Selection of intensive shrimp farming technology for small farmers with analytical hierarchy process: a case for whiteleg shrimp (*Litopenaeus vannamei*)

R Zulkarnain\(^1\), K Adiyana\(^1\), Waryanto\(^1\), H Nugroho\(^1\), B Nugraha\(^1\), L Thesiana\(^1\) and E Supriyono\(^2\*)

\(^1\)Research Center for Fisheries, Agency for Marine Affairs and Fisheries Research and Human Resources Development, Ministry of Marine Affairs and Fisheries, Jakarta, Indonesia
\(^2\)Department of Aquaculture, Faculty of Fisheries and Marine Science, Bogor Agricultural University (IPB University), Bogor, Indonesia

\(^*\)E-mail: eddy_supriyono@yahoo.com

Abstract. Whiteleg shrimp (*Litopenaeus vannamei*) is one of the important aquaculture commodities. This is due to high demand and farming with high stock densities. However, whiteleg shrimp farming is generally large scale, so that farmers with small capital cannot carry out business activities. In this paper, an intensive assessment of four whiteleg shrimp technologies has been carried out with seven criteria. Four intensive shrimp farming technologies are biofloc technology, supra intensive, shrimp farming in mini scale with tarpaulin (BUSMETIK), and Recirculating Aquaculture System (RAS). Seven criteria that used in the assessment are affordability of capital and operational costs on a mini scale, minimum land area for shrimp farming, dependence on the location of raw water sources, environmental friendly, productivity, energy consumption, and biosecurity. The assessment was carried out using the Analytical Hierarchy Process (AHP) method to assess the compatibility of different technologies to low investment. The results of the AHP method show that RAS is ranked first for intensive shrimp farming technology for small farmers. Then followed by supra intensive, BUSMETIK and biofloc technology. Most of the criteria used in the AHP calculation are the advantages that RAS is very suitable for small farmers.

Keywords: AHP, intensive technology, *Litopenaeus vannamei*, shrimp farming

1. Introduction

Fisheries sectors that have a trend of increasing production is aquaculture and one of the important aquaculture commodities is shrimp especially whiteleg shrimp (*L. vannamei*) (FAO 2018, KKP 2018). This is due to high demand and farming with high stock densities.

However, whiteleg shrimp farming is generally in large scale, so that farmers with small capital cannot carry out business activities. In this paper, we only focus on intensive shrimp farming because of its
profit and promising capital returns. An intensive assessment of four whiteleg shrimp technologies has been carried out with seven criteria. Based on the existing of intensive shrimp farming technology, we choose only four intensive shrimp farming technologies are biofloc technology, supra intensive, shrimp farming in mini scale with tarpaulin/High-Density Polyethylene (BUSMETIK-HDPE), and RAS. These technologies also have been applied by shrimp farmers. Seven criteria that used in assessment are affordability of capital and operational costs on a mini scale, minimum land area for shrimp farming, dependence on the location of raw water sources, environmental friendly, productivity, energy consumption, and biosecurity (Atjo 2017, Boyd et al 2017, Boyd et al 2018, Syah et al 2017). The purpose of this study was to assess the compatibility of different technologies to low investment by using AHP method.

2. Materials and methods

2.1. Materials

The data were obtained from questionnaires with pairwise comparisons with a measurement scale of 1-9 based on paper Saaty (1980, 2008) as seen in table 1.

2.2. Methods

The AHP is a multi-criteria decision analysis method that used to determine relative weights of available alternatives. Based on these weights, the AHP can effectively prioritize choices among those alternatives. Many researchers have successfully applied this method in a large number of diverse research areas, such as in architecture (Bitarafan et al 2015), banking (Kamil et al 2014), energy (Ishizaka et al 2016), fishery (Jennings et al 2016), aquaculture (Lembo et al 2018). The procedure used to establish the weights using the AHP method as a flowchart is presented in figure 1 based on paper by Sutadian et al (2017), but it was used for identifying parameter weights for developing a water quality index.

Based on figure 1, the first step of AHP method is to create a hierarchical structure consisting of 3 levels. Level 1 is the goal of the analysis. Level 2 is multi-criteria that consist of several criterions and the last level (level 3) is the alternative choices. After structuring a hierarchy, we continue to construct the questionnaire with pairwise comparison (scale 1-9) for each criterion and technology. Then, the experts input the questionnaire in scale 1-9 depend on the criteria. The results from the experts’ questionnaire were processed to get consistency vector (CV), maximum eigenvalue ($\lambda_{max}$), consistency index (CI), and consistency ratio (CR) based on equation (1) until (4). If the consistency ratio is less than equal to 0.1, the results can be used for relative weights (RW). But, if the consistency ratio is more than 0.1, we need to re-ask the experts to revise the judgments. From results of relative weights (RW), the criteria that are influential can be determined. After we get all the relative weights (RW), we calculate the composite weights (CW) from RW to get a technology ranking. The values of random index (RI) for different values of n (Saaty 1980, 2008) were shown in table 2.

| Scale | Definition      | Scale | Definition          |
|-------|-----------------|-------|---------------------|
| 1     | Equally preferred| 1     | Equally preferred   |
| 3     | Moderately preferred| 1/3  | Moderately less preferred |
| 5     | Strongly preferred| 1/5   | Weakly preferred    |
| 7     | Very strongly preferred| 1/7  | Very weakly preferred|
| 9     | Extremely preferred| 1/9   | Extremely preferred |
| 2,4,6,8| Intermediate values| $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{6}$, $\frac{1}{8}$ | Intermediate reciprocal values |
Figure 1. Flowchart of AHP method (Sutadian et al 2017).

Consistency Vector (CV)
\[
CV = \frac{\text{Weighted Sum Vector}}{\text{Row matrix average}}
\]  \hspace{1cm} (1)

Maximum Eigen value \((\lambda_{\text{max}}) = \text{average of CV} \) \hspace{1cm} (2)

Consistency Index (CI)
\[
CI = \frac{(\lambda_{\text{max}} - n)}{(n-1)}
\]  \hspace{1cm} (3)

| n  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 |
|----|----|----|----|----|----|----|----|----|----|
| RI | 0  | 0.58 | 0.90 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.49 |

Consistency Ratio (CR)
\[
CR = \frac{CI}{RI}
\]  \hspace{1cm} (4)
3. Results and discussion

The existing intensive whiteleg shrimp farming technology such as shrimp farming in BUSMETIK-HDPE, RAS and supra intensive were assessed by using of seven criteria. Seven criteria that used in each intensive shrimp farming technology were:

- C1 = Affordability of capital and operational costs on a mini scale
- C2 = Minimum land area for shrimp farming
- C3 = Location of raw water (brackish water) sources
- C4 = Environmental friendly
- C5 = Productivity
- C6 = Energy consumption
- C7 = Biosecurity

![Intensive whiteleg shrimp farming technology for small capital farmers](image)

**Figure 2.** Hierarchy of intensive whiteleg shrimp farming technology for the small capital farmer.

3.1. **BUSMETIK**

Shrimp farming in small pond area (600-1,000 m²) with BUSMETIK-HDPE. This technology is known in Indonesia by name *Budidaya Udang Skala Mini dalam Empang Plastik*. It was developed and introduced to shrimp farmer from Fisheries University, Serang-Banten (KKP 2014).

3.2. **Biofloc Technology**

Biofloc technology is aquaculture technology that introduced by Yoram Avnimelech. The principles of this technology are the use of heterotrophic bacteria. In order to grow heterotrophic bacteria, carbohydrates (usually molasses or sugar) were added, depending on the C/N ratio (Pantjara *et al* 2010).

3.3. **RAS**

RAS that used in AHP assessment was modified RAS based on patent application (Adiyana *et al* 2018). The modified RAS was equipped by using microbubble for aeration and protein skimmer. This technology operated indoor with greenhouse-like construction.

3.4. **Supra intensive**

Supra intensive technology firstly introduced and applied in South Sulawesi. Compared to BUSMETIK and biofloc technology, the main differences in this technology is stocking density and pond depth for shrimp farming. The consequences are high capital, operational costs, and electricity consumption. (Atjo 2017, Syah *et al* 2014, Syah *et al* 2017).
Table 3. Description of different intensive whiteleg shrimp farming.

| Parameter                          | BUSMETIK         | Biofloc | RAS              | Supra Intensive |
|------------------------------------|------------------|---------|------------------|-----------------|
| Pond area                          | 600-1000 m²      | >1000 m²| >24 m²           | Min.1000 m²     |
| Stocking density                   | 100-200 Post-Larvae/m² | 80-100 Post-Larvae/m² | 300-500, 1000-1500 Post-Larvae/m³ | 1000 Post-Larvae/m³ or 400 Post-Larvae/m³ |
| Shrimp Productivity                | Moderate         | Low     | Moderate-High    | High            |
| Depth of pond (m)                  | 1-1.2 m          | 1-1.2 m | 1 m              | 1.2-2.5 m       |
| Capital investment and operational cost | Moderate         | Moderate | Small            | High            |
| Electricity consumption            | Moderate         | Moderate | Small            | High            |
| Water exchange                     | Yes              | Yes     | Very small       | Yes             |
| Operation location                 | Outdoor          | Outdoor | Indoor           | Outdoor         |
| Waste Water treatment              | None             | None    | Yes              | Yes             |

Table 3 provides concise information for the experts in filling out of the pairwise questionnaire. Then, the pairwise comparison are calculated by using formula (1) – (4) to get their relative weights (RW), maximum eigenvalue (\(\lambda_{\text{max}}\)), consistency index (CI) and consistency ratio (CR) depend on n. The results of RW, \(\lambda_{\text{max}}\), CI, and CR are presented in table 4-10.

Table 4. Pairwise comparison of different criteria and their relative weights (RW).

| C     | C1  | C2  | C3  | C4  | C5  | C6  | C7  | RW  |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|
| C1    | 1   | 3   | 4   | 3   | 1/3 | 2   | 3   | 0.194 |
| C2    | 1/3 | 1   | 2   | 2   | 1/4 | 1/2 | 2   | 0.089 |
| C3    | 1/4 | ½   | 1   | 1/2 | 1/7 | 1/4 | 1/3 | 0.039 |
| C4    | 1/3 | ½   | 2   | 1   | 1/5 | 1/5 | 3   | 0.073 |
| C5    | 3   | 4   | 7   | 5   | 1   | 3   | 7   | 0.380 |
| C6    | 1/2 | 2   | 4   | 5   | 1/3 | 1   | 3   | 0.166 |
| C7    | 1/3 | ½   | 3   | 1/3 | 1/7 | 1/3 | 1   | 0.058 |

\(\lambda_{\text{max}} = 7.455\)
CI     = 0.076
CR     = 0.057

Table 5. Pair wise comparison of different technologies referred to C1.

|       | BUSMETIK | Biofloc | RAS  | Supra Intensive | RW  |
|-------|----------|---------|------|-----------------|-----|
| BUSMETIK | 1        | 5       | 4    | 3               | 0.526 |
| Biofloc | 1/5      | 1       | 1/2  | 1/4             | 0.077 |
| RAS    | 1/4      | 2       | 1    | 1/3             | 0.124 |
| Supra Intensive | 1/3  | 4       | 3    | 1               | 0.273 |

\(\lambda_{\text{max}} = 4.115\)
CI     = 0.038
CR     = 0.043
### Table 6. Pairwise comparison of different technologies referred to C2.

|         | BUSMETIK | Biofloc | RAS      | Supra Intensive | RW   |
|---------|----------|---------|----------|-----------------|------|
| BUSMETIK| 1        | 1/3     | 1/8      | 1/2             | 0.073|
| Biofloc | 3        | 1       | 1/2      | 3               | 0.286|
| RAS     | 8        | 2       | 1        | 3               | 0.507|
| Supra Intensive | 2 | 1/3     | 1/3      | 1               | 0.134|

$\lambda_{max} = 4.071$

CI = 0.024

CR = 0.026

### Table 7. Pairwise comparison of different technologies referred to C3.

|         | BUSMETIK | Biofloc | RAS      | Supra Intensive | RW   |
|---------|----------|---------|----------|-----------------|------|
| BUSMETIK| 1        | 1/2     | 1/5      | 1/3             | 0.076|
| Biofloc | 2        | 1       | 1/5      | 1/2             | 0.123|
| RAS     | 6        | 5       | 1        | 4               | 0.598|
| Supra Intensive | 3 | 2       | 1/4      | 1               | 0.203|

$\lambda_{max} = 4.066$

CI = 0.022

CR = 0.024

### Table 8. Pairwise comparison of different technologies referred to C4.

|         | BUSMETIK | Biofloc | RAS | Supra Intensive | RW   |
|---------|----------|---------|-----|-----------------|------|
| BUSMETIK| 1        | 1/4     | 1/8 | 0.5             | 0.056|
| Biofloc | 4        | 1       | 1/7 | 3               | 0.181|
| RAS     | 8        | 7       | 1   | 8               | 0.677|
| Supra Intensive | 2 | 1/3     | 1/8 | 1               | 0.085|

$\lambda_{max} = 4.206$

CI = 0.069

CR = 0.076

### Table 9. Pairwise comparison of different technologies referred to C5.

|         | BUSMETIK | Biofloc | RAS | Supra Intensive | RW   |
|---------|----------|---------|-----|-----------------|------|
| BUSMETIK| 1        | 2       | 1/4 | 1/6             | 0.094|
| Biofloc | 1/2      | 1       | 1/5 | 1/8             | 0.058|
| RAS     | 4        | 5       | 1   | 1/2             | 0.307|
| Supra Intensive | 6 | 8       | 2   | 1               | 0.540|

$\lambda_{max} = 4.033$

CI = 0.011

CR = 0.012

### Table 10. Pairwise comparison of different technologies referred to C6.

|         | BUSMETIK | Biofloc | RAS | Supra Intensive | RW   |
|---------|----------|---------|-----|-----------------|------|
| BUSMETIK| 1        | 2       | 1/7 | 1/3             | 0.089|
| Biofloc | 1/2      | 1       | 1/8 | 1/5             | 0.055|
| RAS     | 7        | 8       | 1   | 6               | 0.650|
| Supra Intensive | 3 | 5       | 1/6 | 1               | 0.206|

$\lambda_{max} = 4.195$

CI = 0.065

CR = 0.072
Table 11. Pairwise comparison of different technologies referred to C7.

|          | BUSMETIK | Biofloc | RAS | Supra Intensive | RW |
|----------|----------|---------|-----|-----------------|----|
| BUSMETIK | 1        | 3       | 1/6 | 1/3             | 0.190 |
| Biofloc  | 1/3      | 1       | 1/8 | 1/5             | 0.051 |
| RAS      | 6        | 8       | 1   | 5               | 0.622 |
| Supra Intensive | 3   | 5     | 1/5 | 1               | 0.218 |

\( \lambda_{\text{max}} = 4.204 \)

CI  = 0.068

CR  = 0.075

In order to get the most suitable intensive whiteleg shrimp farming technology for a small capital farmer, we must know the highest composite weights (CW) from different technologies. Composite weights are obtained by multiplying the results of relative weights (RW) from table 4 with relative weights (RW) from table 5-11. The results of composite weights (CW) are presented in table 12.

Table 12. Composite weight of intensive whiteleg shrimp farming for a small capital farmer.

|          | C1  | C2  | C3  | C4  | C5  | C6  | C7  | CW  | Rank |
|----------|-----|-----|-----|-----|-----|-----|-----|-----|------|
| RW       | 0.194 | 0.090 | 0.039 | 0.073 | 0.380 | 0.166 | 0.058 |     |      |
| BUSMETIK | 0.526 | 0.073 | 0.076 | 0.056 | 0.094 | 0.089 | 0.109 | 0.172 | 3    |
| Biofloc  | 0.077 | 0.286 | 0.123 | 0.181 | 0.058 | 0.055 | 0.051 | 0.093 | 4    |
| RAS      | 0.124 | 0.507 | 0.598 | 0.677 | 0.307 | 0.651 | 0.622 | 0.404 | 1    |
| Supra Intensive | 0.273 | 0.134 | 0.203 | 0.086 | 0.540 | 0.206 | 0.218 | 0.331 | 2    |

From table 12, productivity criteria (C5) is the most important criteria of intensive whiteleg shrimp farming for a small capital farmer with value 38.02% and this is logical considering productivity as a source of revenue and high income. Supra intensive is intensive whiteleg shrimp farming with high productivity with value 53.99%. The second criterion is affordability of capital and operational costs on a mini scale (C1) with value 19.36%, then followed by electrical consumption (C6) as third criteria with value 16.61%. The fourth criteria until the last criteria are minimum land area for shrimp farming (C2), environmentally friendly (C4), biosecurity (C7), and location of raw water (brackish water) sources (C3).

Although supra intensive have high productivity and affordable for capital and operational cost, the most suitable for intensive whiteleg shrimp farming technology is RAS. This is due criteria for a minimum land area for shrimp farming (C2), sources location brackish water (C3), environmentally friendly (C4), energy consumption (C6), and biosecurity (C7) with high value. BUSMETIK is ranked third and biofloc in the last rank.

4. Conclusion

Productivity is the most important criteria of intensive vanamee shrimp farming for a small capital farmer with value 38.02%. Supra intensive is intensive whiteleg shrimp farming with high productivity with value 53.99%. The second criteria is affordability of capital and operational costs on a mini scale with value 19.36%, then followed by electrical consumption as third criteria with value 16.61%. Furthermore, other criteria are minimum land area for shrimp farming, environmentally friendly, biosecurity, and sources location of brackish water. The most suitable for intensive vanamee shrimp farming technology was RAS with value 40.35%. RAS has advantages for shrimp farming with minimum land area, sources location of brackish water, environmentally friendly, electrical
consumption, and biosecurity. Supra intensive ranked in second, BUSMETIK is ranked third and biofloc in the last rank with value 33.11%, 17.24%, and 9.30%.

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