Computer Simulation Modeling for Prediction of the Extent of Adoption of Shrimp Culture Technologies

Swathilekshmi P.S.[1], Balasubramani N.[2], Chandrakandan K[3], C. R. Renganathan[4], C. Karthikeyan[5] and Saradha C.H.[6]

1&2. Ph.D.Scholars, 3. Emeritus Professor and Chairman (Agrl. Extension and Rural Sociology), 4. Prof. and Head (Mathematics), 5. Asstt. Prof., Dept. of Agrl. Extension and Rural Sociology, TNAU, Coimbatore, 6. Scientist (SS), Central Institute of Brackish Water Acquaculture, Chennai

Corresponding author E-mail: swathiamba@yahoo.co.in

ABSTRACT

Computer Simulation Modeling was used to Predict/forecast the extent of adoption of Shrimp Culture technologies by Shrimp farmers. The adoption behaviour of 120 Shrimp farmers was studied for the years ranging from 1997 to 2003 and the data was used to predict/forecast the adoption behaviour for the years 2004 to 2020. The forecast values generated by the Boot Strap Computer Simulation model suggested a gradual increase in the overall extent of adoption from 2004 onwards which rises to reach a maximum value of 85.81 per cent in 2010. From 2011 onwards the model predicts a gradual decrease in the overall extent of adoption and continues to show this trend until in 2020 the overall extent of adoption reaches 80.53 per cent. Besides, the model generated a goodness-of-fit value of 0.9847 which indicated that the model explained 98.47 per cent of the prediction / forecasting of the overall extent of adoption of Shrimp culture technologies.

Key words: Computer simulation modeling; Shrimp culture technologies;

One of the goals of Social Science is to provide an empirical basis for predicting human behaviour. Apart from the conventional methods of prediction of human behaviour, such as clinical and statistical methods, Computer assisted simulation has of late, become somewhat more common as a method of enquiry in the Social Sciences over the last quarter of the century. Simulation methods involve the creation of models, understanding the behaviour of the models by means of experimentation, and evaluation of the extent to which the behavour of the models provides a plausible account of the behaviour of observed 'natural' systems. (*Hanneman, 1995*). In other words simulation can be defined as the use of mathematical models, describing the phenomenon, process or behaviour of complex system in ways approaching real world conditions to perform experiments in order to predict the likely behaviour of a given set of input, initial and boundary conditions. (*Wright, 1971*). When the model is in the form of a 'Computer Program' rather than a statistical equation, and when this model is run and its behaviour measured, the model generates the simulated data. These simulated data can then be compared with data collected in the usual ways to check whether the model generates outcomes, which are similar to those produced by the actual processes operating in the social world. (*Gilbert and Rosaria, 1995*). A Computer Simulation model is thus a mathematical model written in the form of a Computer programme and the model is run through simulated time to predict the future course of behaviour of a natural phenomena.

With this background, it was decided to design a Computer Simulation model for predicting/forecasting the extent of adoption of Shrimp culture technologies by the Shrimp farmers, in the major Shrimp producing States of Andhra Pradesh and Tamil Nadu.

METHODOLOGY

60 Shrimp farmers drawn randomly from 6 villages belonging to 3 blocks of Nellore district and 60 farmers from 6 villages belonging to 3 blocks of Nagapattinam district totaling 120 farmers formed the sample for the study. The multistage random sampling method was used for the study. The steps used for designing of the Computer Simulation model were as follows.

Designing of diffusion simulation modeling : Diffusion Simulation model for the present study was operationalised as a model which faithfully reproduces the dynamic of adoption behaviour of Shrimp farmers, by simulating the passing of time and then using the model to look into the future with fair accuracy. Since simulation means 'running' the model forward through simulated time, and watching what happens, the background data was collected with respect to the adoption behaviour of the respondents for the past seven years from 1997 onwards till 2003. Most of the technologies such as feed management, water management and health management were evolved and transferred to the target community only after 1995. Hence a reasonably good sample of farmers practicing scientific Shrimp Culture could be obtained only from 1997 onwards. Out of the total 120 respondents who constituted the sample, each respondent was asked to indicate his farming experience in terms of years.

Based on the farming experience of each Shrimp farmer, for each year starting from 1997 onwards, the list of Shrimp farmers were tabulated, along with their adoption behaviour for all the selected 12 Shrimp culture technologies. The resulting adoption behaviour in percentage was recorded for 7 years starting from 1997 till 2003. The adoption behaviour of Shrimp farmers was studied by selecting 12 practices/recommendations, starting from pond preparation till harvest based on judges ranking, and measured by using the adoption quotient developed by *Balasubramaniam (1998*) using the formula

$$\text{Adoption Quotient} = \frac{\sum_{j=1}^{M}\left\{\frac{ej}{Ej}\times wj\right\}}{\sum_{j=1}^{M} W_j}\times 100$$

ej = Extent of adoption of jth practice in terms of magnitude

Ej = Potentiality for adoption of jth practice in terms of magnitude

Wj = Weightage assigned to jth practice

M = No. of applicable practices

S = Summation

Development of mathematical simulation model : Curve simulation software was used for the development of Mathematical Simulation model. The process of finding the best fit was automated by letting curve expert compare the data to each model to choose the best curve. Using the curve simulation software the x values which represented the years from 1997 to 2003 were fed and the corresponding Y values which represented the overall mean adoption behaviour (i.e. the predicted adoption behaviour in percentage) of the Shrimp farmers for all the 12 technologies were generated.

A total of 6 mathematical models such as quadratic, cubic, logarithmic inverse, power and exponential models were used for the study. Among the various models enlisted, the model having the highest value of R^2 was selected as the best mathematical model in terms of accuracy and efficiency in explaining the prediction, and was used for developing the Computer Simulation model. The predicted values made for 2004 up to 2010 were called as forecast values as prediction was made for the future.

Development of computer simulation model : Among the six mathematical models studied, the model having the highest value of R^2 was used to design the Computer Simulation model. This mathematical model which was in the form of mathematical equation was written in the form of a Computer Programme in Java. The resulting Computer programme was run using the Boot Strap Computer Simulation methods for 100 iterations, to generate the simulated data. The simulated data generated by the Boot Strap Simulation method was compared with the observed values and the model was tested for its efficiency by measuring the co-efficient of determination R^2. Thus the prediction / forecasting values for the extent of adoption of Shrimp Culture technologies from the years 1997-2020 was carried out.

RESULTS AND DISCUSSION

The observed values of the overall extent of adoption of Shrimp culture technologies, for period ranging from 1997 to 2003 were fitted in the six mathematical models and the predicted and forecast values for the extent of adoption of Shrimp culture technology up to the year 2020 were generated and the result was presented in Table 1.

It could be observed from Table 1, that six different mathematical models were applied to the observed values in terms of the overall extent of adoption of shrimp culture technologies for the years ranging from 1997 to 2003 and the corresponding predicted and forecast values from 2004 to 2020 were generated. Further it could be observed that for the six models studied the goodness-of-fit of the models as denoted by the co-efficient of determination (R^2) (*Kvalseth, 198*5) ranged from 0.975 to 0.985. The quadratic model having the highest R^2 of 0.985 emerged as the best model, as it implies that the quadratic model explains 98.5 per cent of the prediction/forecasting of the overall extent of adoption of Shrimp culture technologies. With respect to the 6 mathematical models namely quadratic, cubic, logarithmic, inverse, power and exponential models, it was observed that for the years ranging from 1997 to 2003, the observed values and the predicted values for the overall extent of adoption were fairly close to the observed values, which strengthens the accuracy for these models. With respect to the quadratic model and the cubic model the forecast values from 2004 onwards, suggest a gradual increase in the

Table 1. Mathematical models showing the observed, predicted and forecast values for overall extent of adoption of shrimp culture (n = 120)

Models	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
QUADRATIC MODEL																								
Observed (%)	75.40	77.30	78.40	80.10	80.40	81.50	83.00																	
Predicted (%)	75.60	77.07	78.43	79.67	81.81	81.81	82.71																	
Forecast (%)								83.50	84.17	84.73	85.17	85.50	85.71	85.81	85.80	85.67	85.43	85.07	84.60	84.01	83.31	82.50	81.57	80.53
CUBIC MODEL																								
Observed (%)	75.40	77.30	78.40	80.10	80.40	81.50	83.00																	
Predicted (%)	75.60	77.07	78.43	79.67	80.80	81.81	82.71																	
Forecast (%)								83.48	84.14	84.67	85.07	85.35	85.49	85.50	85.38	85.12	84.72	84.18	83.49	82.67	81.69	80.58	79.30	77.88
LOGARITHMIC MODEL																								
Observed (%)	75.40	77.30	78.40	80.10	80.40	81.50	83.00																	
Predicted (%)	75.88	77.07	78.26	79.44	80.63	81.31	82.99																	
Forecast (%)								84.18	85.36	86.55	87.73	88.91	90.09	91.27	92.45	93.63	94.81	95.99	97.16	98.34	99.52	100.69	101.87	103.04
INVERSE MODEL																								
Observed (%)	75.40	77.30	78.40	80.10	80.40	81.50	83.00																	
Predicted (%)	75.88	77.07	78.26	79.45	80.63	81.82	82.99																	
Forecast (%)								84.18	85.36	86.53	87.71	88.88	90.05	91.22	92.40	93.56	94.72	95.88	97.05	98.21	99.36	100.52	101.67	102.83
POWER MODEL																								
Observed (%)	75.40	77.30	78.40	80.10	80.40	81.50	83.00																	
Predicted (%)	75.93	77.07	78.23	79.41	80.60	81.82	83.05																	
Forecast (%)								84.30	85.57	86.86	88.16	89.49	90.83	92.19	93.58	94.98	96.41	97.85	99.31	100.80	102.31	103.84	105.40	106.99
EXPONENTIAL MODEL																								
Observed (%)	75.40	77.30	78.40	80.10	80.40	81.50	83.00																	
Predicted (%)	75.93	77.07	78.23	79.40	80.60	81.80	83.04																	
Forecast (%)								84.28	85.55	86.83	88.14	89.46	90.81	92.17	93.55	94.96	96.38	97.83	99.30	100.79	102.31	103.84	105.41	106.99

Quadratic model : $R^2 = 0.985$, *Cubic Model :* $R^2 = 0.984$ *Logarithmic Model :* $R^2 = 0.978$ *Inverse model :* $R^2 = 0.978$ *Power model :* R^2 *0.975* *Exponential Model :* $R^2 = 0.975$

overall extent of adoption, which rises to reach a maximum value of 85.81 per cent in 2010; for the quadratic model and a maximum value of 85.50 per cent for the cubic model.The plausible reasons for the initial increase in the overall extent of adoption may be attributed to the fact that Shrimp farmers were motivated by quick profits with quick turnovers from Shrimp culture, which makes them adopt more of the Shrimp culture technologies.

This increase can also be attributed to an expanding market, coupled with an increase in demand for Shrimp which might have been a motivating factor for the farmers to go in for greater adoption of the technologies for getting higher yield. A further observation of the table reveals that from the year 2011 onwards, the overall extent of adoption gradually decreases, and continues to show the trend till the year 2014, after which the overall extent of adoption goes on decreasing further to reach 80.53 per cent in 2020 for the quadratic model and 77.88 per cent for the cubic model.

The gradual decrease in the overall extent of adoption from the simulated time period from 2011 to 2020 implies that the overall extent of adoption of Shrimp culture technologies might have been affected by policy changes or due to a shift towards alternative more profitable culture technologies, such as those of crab, and fresh water prawn culture. Further the co-efficient of determination value R^2, for the cubic model was 0.984 which implies that the cubic model explained 98.40 per cent of the prediction in the overall extent of adoption of Shrimp culture technologies, which further confirms the adequacy of the model. Further perusal of the table, reveals the logarithmic model and inverse model which show a close resemblance in their prediction/forecasting trends. With respect to the logarithmic model it could be inferred that there is a gradual increase in the overall extent of adoption from 2010, until in 2018 the overall extent of adoption exceeded 100 per cent, and is further seen to increase in the consecutive years of 2019 and 2020. In close similarity the inverse model shows gradual increase in the forecast values from the year 2004, until in 2009, the overall extent of adoption is 90.05 per cent.

In both the logarithmic models and inverse models, the overall extent of adoption has exceeded 100 per cent in 2018 and is further seen to increase in the consecutive years of 2019 and 2020. This might have been due to the introduction of newer technologies by the Research System and adoption of the same by the clientele system.

Further it could be observed from the table that the co-efficient of determination R^2 was 0.978 for both the logarithmic and inverse models which indicates that these two models explain 97.80 per cent of the prediction in the overall extent of adoption of Shrimp culture technologies, which further confirms the adequacy of the model.

With respect to the power model, it could be observed that the forecast values from the year 2004 goes on increasing, until in the year 2009, the overall extent of adoption of the Shrimp Culture technologies, reaches 90.83 per cent. This implies a prediction of a major technological break through in the year 2009. Further a similar technological break through is predicted in the year 2016, when the mean extent of adoption reaches 100.80 per cent and thereafter shows an increasing trend for the consecutive years of 2019 and 2020. Hence it is concluded that the large scale extent of adoption is the result of major technological breakthroughs in the production of hybrid strains, disease control mechanisms and improved culture methods. A similar forecast trend was obtained for the exponential model. It could be further observed that the co-efficient of determination R^2 was 0.975 for both the power model and exponential model which indicates that both these models explained 97.50 per cent of the prediction in the overall extent of adoption of Shrimp culture technologies which further confirms the adequacy of the model.

Computer simulation model: Computer Simulation Model was designed by selecting the Mathematical model which yielded the best measure of model accuracy with respect to R^2, the co-efficient of determination. Among the 6 mathematical models studied it was found out that the quadratic model had the highest value of R^2 i.e. $R^2 = 0.985$. Hence this model was used to design the computer simulation model. A computer programme in Java was written for the mathematical equation representing the quadratic model

i.e. $y = a + bx + cx^2$

The programme was named as “SIMPRESH” (acronym for simulation, prediction and shrimp) by the researcher and is presented as follows:

The computer simulation model “Simpresh” was run through the simulated time, using the ‘Boot Strap’ Computer simulation method and the model was used to generate the simulated data and the results are presented in figure 2.

A perusal of Table 2 shows the Boot Strap computer simulation programme output. The Bootstrap simulation programme was run for 100 iterations and it was found that an optimal solution was found with four major iterations itself. A cursory look at figure 1 revealed that for the years ranging from 1997 to 2003, the predicted values of the overall extent of adoption of Shrimp culture technologies generated by the Boot strap computer simulation model are fairly close to the observed values.

Table 2. Details of bootstrap simulation

Parameter	Estimate	Std. Error	95% Confidence Interval (Bounds)	
			Lower	Upper
A	74.014	2.224	69.562	78.465
B	1.6428	0.937	-0.232	3.518
C	-.057	0.098	-0.253	0.139

F value – 95.52**

The forecast values from 2004 onwards, suggest a gradual increase in the overall extent of adoption, and rises to reach a maximum value of 85.81 per cent in 2010. This predicted increase in the overall extent of adoption suggests that the Shrimp farmers are motivated by quick profits with quick turnovers from Shrimp culture, which makes them adopt more of the Shrimp culture technologies. This increase can also be attributed to an expanding market, coupled with an increase in demand for Shrimp which might have been a motivating factor for the farmers to go in for greater adoption of the technologies for getting higher yield. Further observation of figure 1 shows that from 2011 onwards, the overall extent of adoption gradually decreases, and continues to show this trend till 2014 where the overall extent of adoption is 85.07 per cent. This gradual decrease might be due to changes in policy or due to a shift towards more profitable culture technologies like crab culture or fresh water prawn culture.Thus the validation of the simulated model was established thus proving that the model was an accurate representation of the real system (observed values). Further it was seen that the R^2 value was 0.9847. Thus the model explained 98.47 per cent of the prediction / forecasting of the overall extent of adoption of Shrimp culture technologies.

A cursory look at Table 2 indicates that when Bootstrap computer simulation method was applied, the estimate was found to lie between 69.56 and 78.46 per cent confidence interval. Thus we can say with 95% confidence that the sample estimate will not exceed the limits of tolerance or margin of error.

Among the two methods of prediction / forecasting, the most accurate is the computer simulation model followed by the mathematical model. This is because in computer simulation, the prediction / forecasting is generated with respect to simulation of 60 data sets, unlike in mathematical model where only a single set of observations are used.

CONCLUSION

Shrimp culture which started a century ago as a traditional practice in the form of trapping, holding and harvesting has undergone a metamorphosis, in the past two decades and has scaled, great heights and attained the status of an industry. Shrimp culture on a commercial scale was started by farmers in the early 1990's and since then, it has completed a little more than a decade of development in India. The critical technologies in Shrimp Culture such as feed management, disease management, soil and water management were developed by the Research Institutions in the country only after the mid 1990's.The results of the study indicate that Shrimp farmers are very receptive to the technological advancements and show a relatively high adoption rate.Use of novel and effective tools like Computer simulation would give a fair idea of the extent of adoption of Shrimp culture technologies by Shrimp farmers which in turn would indicate the future scenario of the industry in the country and help the researchers, extension personnel, shrimp farmers and the government to plan accordingly and take corrective steps for the future.

REFERENCES

1. Balasubramaniam, S. (1988). Analysis of technology transfer effectiveness in Inland: Fish farming, unpub. Ph.D. Thesis, TNAU, Coimbatore.
2. Gilbert Nigel and Rosaria Conte (1995). Computer simulation for social theory, www.elcster.org.
3. Hanneman, Robert (1995). Simulation modeling and theoretical analysis in sociology. *Sociological Perspectives*, **38** (4) : 457-462.
4. Kvalseth T.O. (1985). Cautionary note about R^2, *The American Statistician*, **39** (4) : 279-285.