

THE USE OF PATH ANALYSIS IN THE DETERMINATION OF ENVIRONMENTAL FACTOR EFFECTS ON THE TOTAL PRODUCTION OF AQUACULTURE PONDS IN PASURUAN, EAST JAVA PROVINCE

Andi Indra Jaya Asaad, Erna Ratnawati, and Akhmad Mustafa

Research Institute for Coastal Aquaculture

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ABSTRACT

Environmental factors in the form of soil and water quality are the important factors of aquaculture pond productivity, including total production (tiger shrimps, *Penaeus monodon*, and milkfish, *Chanos chanos*) in Pasuruan, East Java Province. The objective of this study was to analyze the direct or indirect effects of soil and water quality on the total production of ponds in Pasuruan using a path analysis application. Data were collected in the pond areas around Pasuruan Regency including Nguling, Lekok, Rejoso, Keraton, and Bangil Sub-Districts as well as Pasuruan City. Soil quality was determined as a free variable and exogen; water quality as mediate variable, suspended, and endogen; as well as milkfish production as suspended variable and endogen. Environmental characteristics were illustrated using descriptive statistics, while environment factor effects on total production were analyzed using path analysis. The results of path analysis show that from the 12 analyzed soil quality variables, only two variables were affected in the total production of pond (tiger shrimps and milkfish) namely: contents of soil organic carbon and soil phosphate. While based on 11 water quality variables, two variables (water salinity and water iron) were affected the total production of ponds in Pasuruan Regency. The direct effects of soil organic carbon and phosphate on the total production were 0.314 and -0.600, respectively. Water salinity and water iron gave direct effects on total production amounting to -0.678 and 0.358 respectively. It is also found that two soil variables which were affected in the total production, did not indicate the effect towards water quality in ponds. Further implication of this research is put more attention for these variables into pond's management in order to gain more production. Technical application could be appropriate for pond preparation and frequently water changing during grow out.

KEYWORDS: path analysis, environment, aquaculture pond, Pasuruan Regency

INTRODUCTION

Geographically, Pasuruan Regency consists of mountains, lowland, and coastal region. Some areas have potential natural sources for developing fish-farming industry. Aquaculture potency in Pasuruan Regency includes fresh-water and brackish-water aquaculture. Ministry of Marine Affairs and Fisheries has promoted an industrialization program of brackish-water aquaculture for tiger shrimps and milkfish in some regencies of Java Island, including Pasuruan Regency in East Java Province. The existing pond in Pasuruan Regency is about 3,966.9 ha and in Pasuruan City is about 502.4 ha. Furthermore, the traditional technology is applied with commonly shrimp and milkfish as targeted culture commodity. Other cul-

tured commodities are tilapia, mud crab, and seaweed (Anonim, 2011).

In general, pond environmental factors (soil and water quality) are the important aspects in pond aquaculture (Mustafa & Ratnawati, 2007; Mustafa & Sammut, 2007). These factors are commonly considered as the criteria in land suitability for pond aquaculture (Muir & Kapetsky, 1988; Boyd, 1995; Treece, 2000; Salam *et al.*, 2003; Karthik *et al.*, 2005; Mustafa *et al.*, 2007). Although management of water quality is considered as one of the most important aquaculture factors, some evidences are indicated that pond basic condition and substance exchange between soil and water highly effect on water quality (Boyd, 1995; Boyd *et al.*, 2002). The pond basic quality and its process together with the relationship between pond soil and water become very important parameter for the growth of fish or shrimps in brackish-water pond aquaculture (Avnimelech & Ritvo, 2003). In pond soil

Correspondence: Research Institute for Coastal Aquaculture, Jl. Makmur Dg. Sitakka No. 129, Maros 90512, South Sulawesi, Indonesia. Phone: + (0411) 371544/5
E-mail: andi_asaad1@yahoo.com

condition, chemical, physical, and biological processes occur due to aquatic organisms and microorganisms which could change nutrient elements in soil, and then will affect the quality of the pond water (Boyd, 1995). Problems on pond water quality often begin with soil quality, like low pH and alkalinity of water in acid soil, low content of dissolved oxygen due to the large amount of oxygen required to decompose organic material in soil, and the presence of reduced compound such as nitrite, sulfide hydrogen, iron, and manganese produced by microorganisms in anaerob soil. There has not been any detailed information about the cause-and-effect relationship of soil quality and/or water quality in affecting the production of ponds in Pasuruan Regency.

Path analysis is a technique to analyze the cause-and-effect relationship that occurs in double regression when the free variables affect the suspended variables, not only directly, but also indirectly (Rutherford & Choe, 1993; Everitt & Dunn, 2001). The aim of path analysis is to give an estimation of importance and significance levels of hypothetical cause-and-effect relationship in a set of variables (Webley, 1997 in Sarwono, 2007). In the development, this analysis has been extensified and intensified into a form of Structural Equation Modeling/SEM (Sarwono, 2007). Path analysis is not functioned to find causing factors but only used to make a causal model that can be utilized to make a theoretical explanation (Amir, 2006). Several studies in term of fisheries and aquac-

ulture have been completed by using this analysis. For example, Prein & Pauly (1993) was using path analysis approach to analyze the fish growth in aquaculture. Furthermore, Wahyudi *et al.* (2014) found that economic factor was the largest effect on the small-scale fisheries system in Indonesia based on causal model on economic, social, ecological, and governance variables. The objective of this study was to analyze the direct or indirect effects of the soil and water quality on the total production of ponds in Pasuruan Regency, East Java using path analysis application.

MATERIALS AND METHODS

Field survey to collect soil and water samples as well as interviews with respondents was carried out in May-July 2012. The research was conducted in Nguling, Lekok, Rejoso, Keraton, Bangil Sub-Districts (Pasuruan Regency) and Bugul Kidul Sub-District (Pasuruan City) (Figure 1).

Data Collection

Data were collected in this research including soil, water quality, and pond production. Soil data were measured and collected at the depth of 0-0.25 m from the surface. The soil quality data were measured in the field such as pH_F (soil pH was measured directly in the field) by using pH-meter (Ahern *et al.*, 2004), pH_{FOX} (the soil pH was measured in the field after being oxidized with peroxide hydrogen 30%) using

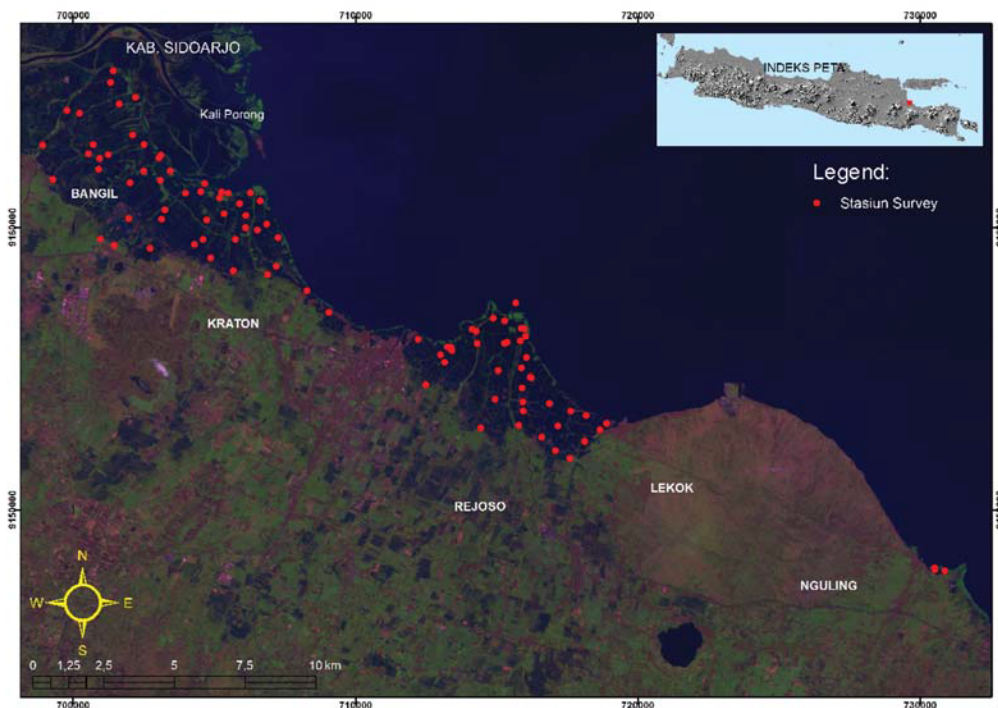


Figure 1. Research Location in Pasuruan, East Java and the distribution of sampling points

pH-meter (Ahern *et al.*, 2004), and redox potential was measured with redox-meter.

For further analysis, the soil samples were placed in a plastic bag and stored into a cool-box. Unnecessary materials such as fresh plants, shells, and other dirt were removed from the soil sample, and big pieces of soil sample were made small by hand. Soil sample was dried naturally by wind in a special room that was contaminant free and protected from sunlight. After dried, the soil sample was made fine by pounding it in a porcelain bowl and sifting it by using a sieve with 2 mm and 5 mm mesh size. Soil quality was then analyzed in laboratory including organic carbon with the method of Walkley and Black (Eviati & Sulaeman, 2009), N-total was analyzed by Kjeldhal method (Eviati & Sulaeman, 2009), PO₄ by Bray 1 method (Eviati & Sulaeman, 2009), Feby spectrophotometer (Menon, 1973), Al by spectrophotometer (Menon, 1973) and texture by hydrometer method (Agus *et al.*, 2006).

Water quality variables were measured in the field, including temperature, salinity, dissolved oxygen, and pH by using Hydrolab® Minisonde. Kmerer Water Sampler was used to collect sample of water. The sample was then analyzed in the laboratory, including NH₃ (fenat method), NO₃ (cadmium reduction method), NO₂ (colorimetri method), PO₄ (ascorbat acid method), Fe (penantrolin method), SO₄ (turbidimetri method), total organic material (base method), and total suspended solid (gravimetri method) by following Menon (1973), Parsons *et al.* (1989), APHA (2005). Soil and water quality samples were analyzed in Soil Laboratory and Water Laboratory, Research and Development Institute for Coastal Aquaculture, Maros, in South Sulawesi Province.

Pond production data were obtained through interviews using structured questionnaires. The data were recorded for the past three years or for six cycles. The production data were then averaged. A total of 22 respondents was chosen. The selection of respondents was based on the owner of pond where the measurement of soil and water quality was conducted.

Data Analysis

Descriptive statistics such as minimum, maximum, average and standard deviation were used for data analysis of each soil quality, water quality and pond total production. Reliability test and validity test were done on the data obtained from questionnaires, namely the total production. These were accomplished to confirm that instrument is reliable and valid to in measurement. In path analysis a mediating model was applied where water quality variables (as medi-

ate variable, dependent variable/endogen variable) modified the effects of soil quality variable (as independent variable/exogen variable) on pond total production (as dependent variable/endogen variable), recursive model where all arrows lead to one direction, and two-path equation model where soil quality variable is as independent variable and water quality and total pond production are as suspended variables. Sarwono (2007) explained that, in path model, exogen variables as independent variables are all variables that have no explicit causes. In the diagram, those represented by no arrows heading towards, while endogen variables have arrows heading towards them. Mediate variables are defining as intermediaries to the dependent variables. In the path analysis, all these variables can be model at once to develop all possibilities of causal model as well as decomposite the correlation into direct effect and indirect effect.

Correlation coefficient was calculated in order to detect the presence of multi-colinearity phenomenon of pond soil and water quality inter-variable correlations. Regression equation was analyzed using backward method (Draper & Smith, 1981). Correlation coefficient was used again to find out the correlation of the chosen exogen inter-variable, the chosen mediate inter-variable and the combination of exogen and mediate variables. R² test (adjusted determination coefficient) was used to find out the magnitude of exogen variable and explained mediate variable, the combination of exogen and mediate variables explained suspended variable. F test was calculated to test the linearity of exogen inter-variable and the exogen variable with mediate variable. The t test was used to find out the magnitude of exogen variable effects on mediate variable individually or partially as well as the magnitude of exogen and mediate variable effects on suspended variable in a partial way. Significance level was determined to be 0.10.

The magnitude of other variables outside of the model was determined by calculating path analysis coefficient that shows errors by using an equation (Widarjono, 2010; Suliyanto, 2011):

$$Pe = \sqrt{1 - R^2}$$

Pe = path analysis coefficient

R² = determination coefficient

Determination of the magnitude of effects: direct effects, indirect effects, and total effects of exogenous variables on endogenous variables were calculated based on the directions of Everitt & Dunn (2001), Supranto (2004), and Sarwono (2007).

RESULTS AND DISCUSSION

Total Production and Pond Environmental Characteristics

Productivity of ponds in Pasuruan was 230-2.500 kg/ha/cycle with an average production of 835.9 kg/ha/cycle (Table 1). This production was come from polyculture production of tiger shrimps and milkfish. Both of the commodities generally require a relatively similar environmental condition but they inhabit at different ecological parts in a pond. Food habit of both commodities results in no competition between them (Eldani & Primavera, 1981). The benefit of polyculture is increasing total production if two or more fish species compatible to be cultured together (Shang, 1986).

The type of soil commonly found in the fish pond area of Pasuruan was aluvial nonsulphate acid soil. The average redox (Eh) potential of pond soil in Pasuruan has the negative value (-113.7 mV) indicating that the soil was in a reduced condition which can produce toxic compounds for aquatic organisms such as sulfide, nitrite, and ammonia compounds. This condition due to that all of the ponds filled with water were used for polyculture tiger shrimps and milkfish, so a reduction condition is formed in the pond basic soil.

The average pH_F and pH_{FOX} soil of ponds in Pasuruan were 7.554 and 6.973 (Table 1). This low value of pH_F - pH_{FOX} indicates that soil of ponds in Pasuruan was not have high acidity potential.

Table 1. Descriptive statistics of total production, soil quality, and water quality of ponds in Pasuruan, East Java Province (n=21)

Factor/ Variable	Minimum	Maximum	Average	Deviation standard
Production				
Total productivity (kg/ha/cycle)	230.0	2,500.0	835.9	716.11
Milkfish density (fish/ha)	833.0	7,143.0	3102	1768.03
Shrimp density (shrimp/ha)	33,33.0	392,857.0	6,6843	11,968.19
Average weight of milkfish (g/fish)	154.00	333.00	2,08.19	39.618
Average weight of shrimp (g/shrimp)	15.00	67.00	31.13	11.759
Milkfish rearing time length (day)	90.0	120.0	116.2	8.02
Shrimp rearing time length (day)	90.0	120.0	116.1	8.01
Soil quality				
pH_F	7.250	8.280	7.554	0.2617
pH_{FOX}	2.690	8.080	6.973	1.3586
Potential redox (mV)	-241.0	230.0	-113.7	104.27
SO_4 (%)	0.080	1.220	0.403	0.3211
Organic material (%)	1.810	4.940	3.308	0.8986
Fe (mg/L)	0.50	224.60	37.37	55.732
Al (mg/L)	0.00	108.90	7.36	23.958
PO_4 (mg/L)	58.00	142.33	98.524	20.6128
N-Total (%)	0.07	0.19	0.140	0.0316
Sand (%)	46.0	68.0	55.0	5.35
Clay (%)	0.0	20.0	2.5	6.03
Dust (%)	28.0	54.0	42.5	7.48
Water quality				
Temperature (°C)	28.90	33.63	31.651	1.4236
Salinity (ppt)	1.17	26.44	14.064	7.5157
Dissolved oxygen (mg/L)	3.16	12.80	8.202	2.8676
pH	7.35	8.67	8.017	0.3658
NO_2 (mg/L)	0.0001	0.1465	0.03726	0.050963
NO_3 (mg/L)	0.0259	2.4023	0.53648	0.589855
NH_3 (mg/L)	0.1572	12.716	1.73104	2.696256
PO_4 (mg/L)	0.01620	1.4499	0.23758	0.339648
Total organic material (mg/L)	13.30	49.3	37.088	10.2443
Fe (mg/L)	0.0000	0.0094	0.00146	0.002620
Total suspended solid (mg/L)	4.0	334.0	70.20	77.35

The organic material contents of pond soil in Pasuruan varied from 1.810%-4.940% with average 3.308%. This values were classified as low organic material contents. This also showed that soil of ponds in Pasuruan was not classified as organosol soil or peat soil. Peat soil is the soil that characterized with exceeds 20% of organic material content (Boyd *et al.*, 2002).

Availability of phosphate (PO_4) > 60 mg/L in pond soil can be classified as slight or classified as good with a limiting factor that is easy to overcome (Karthik *et al.*, 2005). Therefore, the PO_4 content of ponds in Pasuruan was classified as high because it reached an average of 98.524 mg/L (Table 1).

On average, pond sand fractions were generally high (averaging 55.0%) and in contrast the clay fraction was very low (with average 2.5%) in the study area. Such soil texture is classified as physically less-beneficial texture for pond dike construction. Chemically, such soil texture also can not keep nutrient elements and has low soil supporting power, so pH fluctuation can be larger. Pond soil is often found to have fine texture with clay content of at least 20%-30% to hold sideway absorption (Boyd, 1995).

Pond water temperature generally plays an important role in relation to appetite and metabolism process of aquatic organisms. Water temperature of pond in Pasuruan ranged from 28.90°C-33.63°C with average 31.651°C (Table 1). The high water temperature was measured in ponds with very shallow water (< 5 cm). The suitable water temperature for tiger shrimps aquaculture is from 26°C-32°C and the optimum is from 29°C-30°C (Poernomo, 1988). The suitable temperature for milkfish is 27°C-31°C (Ismail *et al.*, 1993).

Salinity ranged from 1.17-26.44 ppt with average 14.064 ppt. This is a very beneficial condition, because water salinity is relatively easy to be adjusted in line with the demand of the commodity being cultured, especially for locations that are close to sea and fresh water sources. Tiger shrimps are capable of adapting to the salinity of 3-45 ppt (Tseng, 1987 in Poernomo, 1988), yet for optimum growth the salinity of 15-25 ppt is needed (Poernomo, 1988). Milkfish can reach optimal growth in water salinity of 15-30 ppt (Ismail *et al.*, 1993).

According to Swingle (1968), generally the suitable water pH for aquatic organisms is around 6.5-9.0. When water pH reach about 9.5-11.0 and 4.0-6.0, it can potentially cause low production. Extremely, when water pH is < 4.0 or > 11.0 that will poison the fish. Based on field observation, some ponds in Pasuruan have water pH as neutral to alkaline (Table

1). This was related to the soil ponds in Pasuruan which are classified as acid nonsulphate aluvial soil.

Dissolved oxygen refers to the oxygen gas that is dissolved in water and highly needed by aquatic organisms. Water-dissolved oxygen of ponds in Pasuruan ranged from 3.16-12.80 mg/L with average 8.203 mg/L (Table 1). Water-dissolved oxygen of ponds in Pasuruan was found suitable for pond aquaculture. Mostly the aquaculture technology applied by fish farmers in Pasuruan was classified as traditional technology. According to Poernomo (1989), dissolved oxygen limit for tiger shrimps is 3-10 mg/L and the optimum is 4-7 mg/L. Milkfish grow well in the dissolved oxygen range of 3-8 mg/L (Ismail *et al.*, 1993).

Nitrate (NO_3) is the primary form of nitrogen in natural waters and is the primary nutrient for the growth of plants and algae. Nitrate is not toxic to aquatic organisms. Water nitrate content of ponds in Pasuruan ranged from 0.0259 to 2.4023 mg/L with average 0.53648 mg/L (Table 1). This value was classified as high nitrate concentration. The NO_3 content in natural waters generally no exceeded 0.1 mg/L. The NO_3 content > 5 mg/L is mainly because of anthropogenic contamination that comes from human activities and animal droppings. The high content of NO_3 > 0.2 mg/L can cause the occurrence of eutrophication of waters which then stimulates the rapid growth of algae and water plants.

Nitrite (NO_2) is a transition form between ammonia and nitrate (nitrification) and between nitrate and nitrogen gas (denitrification). Nitrite is less toxic compared to ammonia, but is still very toxic because it hinders blood ability to carry oxygen. The water nitrite content of ponds in Pasuruan ranged from 0.0001-0.1465 mg/L with average 0.03726 mg/L (Table 1). The NO_2 content in waters is relatively small because it is immediately oxidized to become nitrate. Natural waters contain approximately 0.001 mg/L NO_2 and in contrast NO_2 does not exceed 0.06 mg/L. In waters, the NO_2 content rarely exceeds 1 mg/L (Sawyer & McCarty, 1978). The NO_2 content exceeding 0.05 mg/L can be toxic for very sensitive aquatic organisms (Moore, 1991).

In waters, phosphor element is not found in the free form as element; instead, it is in the form of dissolved non-organic compound (orthophosphate and polyphosphate) and organic compound in the form of particulate. Phosphate is a form of phosphor that can be utilized by plants (Dugan, 1972). Phosphate content in natural waters ranges from 0.005 to 0.020 mg/L, while in ground water it is generally about 0.02 mg/L. The PO_4 content rarely exceeds 0.1 mg/L, even though in eutrophic waters. The PO_4 content in natu-

ral waters rarely exceeds 1 mg/L (Boyd, 1988). Based on the phosphate content, waters are classified into three, namely: waters with low level of fertility having the content of phosphate of about 0-0.02 mg/L; waters with medium level of fertility having the content of phosphate of about 0.021-0.05 mg/L; and waters with high level of fertility having the content of phosphate 0.051-0.10 mg/L (Yoshimura, 1966 in Liaw, 1969). Based on that criteria, it is shown that the water quality of ponds in Pasuruan was classified as low, medium, and high levels of fertility (Table 1).

Total organic material of water describes the content of total organic material of waters consisting of dissolved organic material, suspended organic material, and colloid. Organic material in waters is found as planktons, particles suspended from organic material that undergoes a reconstruction (detritus) and total organic material coming from land and carried by river flow. The total organic material content of water in the study area ranged from 13.30-49.30 mg/L with average 37.088 mg/L (Table 1). Total organic material content in sea water is usually low and does not exceed 3 mg/L (Effendi, 2003).

Total suspended solid describes both organic and non-organic materials found in liquid in the suspended form. According to Effendi (2003), total suspended solid is suspended materials with the diameter size $> 1 \mu\text{m}$, held up on the millipore sieve with pore diameter is 0.45 mm. Total suspended solid is in the form of mud, fine sand and microorganisms that float in the waters. Total suspended solid of water ponds in Pasuruan ranged from 4.00 to 334.00 mg/L with average 70.20 mg/L (Table 1).

Relationship Between Environmental Factors and Total Production of Pond

In this study, there were 12 soil quality variables analyzed (Table 1), but only two variables were found affecting the total production of tiger shrimps and milkfish, namely: soil organic carbon (C- OrgT) and soil phosphate (PO_4T) (Figure 2). C- OrgT had significant effect to the total production with direct effect as 0.314 ($P < 0.10$). Furthermore PO_4T had also significant effect to the total production with direct effect as 0.600 ($P < 0.01$). On the other hand, there were 11 variables of water quality analyzed, but only two variables had significant effects to the total production which were water salinity (SalinityA) and content of water iron (FeA) (Figure 2). These variables had significant effect ($P < 0.01$) to the total production with direct effects of -0.678 and 0.358 respectively. Moreover, the two soil quality variables (C- OrgT and PO_4T) that affect to the total production were not significantly affect the water quality. In this case, the soil

quality variables effect to the total production was not through water quality mediate variables. All those effects (direct effect, indirect effect, and total effect) are shown in Table 2.

It has been mentioned before that soil organic carbon directly affects the total production of ponds. Soil organic carbon frequently becomes a consideration matter in the management of pond. It can affect the soil chemical, biological, and physical properties. Decomposed organic material can become a source of nitrogen, so the pond soil fertility can increase which also cause an increase in natural food and production of pond. Organic material can become a source of food for microorganisms. Furthermore, it can also be as granulator which is to improve pond soil structure. Decomposing of organic material to become humus creates molecule particles that function as "cement" of sand, dust, and clay fractions in aggregate which are not easily dissolved in water (Christensen, 1986). The content of soil organic material of ponds in Pasuruan was relatively low (Table 1), so an increasing in soil organic material can increase the pond total production. It has also been reported that sand fractions are fractions of soil texture that were dominant in soil of ponds in Pasuruan, so the application of organic material can improve soil structure and decrease dike porosity.

Phosphor is a primary productivity limiting factor in ponds. The high content of phosphate does not guarantee primary productivity growth to take place optimally because the phosphate is bound by calcium (Avnimelech & Ritvo, 2003). This was found in ponds of Pasuruan, where the increase of soil phosphate content caused a decrease in pond total production. This condition was strengthened with the fact that soil phosphate content of ponds in Pasuruan was rather high, ranging from 58.00 to 142.33 mg/L with average 98.524 mg/L (Tabel 1). The soil phosphate content was in a saturated condition due to intensive fertilization. Soil phosphate was not yet used effectively by planktons because it was strongly bound as phosphate calcium. When soil pH exceeds 7.0, the unavailability of phosphate will increase because it is fixated in the form of phosphate calcium (Tisdale & Nelson, 1975; Mustafa & Sammut, 2007; Shen *et al.*, 2011).

Tiger shrimps and milkfish are eurihalin organisms, in fact, they are cultured for commercial purposes, and hence optimum salinity range needs to be maintained. Water salinity highly affects the total production of ponds in Pasuruan. It has been reported that tiger shrimp and milkfish reach optimum growth in the optimal salinity subsequently 15-25 ppt (Poernomo, 1988) and 15-30 ppt (Ismail *et al.*, 1993),

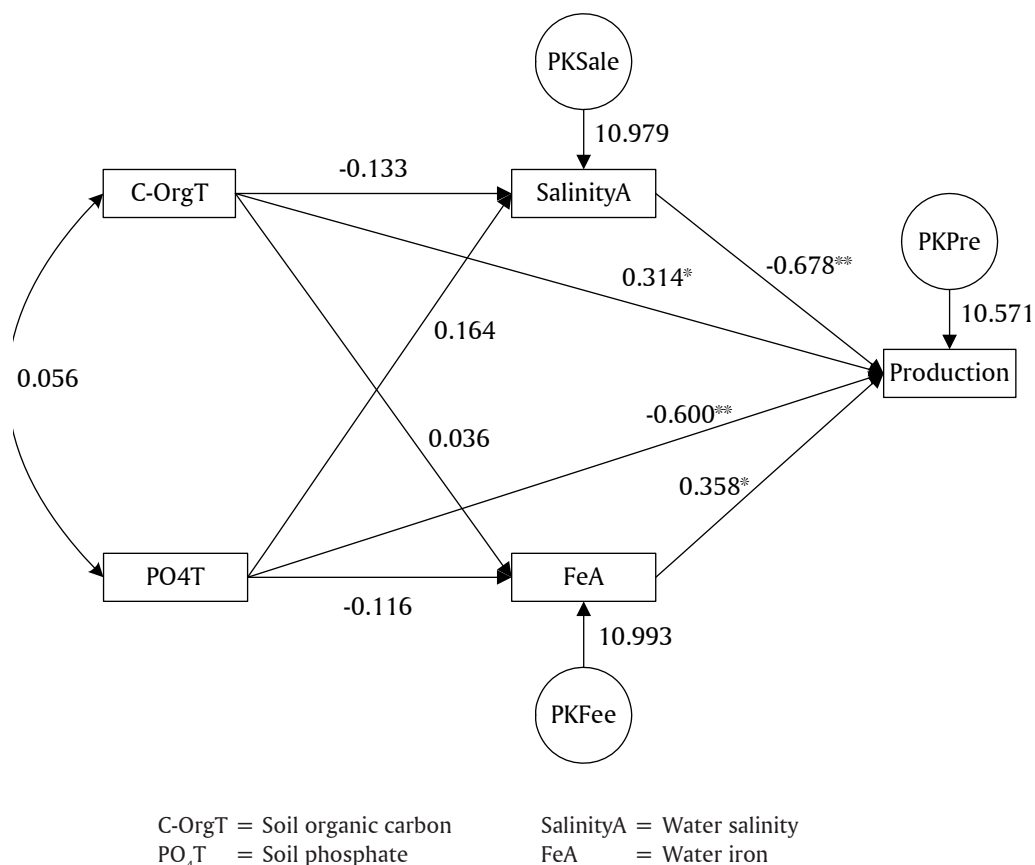


Figure 2. Diagram of path analysis results of soil quality toward water quality and total production of ponds in Pasuruan, East Java Province (* = weakly significant; ** = significant)

that is the most ideal water salinity condition for rearing pond aquaculture because it gives a suitable environment condition for tiger shrimp and milkfish body fluid osmotic. However, it seems that lower salinity can increase total production of ponds in Pasuruan. In various regions of Indonesia tiger shrimp and milkfish culture has developed in pond with low

salinity (less than 10 ppt) to prevent from being infected by a disease that causes shrimps mortality (Sudradjat & Wedjatmiko, 2010).

Iron is a micro nutrient element found the most in soil, followed by manganese, zinc, chlor, copper, boron, and molibdenum. Iron is found in sitokrom, katalase, peroksidase, and dehydrogenase. Acid sul-

Table 2. Values of direct effect, indirect effect, and total effect of each correlation in path analysis for environmental factor and total production of ponds in Pasuruan, East Java Province

Correlation in path analysis	Direct effect	Indirect effect	Total effect
C-OrgT→ SalinityA	-0.133	0.009	-0.124
C-OrgT→ FeA	0.036	-0.007	0.029
C-OrgT→ Production	0.314	0.061	0.375
PO ₄ T→ SalinityA	0.164	-0.007	0.157
PO ₄ T→ FeA	-0.116	0.002	-0.114
PO ₄ T→ Production	-0.6	-0.129	-0.729
SalinityA→ Production	-0.678	-0.142	-0.82
FeA→ Production	0.358	0.095	0.453

Remarks: C-OrgT: soil organic carbon; SalinityA: water salinity; PO₄T: soil phosphate; FeA: water iron

phate soil, which is known iron content is high, can cause clogging in gills of fish and shrimps (Sammut, 1999) and give negative impact on natural feed (Mustafa *et al.*, 2008). Nevertheless, the iron content in ponds in Pasuruan was still classified as low compared to the acid sulphate soil ponds. Therefore, application to increase soil iron content can increase the total production of ponds in Pasuruan.

The result should be considered in the pond management that pond preparation should be done appropriately before grow out process. This is relevant to management of organic matter in soil as well as soil phosphate. Furthermore, in grow out process, water changing frequently should be take into account in order to ensure the water quality such as salinity is in optimum range for commodity cultured.

These result, to some extent, should be carefully generalized to other location, as this study limitation, due to time frame and specific characteristic of research location. It should be comprehensively considered the period of data collection and research location characteristic. However, this study depicted the actual fact of current location and could be used as comparison to other location.

CONCLUSION

The path analysis of 12 soil quality variables showed that only two variables affected the total production (tiger shrimp and milkfish) namely: contents of soil organic carbon and soil phosphate, whereas of 11 water quality variables, only two variables affected the total production of ponds in Pasuruan. Soil organic carbon had significant effects with direct effects as 0.314 to the total production, as well as soil phosphate has significant effects with direct effects as -0.600 to the total production. Water salinity and water iron had significant effect to the total production with direct effects of -0.678 and 0.358 respectively to the total production. Those two of the soil quality variables, which were affecting the total production, did not affect the pond water quality. Pond preparation and water changing frequently during grow out have been considered as technical aspect regarding the result.

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