days).

The checked hypothesis about similar average parameters in 2018-2024 was examined by means of Tukey's test, that compared $M = 7$ annual samples of projects. Namely, N_m denoted a total number of the projects, $m = 1…M$ where $m = 1$ related to 2018 and $m = M$ related to 2024. Therefore,

$$\Sigma_{m=1…M} N_m = N = 82. \quad (1)$$

The auxiliary parameters were

$$K = M / \Sigma_{m=1…M} (1/N_m) \quad (2)$$

$$S^2 = (\Sigma_{m=1…M} (N_m - 1) \cdot S^2_m) / (N - M) \quad (3)$$

where S^2_m denoted the variance of sample m.

With formulas (1), (2), (3), a limit of Tukey's test was calculated as follows

$$C = C_{crit} \cdot S / (K)^{0.5} \quad (4)$$

where C_{crit} was a critical value of the Studentized range for multiple comparison with a degree of freedom $N - M = 75$ and a conventional level of significance $\alpha = 0.05$.

Tukey's test was performed three times concerning parameters T, F, D with average sample values T_m, F_m, D_m, and limits (formula (4)) C_T, C_F, C_D, respectively, i.e.

$$10.5 = MAX_{i,j=1…M} (T_i - T_j) < C_T = 17.49 \quad (5)$$

$$11.3 = MAX_{i,j=1…M} (F_i - F_j) < C_F = 18.39 \quad (6)$$

$$3.8 = MAX_{i,j=1…M} (D_i - D_j) < C_D = 6.04 \quad (7)$$

Hence, inequalities (5), (6), (7) give clear evidence that general approach to training farmers was stable over the years of 2018-2024. It confirms unwavering commitment to develop contemporary farmers in the Maldives so that they will successfully face agricultural risks that challenge the national food security.

Moreover, future training programs deserve a special focus that makes it possible to approach islands exposed to similar risks and natural disasters in the same way. To reach this goal, the research utilized divisive hierarchical clustering. This method generates a binary tree unfolded by conditional splits. It was applied to a set of 20 training projects that are planned for 2024-2026 [28]. These programs were identified by

- a total number of engaged farmers (P, people),
- a share of involved female farmers (W, %),
- an indicator of land availability (L, people per square feet).

Splits in divisive hierarchical clustering were specified by average values of parameters P_{mean}, W_{mean}, and L_{mean}. The performed procedure calculated 5 patterns and distributed the analyzed projects as follows.

The group with $P<P_{mean}$, $W<W_{mean}$, $L<L_{mean}$ included Th. Kandoodhoo, R. Kinolhas, R. Vaadhoo, L. Dhambidhoo, B. Goidhoo, and S. Meedhoo. As their farming lands are often located near coastal zones, these islands are highly susceptible to natural disasters such as storm surges, saltwater intrusion, and coastal erosion. Along with the scarcity of available land, these natural disasters make it impossible for farmers to continue with their traditional methods of farming. Therefore, they need more knowledge about disaster risk mitigation plans and disaster preparedness, along with climate-smart agricultural methodologies such as technology-integrated farming to improve their efficiency.

The group with $P<P_{mean}$, $W>W_{mean}$, $L<L_{mean}$ combined R. Fainu, GA. Kondey, GDh. Hoadehdhoo where are more women but less land accessible. These islands are susceptible to reduced food production and potential food insecurity as limited resources essentially impact people's livelihoods. These issues can be offset by training in climate-smart agriculture to adapt to changing conditions and bolster economic stability.

The group with $P<P_{mean}$, $W>W_{mean}$, $L>L_{mean}$ comprised F. Magoodhoo, GA. Maamendhoo, F. Dharanboodhoo, N. Kendhikulhudhoo which can benefit

from a higher land availability. It can help them prepare for, respond to, and recover from natural disasters. With more land available, these islands can implement and expand disaster preparedness and mitigation strategies. Specifically, farmers can engage in more extensive farming activities and diversify their crops and practices, which can reduce the risk of total crop failure due to adverse conditions. Ultimately, this can improve food security and lessen the risk of food shortages during and after disasters.

The group with $P>P_{mean}$, $W>W_{mean}$, $L<L_{mean}$ included GA. Nilandhoo, Gn. Fuvamulah, L. Isdhoo, L. Kalaidhoo. These islands especially need training in farm management skills, financial literacy skills, and skills to allocate available natural resources efficiently for agricultural production, addressing the environmental constraints and climatic challenges faced by the farmers of these islands.

The group with $P>P_{mean}$, $W<W_{mean}$, $L<L_{mean}$ combined AA. Thoddoo, L. Gan, K. Kaashidhoo where male farmers are prevailing. This aspect implies a special focus on retention to reduce risks associated with the agricultural workforce and its sustainability. To improve the sector's resilience, it needs programs to retain farmers, such as providing financial incentives, improving working conditions, supporting training and development, and promoting gender inclusion. Encouraging more balanced participation in farming can address potential imbalances in the workforce and improve overall sector stability.

3.2 Development of human resources in fisheries

Since Maldivian agriculture can maintain mostly crop produce, fisheries are responsible for providing the national food security by animal protein. That is why training fishermen is invaluable especially when it comes to dealing with increasing risks and intensifying natural disasters observed both in the region and globally. The core analysis of workforce in fisheries was about its alignment by Atolls and with regard to the registered numbers of vessels as technical equipment is a prerequisite to a large fish catch. The Box and Whisker chat is a powerful tool that visualizes means and variances by compared samples. Central 50% of data (between quartiles $Q1$ and $Q3$) are displayed as boxes, the rest of the data are depicted as whiskers within limits

$$[2.5Q1 - 1.5Q3; 2.5Q3 - 1.5Q1] \quad (8)$$

and remote outliers. Statistical yearbooks offer registered quantities of fishermen by Atolls only for 2012-2016 [29]. The respective calculated Box and Whisker chat is presented in Fig. 3.

The found distinctive peculiarities are as follows. According to (8), there were two Atolls-oulires (GDh and N) with excessive numbers of fishermen in 2012 and 2013. However, Atoll Gn had spare vessels that remained in idle mode because of lack of human resources.

In 2014 there were the least average number of fishermen per vessel. It was a warning signal because fishermen were actively leaving the industry.

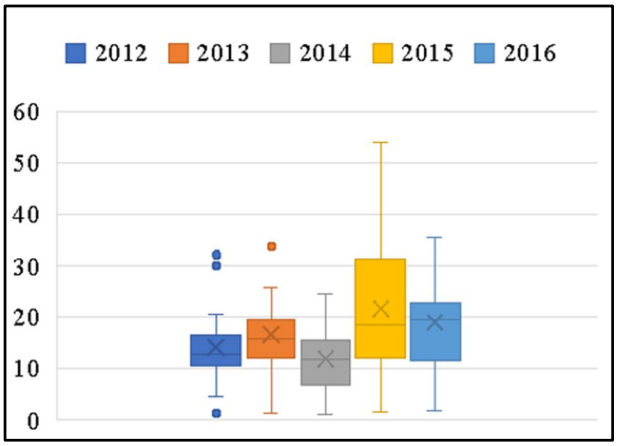

Fig. 3. Fluctuation of fishermen's quantity in 2012-2016.

In 2015 there was the biggest difference between Atolls by labor force per vessel. It put the industry at risk since declining the number of fishermen poses a significant risk as it diminishes the workforce, leading to decreased fish production and impacting the local economy reliant on fishing.

In 2016 the range shrank but it was reached via the largest fishermen' redundancy even among highly professional and experienced anglers. It is no surprise because owing to unstable incomes men quit fishing and sought employment in a lucrative resort industry. The observed tendency put all the used methods of fishermen's retention under question.

Unfortunately, official statistics on the number of fishermen in the Maldives is unavailable since 2017. However, the prevalent fishing vessels in the Maldives are Mechanised Masdhoni which optimally need 10 fishermen per vessel. This assumption made it possible to evaluate dynamics of fishermen in 2023 compared to 2016. The research findings are illustrated by Fig. 4 which depicts ascending and descending fluctuations in the Atoll fishing workforce for 7 years. The performed analysis revealed that there were 4 groups of Atolls of

- high redundancy, including Sh, GDh, L, B, Th, and R,
- middle redundancy, including HDh, GA, AA, K, and M,
- stable employment, including HA, F, N, Lh, V, and ADh,
- staff expansion, including S, Gn, Dh.

Top three Atolls with excessive human resources were Sh, GDh, and L, where there is abundant of natural resources compared to other Atolls, such as rich fishing grounds and access to ice plants and fish collection facilities, attracting more individuals from other islands seeking work is presented. This leads to a higher concentration of human resources in these atolls compared to others. Top three Atolls whose fisheries hired more fishermen were S, Gn, Dh. This approach likely helped them mitigate risks of potential labor shortages, ensuring that fishing operations are adequately staffed and improving the efficiency of fish harvesting and processing, maximizing the economic benefits from

the fisheries sector. Finally, the most balanced Atolls by a number of fishermen were Lh, V, ADh which had good chances to address challenges related to natural disasters as their fishermen were experienced enough to use vessels in an efficient way.

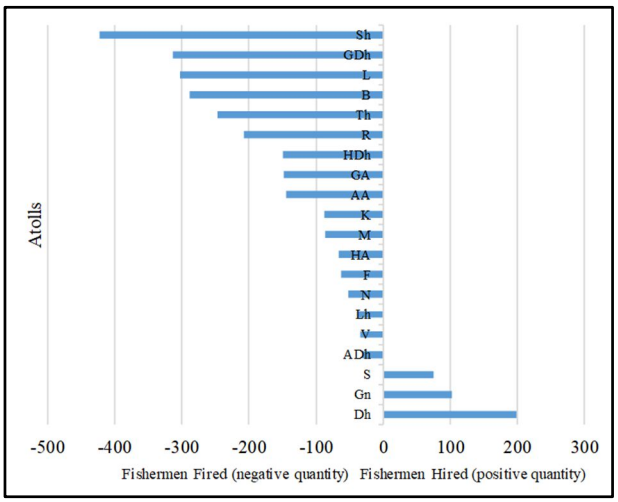

Fig. 4. Calculated dynamics of fishermen by Atolls for 2016-2023.

All of the above proves that an observed decline in labor force in fisheries jeopardizes food security in the Maldives regarding risks of natural disasters that accompany ongoing climate change. To compensate them, local fishermen need advanced knowledge. When asked about priorities, they highlighted three equally crucial topics, such as

- using GPS, sonars, and other innovative technology to locate shoals of fish;
- implementing pole and line fishing methods to reduce by catch;
- handling a fish catch and icing fish to minimize a harvest loss.

This way fishermen would be able to store enough fish for periods of adverse weather conditions and support the national food security in case of disasters.

4 Conclusion

Food security is in the top of global agenda for a long time. This challenge combines economic and social dimensions exacerbated by adverse weather conditions and numerous natural disasters caused by ongoing climate change. In the Maldives farming and fisheries are prime contributors to food security. These sectors lack natural and technical resources. Thus, qualified human resources can partly offset them.

The analyzed training programs provided by agricultural extension officers fail to cover innovative technologies like Hydroponics and Pest Control and they are unevenly held by Atolls. It may repel young farmers and doesn't empower vulnerable female farmers. Therefore, it is advisable to perform training for farmers noticing the share of engaged women and availability of land that will shape the discussed topics on mitigating agricultural risks and consequences of natural disasters.

The major problem facing fishermen in the Maldives is precarious employment caused by a sharp disproportion between a number of vessels and a quantity of anglers in most Atolls. Hence, human resource development should focus on how to retain skilled fishermen in the industry and also share contemporary technical knowledge on fishing methods and handling a fish catch.

There are various prospects for further scientific research as providing food security is a complicated problem. One of relevant vectors is to study its financial and ecological aspects concerning risks of adverse weather conditions and natural disasters.

The authors confirm that all data underlying the findings are fully available without restriction. The authors confirm equal contribution to the paper and equal responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

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