Early Warning System in Agroindustry: a Chaos Theory Based Analysis

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***Abstract*-- Chaos could occur anytime in agriculture sector, and that some occurences will be predictable and some will not, so it needs early warning system that could detect early chaotic conditions and take action for crisis recovery.This research was aimed to design early warning system for tapioca agroindustry with the chaos existence test. The methodology in this research we investigate the existence of chaos in agroindustry. Such an investigation is necessary to use appropriate and correct methods for further analysis, as linear system techniques will not be usefull. If a system exhibits chaos, decision making should consider the system characterization parameters from a chaos theory perspective. In this paper two models from the existing literature are reported. Of this models, the chaos existence test is further exploration to get crisis signal analysis. A tapioca smal scale industry example is used and the resulting behavior is characterized. At certain input values the behavior of the material supply system exhibits chaos. Lyapunov exponent value for the raw material supply was 0.15656 bits/week. These properties indicate that the raw material supplies could not be predicted in the long term. Raw material supply could be predicted within a period of 1/0,15 656 = 6,34942 approximately in 6 weeks. And status alert will be presented, wich is "Supply of Raw Materials have the potential Chaos". The alert shows that tapioca industry had no strong position on integration into the upstream raw material supply sources. The recommended strategy was the strengthening of the upstream sectors This information is useful for further analysis for prediction and control.**

***Index Term*-- Early Warning system, chaos theory, agroindustry**

1. INTRODUCTION

In an agroindustry system one of the most fundamental question is the analysis of this system behavior. Charateristics raw material in agroindustry are perishable, bulky and seasonal, so that are cause uncertainty in logistic raw material supply. A typical logistics system is characterized by a supply chain [1]. Hypothesis in this paper is that system are non linear, dynamic and in specific chaotic. That is, the time evolution of the system behavior which is measured by certain behavior parameters of system is chaotic. The question now is how do really characterize the time evolution and how can we use the insigts obtained from such analysis

Tapioca agroindustry turbulence condition was characterized by decreasing ability of the industry in production and business functions. Material supply was identified as key crisis factors in tapioca small scale agroindustry. This research was aimed to design early warning system for tapioca agroindustry with the chaos existence test.

2. THEORETICAL BACKGROUND

Crisis Management

Base on its anatomy cycle of crisis consist of the following four components[3]:

1) prodomal,
2) acute,
3) cronis and
4) *resolution*.

Crisis Management is a knowledge or model procedural to navigate organization after crisis to get sustainable activity as soon as [2].

Proactive action in crisis management characterized by crisis potensial forecasting and control planning. Crisis management indentify of crisis triger, minimize damage as impact of crisis and then recovery of crisis [6].

Early Warning System

Early warning definition is a system or procedure designed to warn of a potential or an impending problem [2]..Early warning system is an importan tools in a government's or industry's toolbox for achieving sustainable development. It can be used to encourage setlements to develop in relatively secure areas [4].

Efective early warning system can be done continously from risk identification to get crisis impact indicator, intelligence monitoring to get crisis alert, and then management action as anticipation of crisis [4]..

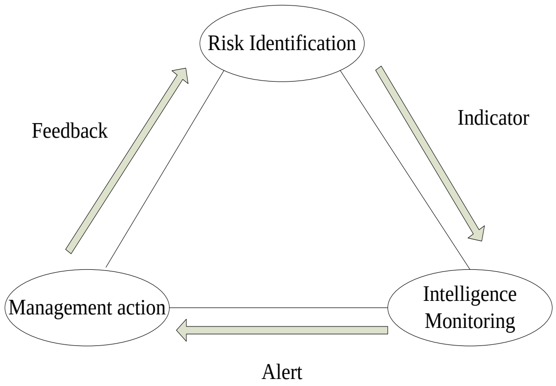

Fig. 1. The competitive Early warning triangle [4].

Chaotic Management System

In Collins English dictionary Chaos is “great disorder”. Three primary keys of chaos are:

1). Nonlinierity,

2) Unstable system (unstable structure and unstable behavior), and

3) Emergent order.

Chaotic Management System is a systematic approach to detecting, analyszing,and responding to turbulence and chaos. To getSustainable Business Enterprize, the Chaotic Management System consists of the following three components:

1. Detecting source of turbulence through development of Early-Warning Systems
2. Responding to chaos by the construction of key Scenarios
3. Selecting strategy based on scenario prioritization and risk attitude[5].

Nonlinear Dynamics, Chaos and Fractals

Many physical system that produce continous time response may be modeled by a set of differential equations of the form.

$$\frac{d\bar{x}(t)}{dt} = F(\bar{x}(t)) \qquad (1)$$

$F(.)$is generally a nonlinear vector field. The solution to this results in a trajectory

$$\bar{x}(t) = f(\bar{x}(0), t) \qquad (2)$$

Where f:M→M represents the flow that determines the evolution of x(t) for particular initial condition x(0). If the system is dissipative, as the system evolves from different initial conditions, the solutions usually shrink asimptotically to a compact subset of the whole state space M. This compact subset is called an attracting set. Every attracting disjoint subset of an attracting set is called an attractor[11].

In dissipative system, the overall volume of the state space srinks with time. However, there may be some directions along which the state space actually expands. That is, the system trajectories tend to move apart along certain directiobs and shrink along the others. However, as the attractors usually remain bounded, the flow exhibits a horseshoe-type pattern [11]. Because of this, trajectories starting from near-by points within an attractor may get separated exponentially as the system evolves. This condition is known as sensitive dependence on initial condition, and the attractor is called a strange attractor.

A flow f, for particular initial condition, is said to be chaotic if the trajectories in attractor exhibit:

1. Sensitive dependence on initial condition, but are bounded,
2. Irregular and aperiodic behavior, and
3. Continousbroadband spectrum.[10]

Measure of chaos

Sensitive dependence on initial condition is main component in chaotic system, it can be measured by determine number of exponent Lyapunov. Formal equation of exponent Lyapunov (λ) for i ($p_{i(t)}$) dimension is :

$$\lambda = \lim_{t\to\infty}\left(\frac{1}{t}\right)^2 \log\left(\frac{p_i(t)}{p_i(0)}\right) \qquad (3)$$

For the logistic function

$$\lambda = \frac{1}{N}\sum_{n=1}^{N}\log_2(r - 2rX_n) \qquad (4)$$

where

λ = exponen Lyapunov
t = t-periode
$p_i(t)$ = data-i for t periode
$p_i(0)$ = data-i for initial periode
X_n = data -n
N = number of data
r = input parameter

Chaos identification consists of the following three conditions:

$\lambda < 0$ system in stable point or periodic stable
$\lambda = 0$ system in steady state condition .
$\lambda > 0$ condition of system is chaos

Unit of exponen Lyapunov is bits/iteration. The meaning of measure accuration is how long we know actual condition. For example, maximum exponen Lyapunov is 0,05 bit/day, that means we will loss 0,05 bit every day for prediction, so information wiil not accurate after 1/0,05 or 20 days[8].

Fractal dimension

Fractal dimension explain how an object is accomodate on its space. For example, system have 2,37 fractal dimension that is at least consist three variables for arrange in dinamic system. Fractal dimension can be measured by the follow equation:

$$N * d^{D} = 1 \qquad (5)$$

Where N=number of circle
d=diameter of cirle
D= fraktal dimension

$$D = \frac{\log N}{\log d^{-1}} \qquad (6)$$

Grassberger dan Procacia (1983) developed method of *correlation dimentsion* as approach of fractal dimension measurement with *correlation integral*, Cm(R). *correlation integral* is pair of point probability in attractor which have a distance R among the other point[9].

$$Cm(R) = (1/N^{2}) * \sum_{\substack{i,j=1 \\ i \neq j}}^{N} Z(R - |X_i - X_j|) \qquad (7)$$

Where $Z(x) = 1 \text{ if } (R - |X_i - X_j|) > 0$

N = number of observation
R = distance
Cm = correlation integral for m-dimension

$$Cm = R^{D} \qquad (8)$$

or

$$\log(Cm) = D * \log(R) + \text{constant} \qquad (9)$$

3. RESEARCH METHODOLOGY

Tapioca industry was a Case study in this research. Source of turbulence identification was done with root cause tree diagram to get chaotic primary factor or chaos trigger. To identification the chaotic situation, exponent Lyapunov and fractal dimension were determined with chaos theory approach.

Chaotic investigation with chaos theory approach identified by positive Lyapunov exponent and fractal dimension. Fractal dimension could determine another chaos component, embedding dimension to be considered as information about how many time lags were involed forecasting. Chaos signal analysis model was set up with Lyapunov exponent, and supplemented with control management procedure. When chaotic primary factor was evaluated at chaos level, then status alert would be presented as “Chaos” , and then proactive action must be done. If the system is normal, management can do continous improvement, see figure 2.

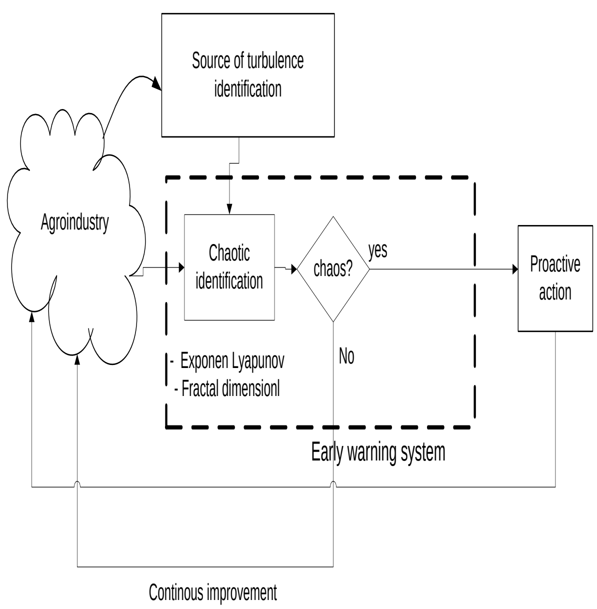

Fig. 2. Step of methodology research

4. RESULT AND DISCUSSION

Situational analysis with root cause tree diagram, material supply was identified as key crisis factors in tapioca small scale agroindustry. Material supply on September 2008 until

March 2009 was under normal capacity so production was stoped, see figure 3.

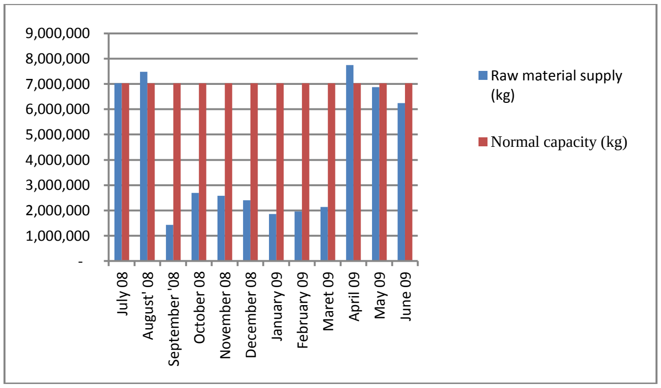

Fig. 3. Normal capacity Vs actual capacity

Lyapunov exponent and fractal dimension determined by Matlab R.7.1. In the case study,Lyapunov exponent value for the raw material supply was 0.15656 bits/week. These properties indicate that the raw material supplies could not be predicted in the long term. Raw material supply could be predicted within a period of 1/0,15 656 = 6,34942 approximately in 6 weeks. Fractal dimension for the raw material supply was 1.59616. While for the value of embedding dimension was [2.4].

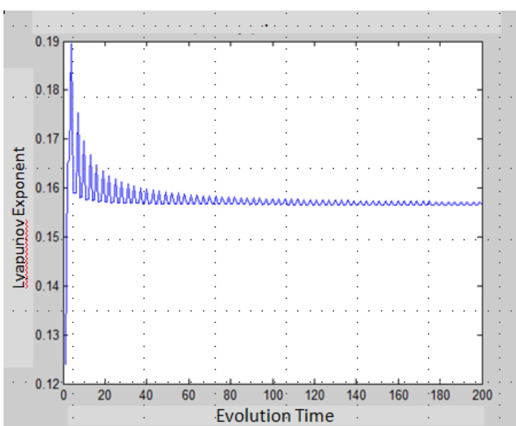

Fig. 4. Lyapunov Exponent

This value could provide information of the number of compiler variables which could be used to determine the number of input variables in the prediction process of raw material supply. There were two variables input of raw material supply forecasting process wich are price of cassava and cassava production.

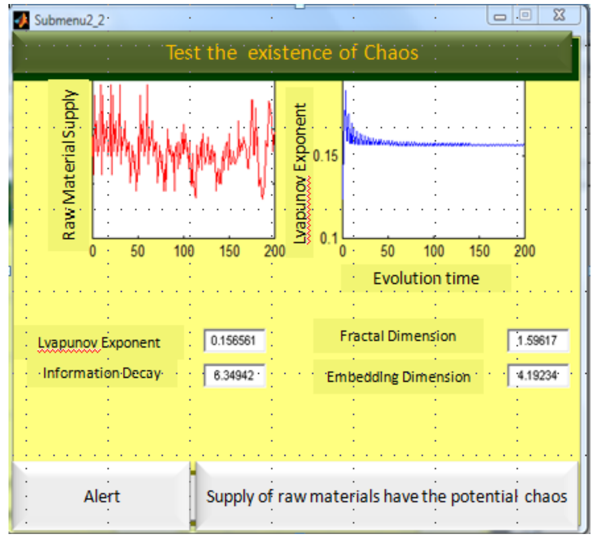

Fig. 5. Output of test the existence of chaos

Crisis signal analysis model was set up with threshold analysis, and supplemented with control management procedure. When raw material supply was evaluated at crisis level, then status alert will be presented, wich is “Supply of Raw Materials have the potential Chaos”, In the case study show that the supply of raw materials for four weeks from six weeks of the predicted normal capacity was insufficient, This shows that tapioca industry had no strong position on integration into the upstream raw material supply sources

The recommended strategy was the strengthening of the upstream sectors (backward linkage). The recommended policy was a cooperative institution to conduct the purchase of the raw material to cover the shortage of raw material supply.

5. CONCLUSION

Tapioca small scale agroindustry turbulence condition was characterized by decreasing ability of the industry in production and business functions caused by raw material supplies insuffience on normal capacity. The positive Lyapunov exponent value indicate that the tapioca small scale agroindustry was chaotic, so proactive action must be done by management to crisis recovery and achieving sustainable development.

Suggested to do more research on the fractal dimension toinvestigate the factors that influence the supply of materials.

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