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Developing a Model For Enhancing Aquaculture Sustainability in Malaysia

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Abstract

The aquaculture business is currently expanding in Malaysia due to domestic demand, but farm operators face issues from cost to environmental. This research aims to build a model, using factors of importance that can be used by policymakers for targeted assistance for the healthy growth of this sector. Two hundred and sixty-eight aquaculture operators were identified and a survey instrument was used to collect the necessary data. The data were used as input for the Random Forest model using machine learning techniques for the analysis. The AUC for the model is 0.87, highlighting the importance of this model as a good predictor of performance. Based on this model's findings, the factor Farming Practices have the highest importance. This is followed by Environmental, Economic, and Institutional Influences, Cost of Feed, and Learning and Development. Factors Provision of Extension Services, Climate Change, Innovative Technologies, Supply Chain Risk Management Culture, and Societal have the least influence on performance.

The results from this study indicate that the Random Forest model can be a viable model to investigate future outcomes based on the major factors identified as input. The factors identified can serve as a useful guide for any targeted assistance and support besides serving as a useful input to any future policy directions. This research is limited in the sense it involves aquaculture operators only and a single model Random Forest, however, this limitation can be expanded in any future studies to include other stakeholders and different analytical approaches.

Keywords: Aquaculture Management, Sustenance, Random Forest, Machine Learning Techniques

Introduction

Malaysia has a growing aquaculture sector, and the government is actively promoting its expansion to meet domestic demand for seafood and reduce reliance on imports. Aquaculture is of critical importance to a country as it generates revenue and contributes significantly to a country's GDP. In addition, it creates jobs in various sectors including farming, processing, distribution, and marketing which lead to income generation and economic growth. As the population of a country rises there is increasing demand for seafood which is a critical source of protein producing seafood domestically not only helps a country reduce its dependence on food imports but contributes to enhancing food security A country’s focus on aquaculture helps reduce its dependence on wild fish populations and at the same time helps reduce the problems of overfishing and depletion of marine resources which has become a critical problem in many countries. The Aquaculture sector by producing fish and other aquatic products through controlled and sustainable aquaculture practices can contribute to marine resource conservation. Sustainable aquaculture practices can also bring about environmental benefits by reducing the need for need for destructive fishing methods promoting responsible resource management, and potentially reducing the carbon footprint of seafood production.

Malaysia's aquaculture industry produces a wide range of aquatic products, including fish, shrimp, prawns, and various shellfish species. Tilapia, catfish, and shrimp were some of the major species farmed in Malaysia. Tilapia, in particular, was a popular choice among farmers due to its adaptability and high consumer demand. Aquaculture products have great potential for exports and a robust aquaculture sector many developing countries have been able to earn substantial foreign exchange earnings by exporting their aquaculture products. Malaysia was not only producing seafood for domestic consumption but was also exporting aquaculture products to international markets, including neighbouring countries.

The aquaculture industry is instrumental in driving innovation in aquaculture technology, equipment, and management practices. These innovations can stimulate technological innovations in related fields. In the context of Malaysia, the Aquaculture sector was gradually adopting modern farming techniques and technologies to improve production efficiency and sustainability. This included the use of recirculating aquaculture systems (RAS), which help reduce water usage and improve water quality.

Aquaculture often takes place in rural areas, where it creates employment opportunities and stimulates economic development where it can create employment opportunities and stimulate economic development. Aquaculture can provide income for small-scale farmers and support livelihoods in remote regions. This will contribute to the development of the rural areas and reduce poverty levels which are higher in the rural areas as compared to the urban areas.

The COVID-19 Pandemic and ensuing lockdowns have had detrimental impacts on all sectors of the economy including the aquaculture sector.in Malaysia. The closure of restaurants and other food service outlets that were the major consumers of aquaculture products resulted in decreased domestic demand for aquaculture products. This was further exacerbated by the changes in consumer spending as a result of reduced incomes and increasing unemployment. Seafood products which are often priced higher than poultry and cattle meat would then not be considered as necessities and might be foregone in favour of the cheaper protein alternative.

In addition to decreases in domestic demand global demand also declined as a result of the Pandemic. The nationwide lockdowns in China affected the seafood export industry of several countries including Malaysia. The cancellation of seafood export contracts resulted in decreasing international demand international seafood demand as seafood export from Malaysia to Singapore was already down by 50 % in mid-February 2020 (Aruno et al., 2020).

The pandemic also disrupted seafood supply chains which comprise 3 to 5 stages. The effects of these disruptions were felt at all stages which included the production of seafood, collection from the producer, preparation, distribution, and sales. The reduction in workforce, imposition of COVID-related sanitary measures, and reduction in animal feed supply during the pandemic due to logistics. In addition, the domestic distribution of seafood products was disrupted by logistic challenges including roadblocks.

Transportation disruption such as the slowing down of ocean freight and air freight transportation as a result of congested ports and/or reduction in shipping frequency was also seen to negatively affect the export of Malaysia's seafood product. The final stage of the seafood supply chain, the sale of products to the consumers was also affected by the closure of fresh and wet markets in the country in compliance with the MCO requirements. A preliminary study by the Department of Fisheries in 2020 showed that 33% of those in the fisheries and aquaculture sectors lost their jobs, and a further 33 % experienced a working hour reduction due to COVID-19 and subsequent income losses.

Problem Statement

Aquaculture provides income for small-scale farmers and supports livelihoods in rural areas in Malaysia. It contributes to the development of these areas and reduces poverty levels which are higher in these areas as compared to the urban areas. However, since COVID-19, this sector is facing challenges to keep operating. Cost and imports from neighbouring countries are some of the factors identified however, there could be other factors influencing in isolation or in tandem that are significantly contributing to the problem. This study will use a specific model and machine learning techniques on these factors and predict the performance of these factors on the model. A higher performance indicator in this model can mean it can be a viable analytical model to gauge the performance of the factors identified for remedies over time.

Limitations

This research is limited in the sense it involves freshwater aquaculture operators only and a single model Random Forest, however, this limitation can be expanded in any future studies to include other stakeholders and different analytical approaches

Literature Review

As reported by the EU (2010), the average annual fish consumption in all the countries forming the European Union is 22.3 kg per person, with the highest annual consumption recorded in Portugal (55.6 kg/person) and the lowest in Bulgaria (4.2 kg/person). The Malaysian scenario is however higher as Malaysia has an annual per capita fish consumption of 56.5 kg/person (The Star, 2014). Fernandes, Bostock, & Eleftheriou (2012) argue that global aquaculture is expected to increase substantially as the population growth rate increases. However, Goh (2018) observes that this is not the case in Malaysia as a downward aquaculture trend is being experienced when compared to a growing yearly population.
According to a study by Innocent and Ukoje (2009) in Ondo state Nigeria, the factors that had a significant influence on the development of aquaculture are; the high cost of inputs (for instance; fertilizer, fingerlings, lime) required for successful aquaculture, limited ability to curtailing disease outbreak, lack of access to loan facilities needed by aquaculture farmers to deploy advance technology. These factors were implicated as major barriers to aquaculture

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security. Schacht et al. (2010) advocate for sustainability as a new paradigm for resilience in food supply, especially aquaculture products. Fernandes et al. (2012) in their study on aquaculture sustainability in Europe proposed a strategy that examined the influence of research and development, environmentally friendly production methods, aquaculture governance, and business-friendly environment in line with capacity building of local institutions for eLearning. Moreover, the findings of Kamaruddin and Baharuddin (2015) via a Structural Equation Modelling method regarding pond management practices by Malaysian aquaculture farmers revealed that 77% of brackish water aquaculture implemented good aquaculture practices at a threshold level of 60% relative to only 20% by freshwater farmers. Physical and human assets were revealed to be the most significant factors that influence the implementation of good aquaculture practices.

According to Othman (2010) among the challenges facing aquaculture sustainability are; weak legislation and enforcement, limited aquaculture education and knowledge, and limited investments. In addition, Fernandes et al. (2012) argue that the major issue with aquaculture in Malaysia is the sustainability of production. Other issues cited are; the low-level adoption of advanced technology, the challenge of environmentally friendly production methods, and limited regulations. Nonetheless, Anderson et al. (2017) argue that expert knowledge as well as deploying new technology are significant factors that improve aquaculture sustainability. Despite the proliferation of studies, a theoretically supported and empirically validated context-specific model that specifies and justifies the determinants for enhancing the sustainability of aquaculture is lacking thus the need for this empirical study

Research Question

Based on the literature review and the focus of the research, the following research question is identified.

Can the Random Forest model with the use of machine learning analysis be a viable model to gauge aquaculture performance using the factors identified?

Research Objective

The objective of this research is to use the Random Forest model with machine learning techniques on the factors identified to gauge the performance and subsequent use of the model to understand the profitability of aquaculture in Malaysia.

Research Methodology

Study Design and Data Sources

The study is on building a model for predicting purposes, a large amount of numerical data is required for this purpose and therefore a quantitative approach is more appropriate. Various factors of importance are identified from the literature and are used to find their relevance in the context of this study from a preliminary field investigation. Twelve factors of importance are identified as relevant for aquaculture investigation, eleven being taken as driver variables and one being taken as target variables. The variables are Provision of Extension Services (A1), Climate Change (A2), Innovative Technologies (A3), Farming Practices (A4), Profitability (A5), Institutional Influences (A6), Supply Chain Risk Management Culture (A7), Cost of Feed (A8), Learning and Development (A9), Economic (A10), Societal (A11), and Environmental (A12)

A survey in the form of a questionnaire was then used to obtain information regarding these variables together with other relevant information from participants for the model-building exercise. A five-point Likert scale is used for this purpose to induce responses, each factor having multiple questions, that run from 'strongly not agreeing' to 'strongly agree', with 3 set as 'no opinion' or neutral.

A sample of 268 participants was selected from an original data list provided (Senarai Syarikat Aqua) for this purpose, the list was wide and had to be counter-checked numerous times with information from the internet and other sources, like calling numbers if provided to confirm they are into aquaculture. Those who are involved in aquaculture are isolated and called later to participate. The focus is on major states that are involved in aquaculture (Selangor, Malacca, Perak, Negri Sembilan, Pahang, Johor) although other states do have some form of this activity. Being a quantitative survey, this sample size is adequate to give validity to the survey at a margin set at 5% with confidence at 95%.

Two approaches are used to adduce the necessary information, printed questionnaires, and the use of Excel questionnaire form for direct entry of responses. Both field visits and telephone calls were made to fill in the necessary information. Most of the participants are workers, mostly foreign workers who have been working for many years with ample exposure in aqua farming, who gave information discreetly but competently. Two enumerators were used for the purpose, one concentrating on northern states and the other focusing on central and southern states.

Data Analysis Plan

In addition to data screening and preliminary data analysis for outliers, missing values, wrongly entered values, and overall distribution, the data was taken through both logit-reg and random forest techniques for model-building purposes. The training and testing of data in these models are robust with a ratio of 20:80 respectively. These models are suitable, as the study involves a cause-effect regression-based analysis where relationship matters, and, therefore, ideal machine learning techniques where a relationship is involved can be logit-reg and random forest. The output from these two models, after all the necessary testing procedures, is observed for their predicting ability and accuracy, with relevancies of factors identified in both methods. The better-predicting model is then identified. The factors (causes/independent variables) from the models are taken as input drivers for that model. As for the target variable, the realization of profit, the information gathered, is identified as, 'not profitable', and 'yes profitable'. This dual classification is necessary for the use of log-logit regression modelling. A cut point is set as more than 3.5 as 'yes' it had led to profit is given a value of '1' otherwise it is given a value of '0' for duality purposes. This is ideal on a Likert scale of 5 points, where the mid-value is 2.5, and 2.5 to 3.5, which can be assumed to be borderline on profitable gains' opinion and more than 3.5 as profitable.

Data Analysis

Profile Analysis

The combination of figures below shows education, states, relationships, and other issues as adduced from the questionnaire survey. The highest frequency in education is the diploma holders, followed by bachelor and secondary education. An observation of the original data (Appendix 2) shows education generally falls around diplomas for the central and southern states and mostly secondary education for the northern states.

Selangor and Perak topped the states in terms of participation, it also reflects the two states with the most numbers of aquafarms, thus its importance.

Most of the participants are the workers as the managers and owners do not want to be identified mostly. The field experience showed most of these workers is foreigners. The responses are willingly shared by these workers based on their best ability and who have been working for many years, some not known to the higher-ups.

There are multiple issues faced by these farmers, but the bulk has indicated water supply issues. Weather together with sedimentation issues too plays a central role.

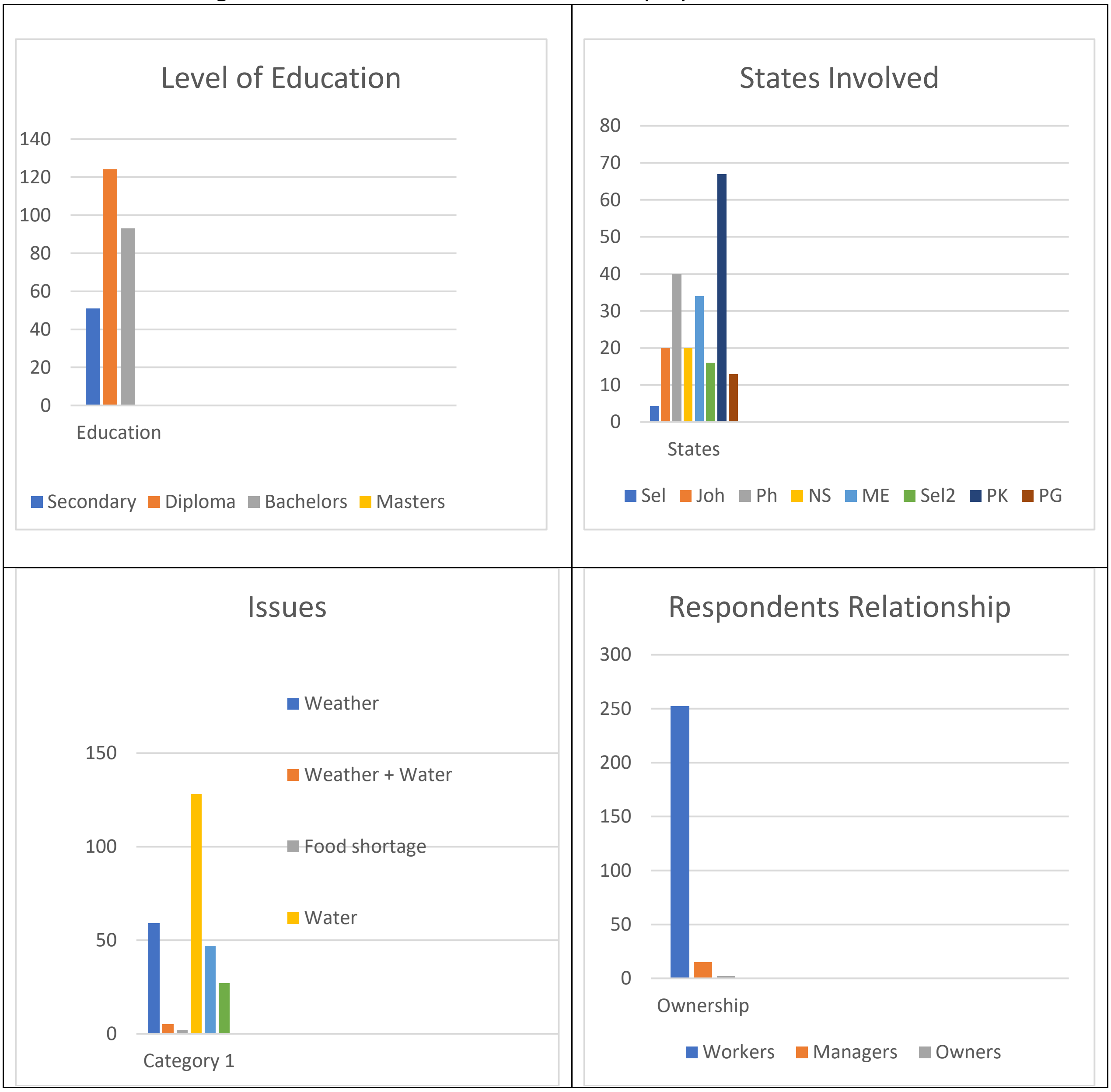

Figure 1: Education, States, Issues identified, Relationship of respondents

Model Building Using Machine Learning Techniques

Visualization of Data

The correlation between the 12 Factors variables using a heatmap is presented below. All the variables as shown in the heatmap indicate a low level of correlation, with the highest being around 0.25, hence the need to drop any significantly correlated factors does not arise.

Figure 2: Heatmap of correlation analysis of Factors

The Outliers and their Treatment

Outliers are seen for variables across all factors, except for A1 and A9. Some of these outliers seem significant especially A2-A4 and A5 in the box-plot output. Hence, a need to clean the data before using them in analysis. The cleaning is capped at +/-5%, on either end as is used in normal practice. The box plot shows before and after cleaning the data set.

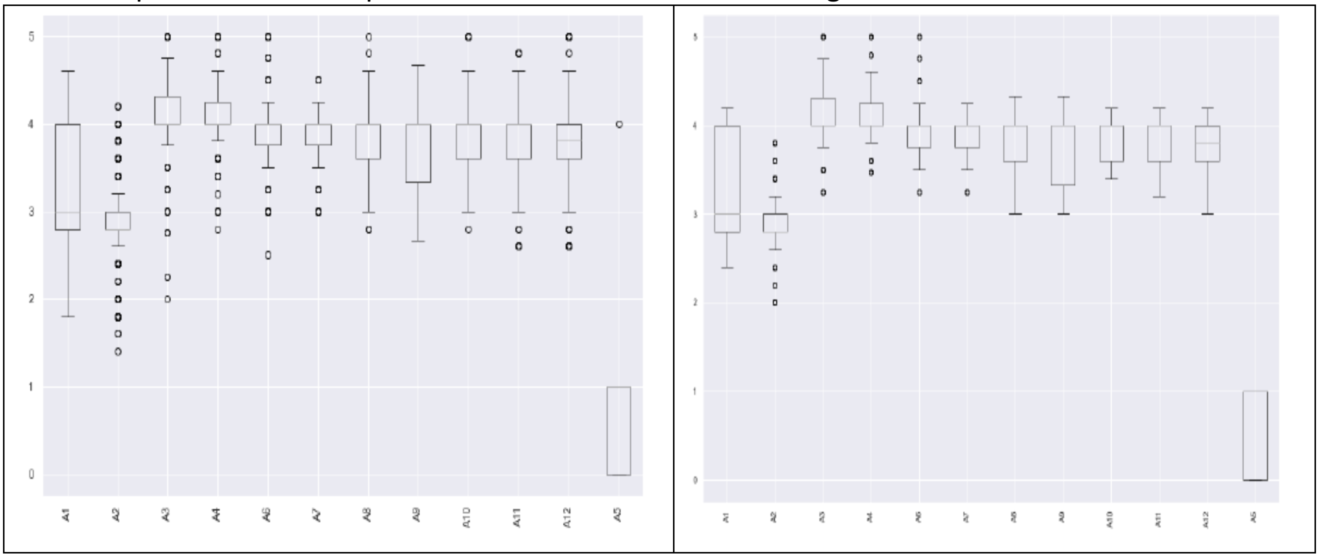

Figure 3: Boxplots before and after treatments

OOB Score

The OOB (out-of-bag) for this model is given together with the necessary coding used. The OOB score tells the number of correctly predicted data on OOB samples taken for validation. The OOB score is 0.7196, number of correctly predicted rows from the out-of-bag sample is 71.96%).

```
RandomForestClassifier(max_depth=4, max_features=5, n_estimators=10, oob_score=True, random_state=100)
rf.oob_score_0.719626168224299
```

ROC Curve

The coding used;

```
plot_roc_curve(rf, X_train, y_train)
plt.show()
```

The ROC curve (receiver operating characteristic curve) plots the True Positive Rate Vs False Positive Rate for all classification thresholds. The closer the curve comes to the 45-degree diagonal line (FPR=TPR) of the ROC space, the less accurate the test. The output ROC curve is closer to the top-left corner indicating a better performance.

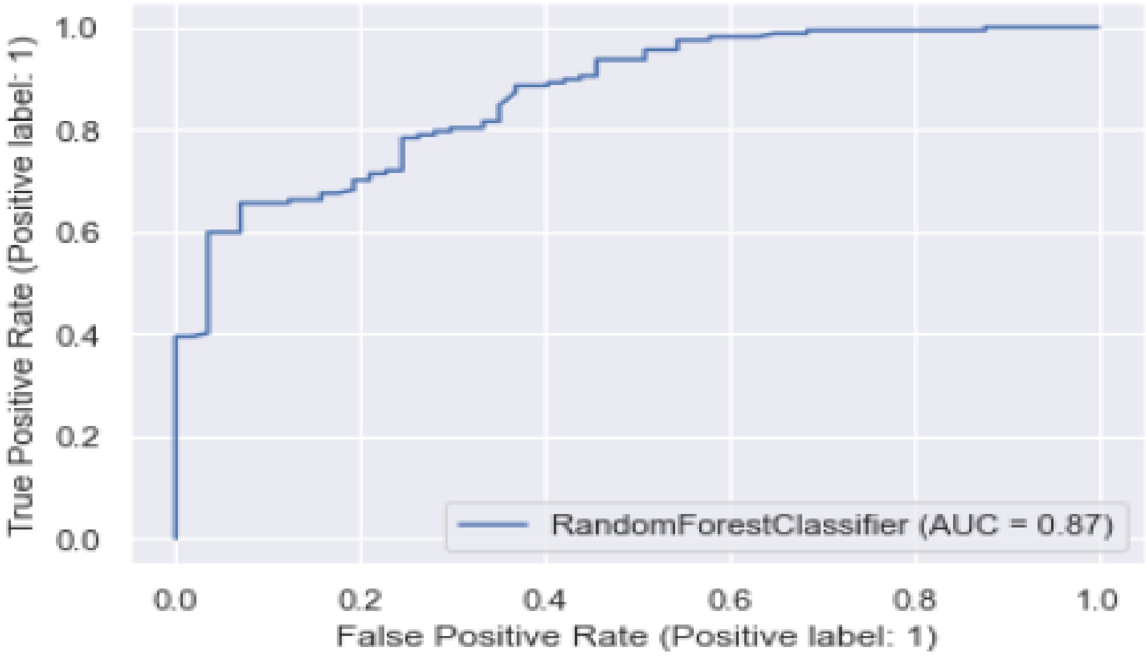

Figure 4: ROC curve

Grid Best Score

Grid search trains different models based on different combinations of the input parameters and finally returns the best model or the best estimator. The score (mean score of the best estimator) is 0.73883 in this case.

```
grid_search.best_score_
0.7382948986722572
```

ROC Curve For the Best Estimator

The ROC space for the best estimator is less than before at 0.75. the less accurate the test but still a good performance.

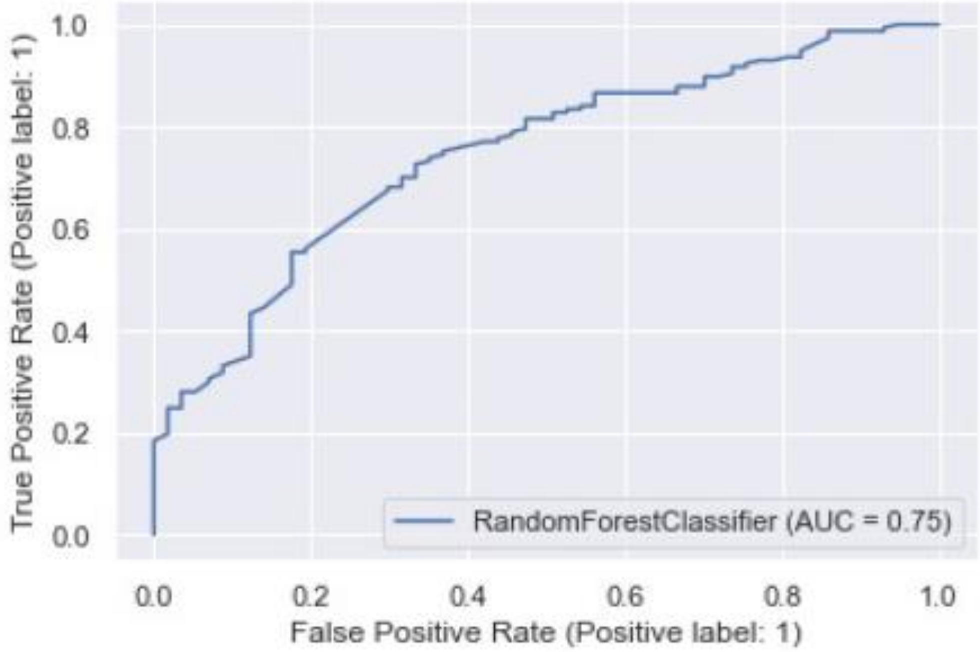

Figure 5: ROC for best estimator

Features of Importance

Best feature of importances output array;

Array ([0.   , 0.   , 0.01716495, 0.25056455, 0.1534581 ,
0.03288722, 0.14077694, 0.05826624, 0.15957531, 0.00652697,
0.18077972])

And sorting, the following factors of important, and declining importance are obtained. Being very low values, A1, A2, A11, A3, A7 can be dropped without affecting the overall model performance.

Table 1

Factors of Importance

	Varname	Imp
3	A4	0.250565
10	A12	0.180780
8	A10	0.159575
4	A6	0.153458
6	A8	0.140777
7	A9	0.058266
5	A7	0.032887
2	A3	0.017165
9	A11	0.006527
0	A1	0.000000
1	A2	0.000000

Findings and Conclusion

The Random Forest model result gives an AUC of 0.87, an aggregate measure of performance across all possible classification thresholds that can be taken as a good model for investigation purposes for future investigations and directions. Based on this model's output, the factor Farming Practices has the highest importance. This is followed by Environmental, Economic, Institutional Influences, Cost of Feed, and Learning and Development. Factors Provision of Extension Services, Climate Change, Innovative Technologies, Supply Chain Risk Management Culture, and Societal have the least influence on performance.

Good farm management has a high influence in the local context for freshwater aquaculture management as this study indicates, but good management is lacking in Malaysia as Kamaruddin and Baharuddin (2015) revealed only 20% of freshwater farmers practice good management and improving this position requires physical and human assets. Cost factors are a perennial issue identified in many studies, and it is also an issue in this study. Innocent and Ukoje (2009) identified costs can come from many activities of aquaculture practices like the cost of inputs (fertilizer, fingerlings, lime), the cost of curtailing disease outbreaks, loans to facilities to deploy advanced technology and many other incidentals. Institutions' influence and support can mitigate many of the cost issues faced by aquaculture operators but are lacking. According to Othman (2010) among the challenges facing aquaculture sustainability here are weak legislation, enforcement, and involvement by the government and its agencies, and this position has not changed much. This is also with education and knowledge development which is inadequate (ibid), where government agencies can actively promote the adoption of advanced technology, and environment-friendly methods for the sustainability of this sector. Technology, which used to be an issue in an earlier study (Fernandes et al., 2012) is relegated as no issue now. It appears some form of technology is been implemented by operators; however, this can be upgraded to new advanced techniques in aquaculture development.

Recommendation

The results from this study indicates that the Random Forest model can be a viable model to investigate future outcomes based on the major factors identified as input. The factors identified can serve as a useful guide for any targeted assistance and support besides serving as a useful input to any future policy directions.

Acknowledgement

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