Chapter 4

# Forest Fire Model

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Additional information is available at the end of the chapter

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**Abstract**

Forest fire model is one of the dynamic system models that used cellular automaton paradigm. In this chapter, we discuss the forest fire model and how to implement in the serious game of real time gross settlement (RTGS) and the serious game of supply chain management (SCM) agroindustry.

**Keywords:** forest fire model, cellular automaton, real-time gross settlement, supply chain management

## 1. Introduction

Forest fire model is any of a number of dynamical systems displaying self-organized criticality (SOC). This model is defined as a cellular automaton on a grid with $L_d$ cells. $L$ is the side length of the grid and $d$ is its dimension. A cell can be empty, occupied by a tree, or burning. The controlling parameter of the model is p/f, which gives the average number of trees planted between two lightning strikes [1].

Dynamic system theory is part of the field of mathematics used to describe the behavior of complex dynamic systems that can be easily analyzed. Dynamic system theory is usually by applying differential equations or difference equations [2].

The differential equation is a mathematical equation for a function of one or more variables, which links the value of the function itself and its derivatives in various orders. Differential equations play an important role in engineering, physics, economics, and other disciplines. Differential equations are used when a deterministic relationship involving a quantity that changes continuously, and the rate of change is known or postulated [3]. The problem that occurs is if continuous data changes are not known.

The basic idea to solve the problem is to consider a system with changes that are considered discrete. One example is the process of cell division that changes continuously but can only be observed in certain time series. The key here is that there is a relatively short and synchronized action that lets one ignore the behavior in the time period for the purpose.

Another alternative to discrete models is the discretization of the continuous time model. That is, we cannot really observe changes constantly, so we only monitor some data at discrete intervals. An example is an individual location (which constantly moves, but we can only observe at discrete intervals). This is the basic idea of time series analysis, which is a statistical approach to describe, predict, and control time-dependent system behavior.

Difference equations are discrete dynamic systems. When a variable time goes over a discrete set of intervals and continued for another interval, it will generate a dynamic equation in the time scale [4]. Some situations can also be modeled by a mixture of operators, such as differential.

Dynamical systems theory is a field of mathematics that used to describe the behavior of the complex dynamical systems. Dynamic system theory usually applies differential equations or difference equations. Dynamic system theory is called a continuous dynamic system if the system uses differential equation [5]. Continuous dynamical systems, from a physical point of view, are generalizable with classical mechanics. The implementation of continuous dynamical systems is generally postulated directly, which is not limited by the Euler-Lagrange equation. Dynamical system theory is called a discrete dynamic system if the system uses a difference equation. When the time variable runs over a discrete set for several intervals and continues over another interval, it will get dynamic equations on a time scale. Some situations can also be modeled by mixed operators such as differential difference equations.

The dynamic system, at any given moment, has a state represented by a tuple of real numbers that can be illustrated by a point in the appropriate state space. Dynamic system rule changes are functions that represent predictions of future circumstances based on the real data of the present situation. The dynamic system function is often a deterministic function, at certain time intervals, only one future state follows from the data of current state. However, some systems are stochastic, and functions in those random events also affect the evolution of the state variables. In order to make a prediction about the system's future behavior, an analytical solution of such equations or their integration over time through computer simulation is realized.

The dynamic systems that discussed in this section focus on dynamic system theory. Dynamic systems theory can be applied to various fields of science such as mathematics, physics, biology, chemistry, engineering, economics, and medicine. Dynamical systems are a fundamental part of chaos theory, logistic map dynamics, bifurcation theory, the self-assembly process, and the edge of chaos concept. In this section, we give examples of the application of dynamic system theory with probabilistic cellular automata forest fire models approach in real time gross settlement (RTGS) and agribusiness.

## 2. Cellular automaton

The world is not static, and the system is always changing over time in accordance with its importance. As the system changes, the value representing the state of the system in a

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particular phase also changes. The dynamic system is a phase along with rules governing how values represent the developing state. The path tracked out of phase space by evolution is called orbit. In order for the system to be a dynamic system with the above-mentioned definition, we require that the future state of the system must be fully determined by the state of the current system.

Chaotic condition is a condition where the system is dynamically growing [6]. In a system that has a chaotic condition is required a fairly complicated method to predict the next conditions, but predictions are a very important to determine a decision taken by an organization. The chaotic state of a system is mostly due to the initial conditions and dynamic rules that are difficult to determine accurately so as to influence the prediction of subsequent conditions.

Although the initial conditions are difficult to determine accurately, these conditions will affect how the system evolves, which means that the system does not really grow exponentially. With the growth conditions that are not really exponential, then the prediction to see the next step is an interesting activity to be studied.

Cellular automaton paradigm is very interesting because it can simplify complex problems. The arrangement of cells that describes the state in each time period is governed by simple local rules. Simple local rules proved to be the best way to analyze many natural phenomena. This is because most natural processes themselves are local. For example, molecules interact locally with their neighbors, bacteria with their neighbors, ants with theirs, and people likewise. Although the natural phenomenon is continuous, the automaton paradigm that tests the system using discrete time steps does not reduce the strength of the analysis. Therefore, in the artificial cellular automaton world, we have a microcosm that can be developed in the real world.

A cellular automaton is a mathematical model for systems in which many simple components act together to produce complicated patterns of behavior [7]. One-dimensional cellular automaton is a simple cellular automaton. The simple cellular automata has two possible values for each cell (0 or 1), and a rule that only depends on the value of the nearest neighbor. As a result, the evolution of elementary cellular automatons can be described completely by a table that determines the state of a cell given to the next generation based on the value of the cell to its left, the value of the cell itself, and the value of the cell to its right as shown in **Figure 1**.

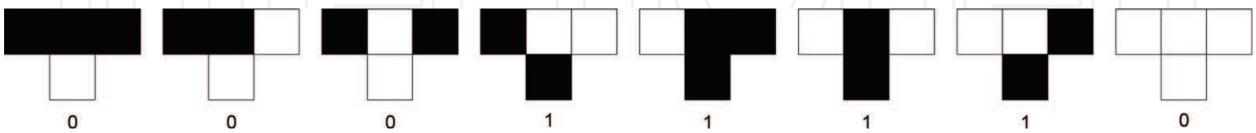


**Figure 1.** The simple cellular automata.

## 3. Agent-based model

The agent-based model has become increasingly used as a modeling approach in social science. This model is widely used because a person in his or her social life can build models with individual entities and their interactions [8]. When compared to a variable-based approach that uses structural equations or when compared to system-based approaches that use differential equations, agent-based simulations provide the possibility of modeling individual heterogeneity, which represents explicitly agents' decision rules and assigns agents to locations in geographic types or any other type of space. This condition allows the modeler to naturally represent some scale of analysis, the appearance of structures at the macro or community level of individual action, and different types of adaptation and learning. Approach to agent-based model is difficult to do with other modeling approach.

### 3.1. The agent-based model for real time gross settlement (RTGS)

In general, the RTGS transaction mechanism is performed by participants who send a payment transaction message to the central of management RTGS system located at the central bank for settlement process [9]. The mechanism at clearing house is a transmitter client who sends a message of transaction through transmitter bank, that having canal at clearing house, then continue to receiver client through receiver bank as shown in **Figure 2**.

**Figure 2** shows that the transmitter client sends the funds through the transmitter bank by sending transaction messages through the channel on the clearing house (B11). From channel B11, the transaction information proceeds to the bank receiver and proceeds to the receiver client via channel on clearing house owned by its neighbors (B12, B13, B21, B22, B23, B31, B32, and B33) using the forest fire model concept [10] .

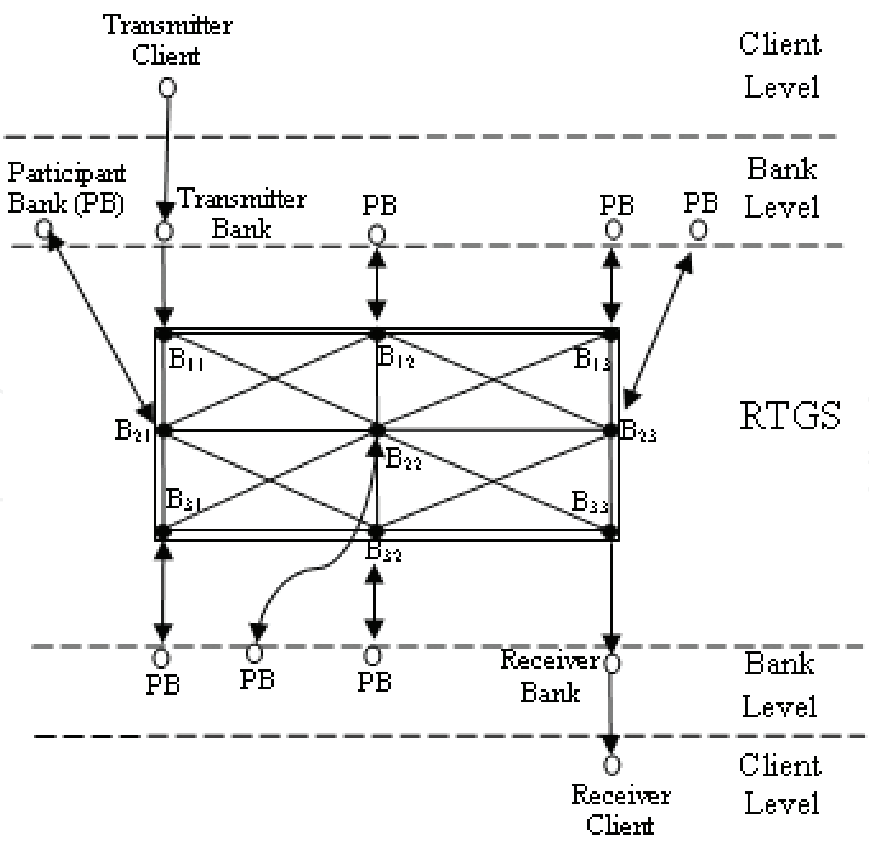


**Figure 2.** RTGS model using clearing house.

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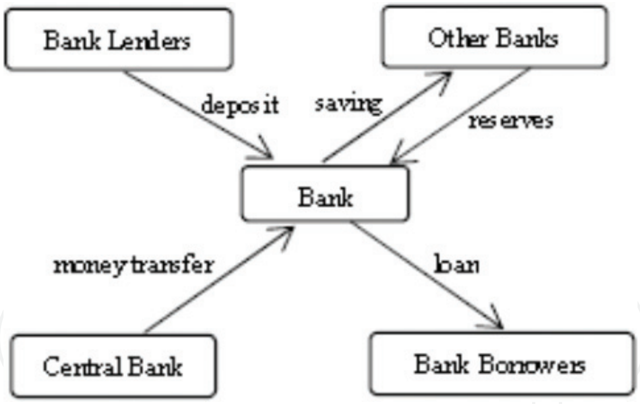


**Figure 3.** The adaptive agent.

Generally, the settlement process is influenced by the balance of the bank account that will carry out the settlement process in the central bank. The value of sufficiency in this discussion is influenced by the fulfillment of another bank participating in the clearing house. The fulfillment decisions made by other banks depend on the information provided by the agent in the clearing house.

The model used in this experiment is a decentralization paradigm that modeled network system's activity. The main component of this network is an adaptive agent consisting of five agents that are saving agent, reserves agent, loan agent, deposit agent, and money transfer agent, as shown in **Figure 3**.

The saving agents are in charge of finding and distributing the information needed in order to make the decision to save to another bank based on the health analysis of both banks so as to get the optimal profit. Reserves agents are tasked to find and share information related to the decision to take the reserve money in other banks based on the health analysis of two banks in order to obtain optimal benefits. Loan agents are responsible for finding and sharing information related to the profits to lend money to other banks based on the health analysis of two banks. Money transfer agents are given information concerning advantage that applies the deposit in central bank. Deposit agents have the duty to seek and share information about the profits when borrowing money from other banks based on the health analysis of two banks.

### 3.2. The agent-based model for SCM agribusiness

Supply chain management (SCM) philosophically is a chain that connects between companies, suppliers and customers. In the supply chain, a company connects between supplier to its upstream and distributor to downstream serving its customers. In general, the flow of material leads to the front while information and money flows backward in the established supply chain as shown in **Figure 4**. The purpose of supply chain management is to optimize services to customers at the lowest possible cost.

A 'value' can be created by the organization for itself and its customers. The creation of value can be done by participating in value chain activities. The value created by growing relationships

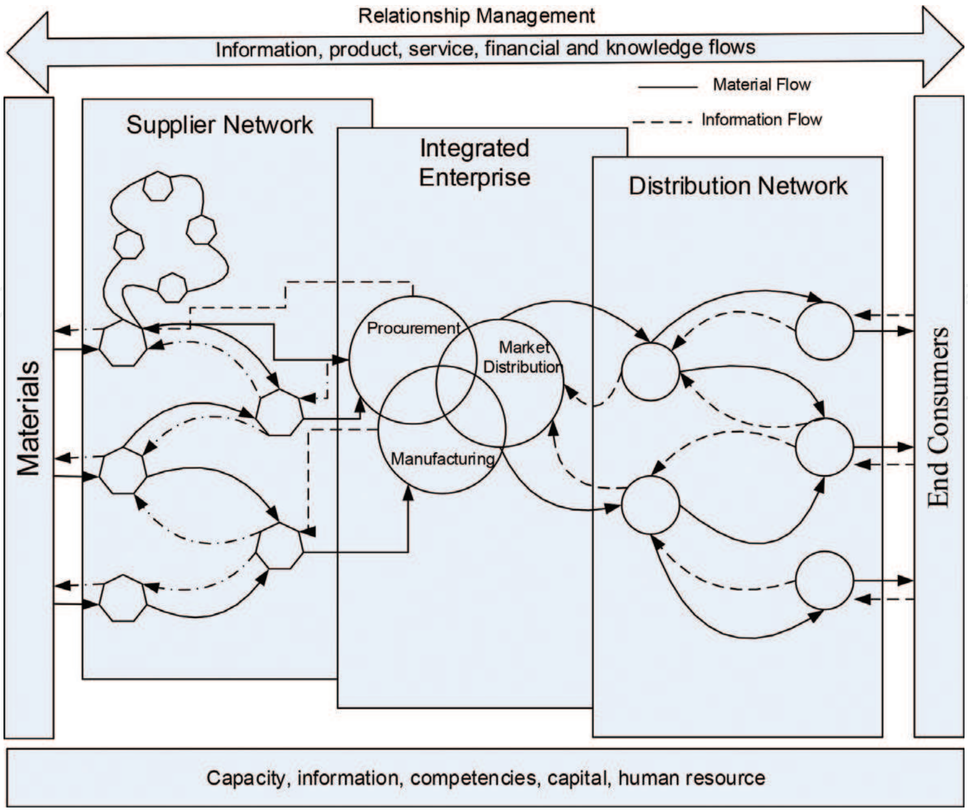


**Figure 4.** The networks model of modern enterprises.

is key in the supply chain. This key value is aggregated as the cumulative value of all exchanges that occur between the companies participating in the supply chain. The nature of the above agribusiness relationship highlights the traditional concept of the company. Traditionally, firms are perceived as separate and independent entities. When determining the chosen strategy, traditional companies seek to strengthen independence. This concept has been transformed into a network-based strategy. The contemporary concept assumes that the company is embedded in the network. The established network causes the merging companies to become interdependent. Because of interdependence, a strategic approach to relationship management in the network is required. The following diagram illustrates the nature of the relationships used by today's modern enterprises in the competitive environment among them in the network.

**Figure 4** illustrates that firms need networking strategies to manage relationships with three different entity types around the supply chain environment, that is, (a) upstream with suppliers and downstream with customers, (b) horizontally with competitors and compliments, (c) with other key players in the economic, political/regulatory, technological and socio-cultural environments [11], as shown in **Figure 5**.

On the basis of network strategy to manage relationships, this model created four agents that can manage the network. These agents are buyer's agent, competitor's agent, seller's agent and support's agent as shown in **Figure 6**.

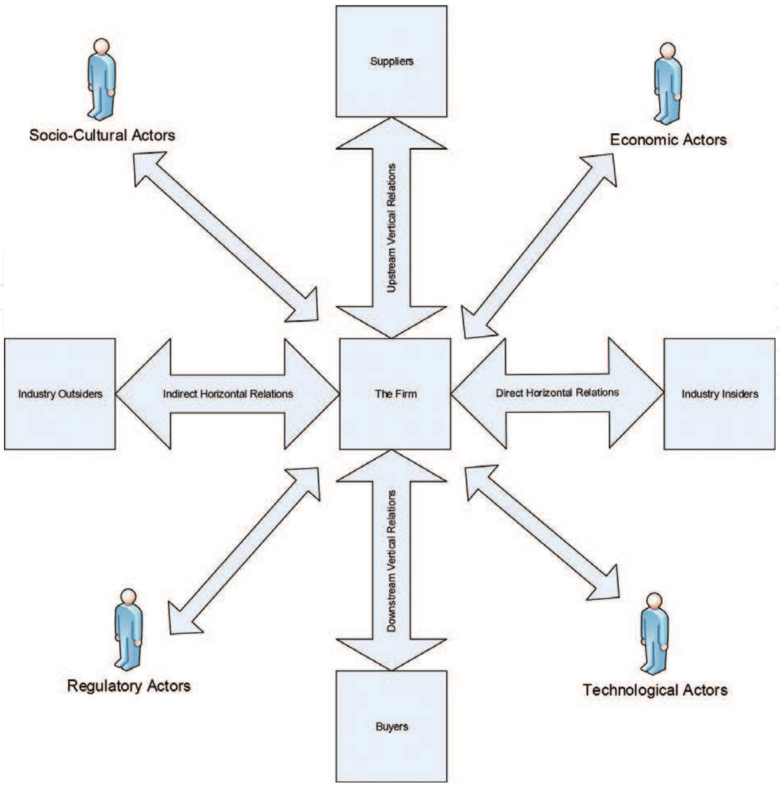


**Figure 5.** Network strategies to manage relationships.

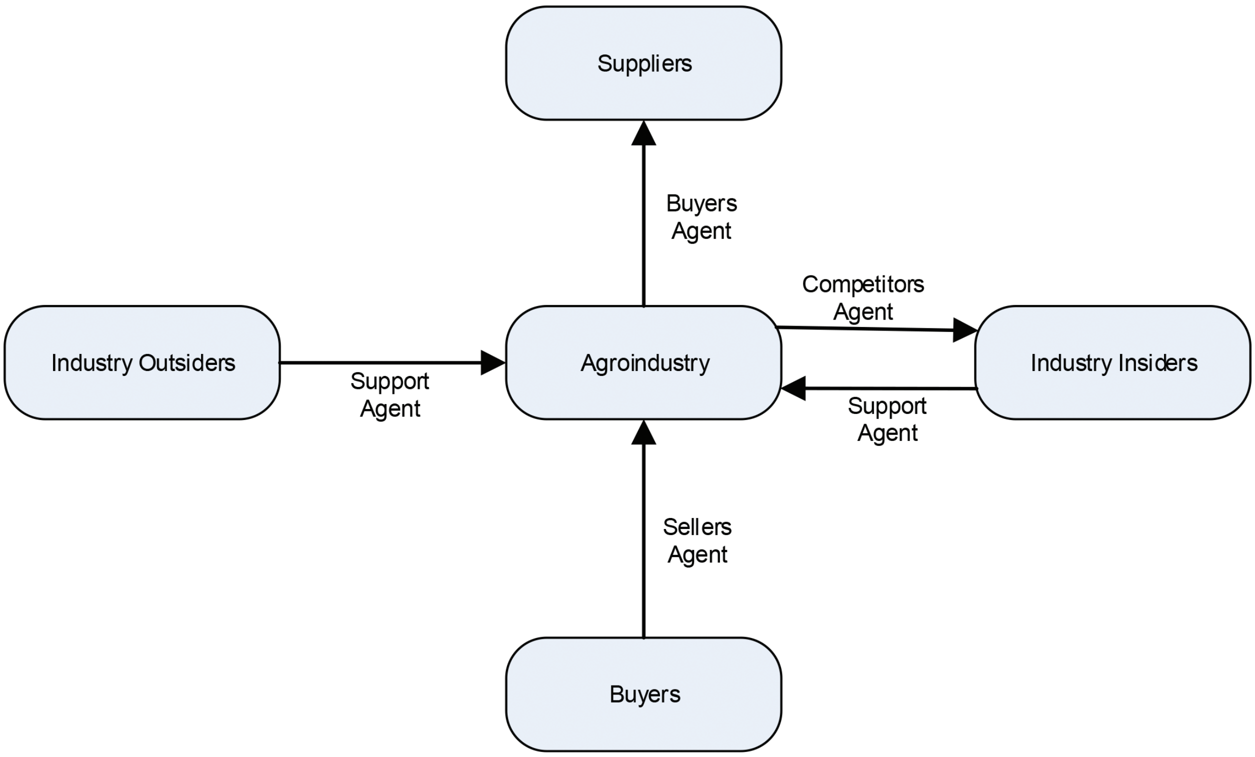


**Figure 6.** Network strategy based on four-agent information.

## 4. Forest fire model

This model starts with uncontrolled tree growth. After some time, lightning strikes will start fire. The fire will spread, destroying trees in large patches. Simultaneously, in the event of a fire, new trees will grow up again. If we have a probability of growth p and a fire probability q set at appropriate levels, we can see a growing group of trees and a burning group of trees, otherwise we just get a random distribution of empty, tree, and burning cells.

Forest fire model is the probabilistic cellular automata forest fire models follow the rules imitated from the phenomenon of forest fires and their growth. The rules built on probabilistic cellular automata forest fire models are as follows [12]:

1. A burning tree causes the area to become empty.
2. A tree becomes a burning tree if at least one of its nearest neighbors is on fire.
3. In the blank area, a tree grows with probability p.
4. A tree with the nearest non-burning neighbors becomes a burning tree with probability f.

### 4.1. Implementation forest fire model in serious game real time gross settlement (RTGS)

This model adopts the decentralization paradigm for modeling activity network system. The principal component of this system are adaptive agents consisting of five agents that are saving agent, reserves agent, loan agent, deposit agent and money transfer agent. Saving agents are in charge of finding and distributing the information needed in order to make the decision to save to another bank based on the health analysis of both banks so as to get the optimal profit. Reserves agents are tasked to find and share information related to the decision to take the reserve money in other banks based on the health analysis of two banks in order to obtain optimal benefits. Loan agents are responsible for finding and sharing information related to the profits to lend money to other banks based on the health analysis of two banks. Money transfer agents give information concerning advantage that applies the deposit in central bank. Deposit agents have the duty to seek and share information about the profits when borrowing money from other banks based on the health analysis of two banks.

Based on information obtained from these five agents, the decision impacts the value of net worth (NW): increased, decreased or permanent (does not form networks). The NW of a bank if it does not declare bankruptcy is the value of its assets (A), initial reserve holding (M) and payment due from other banks (DF) minus its liabilities initial level of deposits (C) and payment due to other banks (DT) as shown in Eq. (1) [13].

$$\mathrm{NW} = \mathrm{A} + \mathrm{DF} + \mathrm{M} - \mathrm{C} - \mathrm{DT} \tag{1}$$

Note that NW at time zero is NW0 = A − C, which we assume to be positive. If a bank declares bankruptcy, its net worth is given by $\alpha$ times its assets, minus $\alpha$ times its deposit liabilities, minus $\beta$ times its interbank liabilities or net due ND = DT − DF as shown in Eq. (2) [13].

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$$\mathrm{NW} = \alpha(\text{asset}) - \alpha(\text{deposit}) - \beta(\text{net due} - \text{tos}) \tag{2}$$

$$\mathrm{NW} = \alpha(\mathrm{A} - \mathrm{C}) - \beta(\mathrm{ND}) \tag{3}$$

$\alpha$ and $\beta$ values are in range $1 > \alpha > \beta > 0$. In other words, the cost of bankruptcy procedures reduces the value of bank's assets, but the bank also transfers the priorities of other banks participating in the payment network. Based on this assumption, bankruptcy punishes the holders of interbank claims disproportionately, implying that bankruptcy occurs in banks with large net debt positions compared to the capital they have.

In the RTGS system, the net worth of the bank at any point during the day is the difference between the original net worth and the value of liquidity penalty paid for the reserves throughout the day. Recall that the amount of reserves purchased at time t is given by L(t). Thus, the total liquidation paid at time t is given as shown in Eq. (4):

$$\pi(\mathrm{t}) = \alpha \max \mathrm{L}(\mathrm{t}) – \mathrm{A1} \tag{4}$$

A1 is the asset value held as a bond. Based on this equation, if the liquidation of assets exceeds the value of A1, then the loan must be liquidated by reducing the loss and net worth of the bank. The NW at time t is shown in Eq. (5):

$$\mathrm{NW}(\mathrm{t}) = \mathrm{A} - \mathrm{C} - \pi(\mathrm{t}) \tag{5}$$

Bankruptcy occurs when NW(t) moves toward a value of zero, this bankrupt condition can be modeled in the form of a mathematical equation like in Eq. (6) [13].

$$\mathrm{L}(\mathrm{t}) = \mathrm{L}^{*} = \lambda - 1\ (\mathrm{A}–\mathrm{C}) + \mathrm{A1} \tag{6}$$

NW(t) is assumed to be impossible not to increase. With this assumption, it is unlikely that a bank with a zero net worth can be bailed out of bankruptcy. If the asset value is considered stochastic, then the analysis made will be more complicated as it should proceed with the values of the options it has.

At an early stage or at each step, the participant bank (the cell as shown in **Figure 7**) has a certain NW value. Banks that will carry out the settlement process, forming a network with other neighboring banks to meet the settlement process with forest fire model [14] as shown in **Figures 8–11**.

**Figure 7** shows the starting position with eight banks that will perform the settlement process with positions at (x, y) = (1, 7), (2, 7), (3, 7), (4, 7), (5, 7), (6, 7), (7, 7), (8, 7), and (6, 5). The next step is viewed from one bank with position (6, 5), as shown in **Figure 8**.

**Figure 8** shows the second step of the bank performing the settlement process with the position (6, 5) distributing the energy (funds) to the neighbor bank in positions (5, 4), (5, 5), (5, 6), (6, 4), (6, 6), (7, 4), (7, 5), (7, 6). Step 3 is shown in **Figure 9**.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2 | 2 | 1 | 2 | 2 | 1 | 2 | 2 | 2 | 2 |
| 2 | 1 | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 2 |
| 1 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 1 |
| 1 | 2 | 1 | 1 | 2 | 1 | 2 | 1 | 2 | 2 |
| 2 | 1 | 2 | 2 | 1 | 2 | 3 | 2 | 1 | 1 |
| 2 | 2 | 1 | 2 | 2 | 1 | 2 | 2 | 2 | 2 |
| 1 | 1 | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 2 |
| 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 |
| 1 | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 2 | 1 |
| 2 | 1 | 2 | 2 | 1 | 2 | 2 | 2 | 1 | 1 |

**Figure 7.** Settlement process using forest fire model in 1st step.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2 | 2 | 1 | 2 | 2 | 1 | 2 | 2 | 2 | 2 |
| 2 | 1 | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 2 |
| 1 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 1 |
| 1 | 2 | 1 | 1 | 2 | 1 | 2 | 1 | 2 | 2 |
| 2 | 1 | 2 | 2 | 1 | 2 | 3 | 2 | 1 | 1 |
| 2 | 2 | 1 | 2 | 2 | 1 | 2 | 2 | 2 | 2 |
| 1 | 1 | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 2 |
| 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 |
| 1 | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 2 | 1 |
| 2 | 1 | 2 | 2 | 1 | 2 | 2 | 2 | 1 | 1 |

**Figure 8.** Settlement process using forest fire model in second step.

**Figure 9** shows the third step of the settlement-holding bank with position (6, 5) proceeding to distribute energy (funds) to the second tier bank level (4, 3), (4, 4), (4, 5), (4, 6), (5, 3), (6, 3), (7, 3), (8, 3), (8, 4), (8, 5), and (8, 6). The energy distribution (funds) should also be in the banks with positions (4, 7), (5, 7), (6, 7), (7, 7), and (8, 7), but banks with those positions while doing the settlement.

**Figure 10** shows the fourth step of a bank that performs a settlement process with position (6, 5) proceeding to distribute energy (funds) to third tier bank level with position (3, 2), (3, 3), (3, 4) (3, 5), (3, 6), (4, 2), (5, 2), (6, 2), (7, 2), (8, 2), (9, 2), (9, 3), (9, 4), (9, 5), (9, 6), and (9, 7). The distribution of energy (funds) cannot pass through the banks with positions (3, 7), (4, 7), (5, 7), (6, 7), (7, 7), and (8, 7) settlement. Step 5 is shown in **Figure 11**.

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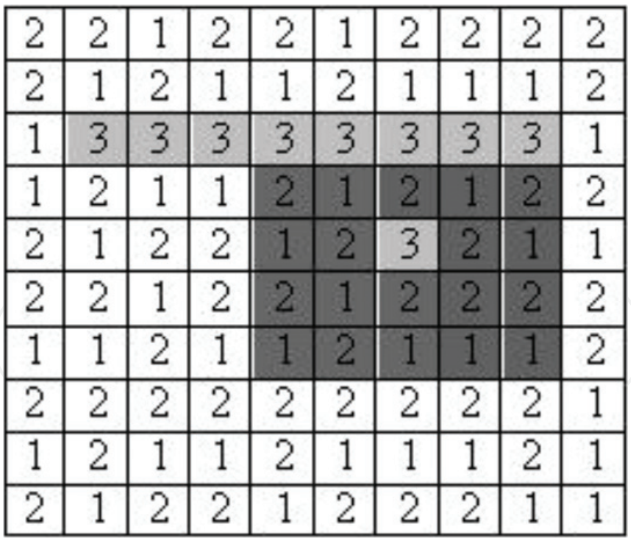


**Figure 9.** Settlement process using forest fire model in third step.

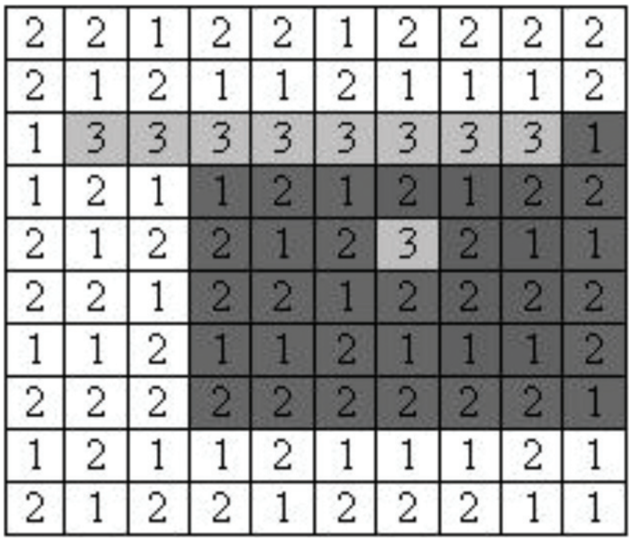


**Figure 10.** Settlement process using forest fire model in fourth step.

**Figure 11** shows the fifth step of the bank performing the settlement process with position (6, 5) proceeding to distribute energy (funds) to the fourth tier bank position (2, 1), (2, 2), (2, 3), (2, 4), (2, 5), (2, 6), (3, 1), (4, 1), (5, 1), (6, 1), (7, 1), (8, 1), (9, 1), and (9, 8). The energy distribution (fund) cannot pass the bank in positions (2, 7), (3, 7), (4, 7), (5, 7), (6, 7), (7, 7), and (8, 7) who is doing the settlement process.

### 4.2. Implementation forest fire model in serious game supply chain management agroindustry

The physical environment of cellular automata (CA) is the universe of the CA that is computed. The physical environment of CA consists of a discrete lattice of cells. In this part, the physical environment of CA represents the part of supply chain management system that

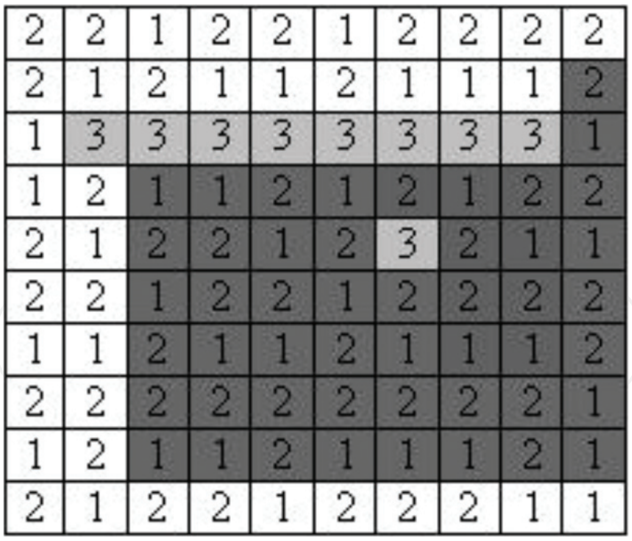

**Figure 11.** Settlement process using forest fire model in fifth step.

manages the buying and selling of tobacco between farmers and cigarette factory. The cells represent the cigarette factory that requires tobacco for the production process. Each cell can be in certain circumstances, and these cells represent the state of cigarette factory conditions. The position of the cigarette factory has four possibilities, namely: a potential to buy, a potential to not buy, position being bought, and positions have been bought.

For each cell representing the tobacco companies, the environment that consists of several tobacco companies that locally determine the evolution of the cell influences the SCM system. Environment consists of the cell itself plus the adjacent cell. In CA cell, there are some cells, for example, with a radius of 1; in addition to the cell itself, there are four cells again located on north, east, south, and west adjacent cells (von Neumann neighborhood), or the previous five cells as well as the four north-east, south-east, south-west, and north-west diagonal cells.

The rule of stochastic CA model acts on tobacco companies and their immediate neighborhood so that the cell's state changes from one discrete time step to another (i.e., system iteration). CA evolves in space and time as the rules are then applied to all cells in parallel. The evolution of CA regulations can use a deterministic or stochastic model. In this model, using the stochastic evolution model of CA because the next step is not only determined by neighboring cells but also by the results of previous processes.

The state of a cell (i, j) at the time t, can assume four values: (0) represents the "potential to buy", (1) represents the "potential for not buy", (2) represents the "being bought", (3) represents the "have been bought" [15]. The transition rules are:

$$
\begin{aligned}
&\textit{if } Nb < 1, \textit{then} < n\ (0) \rightarrow (0)\\
&\textit{if } Nb \geq 1\\
&\textit{Then} \quad (0) \rightarrow (2) \text{ with probability p}\\
&(1) \rightarrow (1)\\
&(2) \rightarrow (3) \text{ after a time step}\\
&(3) \rightarrow (3)
\end{aligned}
\tag{7}
$$

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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Figure 12.** Management of SCM using forest fire model in first step.

The result of the previous process is: Cigarette Factory (C1), position (3, 7), is "being bought." This factory buys tobacco (T4) with NP 4.7. If there is excess tobacco, then it will be offered at the cigarette factory neighbors SCM members who require tobacco with similar qualities to profile rank 1 on its needs. Cigarette Factory (C2), position (7, 5), is "being bought." This factory buys tobacco (T3) with NP 4.9. If there is excess tobacco, then it will be offered at the cigarette factory neighbors SCM members who require tobacco with similar qualities to profile rank 1 on its needs. Cigarette Factory (C3), position (1, 4), is "being bought." This factory buys tobacco (T2) with NP 4.6. If there is excess tobacco, then it will be offered at the cigarette factory neighbors SCM members who require tobacco with similar qualities to profile rank 1 on its needs. Cigarette Factory (C4), position (4, 2), is "being bought." This factory buys tobacco (T9) with NP 4.75. If there is excess tobacco, then it will be offered at the cigarette factory neighbors SCM members who require tobacco with similar qualities to profile rank 1 on its needs. The Cigarette Factories (C1, C2, C3 and C4) are shown in **Figure 12**.

**Figure 13** shows the second step. The cigarette factories (position (3, 7), (7, 5), (1, 4) and (4, 2)) who make purchases distribute energy (tobacco farmers) to the cigarette industry neighbors. Cigarette factory (position (3, 7)) distributes to the cigarette factory with the position (2, 6), (2, 7), (2, 8), (3, 6), (3, 8), (4, 6), (4, 7), (4, 8). Cigarette factory (position (7, 5)) distributes to the cigarette factories that position (6, 4), (6, 5), (6, 6), (7, 4), (7, 6), (8, 4), (8, 5), (8, 6). Cigarette factory (position (1, 4)) distributes to the cigarette factories that position (0, 3), (0, 4), (0, 5), (1, 3), (1, 5), (2, 3), (2, 4) and (2, 5). Cigarette factory (position (4, 2)) distributes to the cigarette factories that position (3, 1), (3, 2), (3, 3), (4, 1), (4, 3), (5, 1), (5, 2), (5, 3).

Step 3 starts going competition between tobacco farmers to offer their crops at a cigarette factory that has not made a purchase. In case it is considered that the price of fresh tobacco in accordance with the hierarchy of tobacco companies obtain tobacco first so C1, C2, C3, and C4 so the market that occurred in SCM as shown in **Figure 14** as well as for competition that occurs in the fourth phase as shown in **Figure 15**.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 2 | 3 | 2 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 2 | 2 | 2 | 0 | 2 | 2 | 2 | 0 |
| 2 | 2 | 2 | 0 | 0 | 0 | 2 | 3 | 2 | 0 |
| 2 | 3 | 2 | 0 | 0 | 0 | 2 | 2 | 2 | 0 |
| 2 | 2 | 2 | 2 | 2 | 2 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 2 | 3 | 2 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 2 | 2 | 2 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Figure 13.** Management of SCM using forest fire model in second step.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 2 | 2 | 2 | 2 | 2 | 0 | 0 | 0 | 0 |
| 0 | 2 | 3 | 3 | 3 | 2 | 0 | 0 | 0 | 0 |
| 0 | 2 | 3 | 3 | 3 | p2 | 2 | 2 | 2 | 2 |
| 2 | p2 | 3 | 3 | 3 | p2 | 3 | 3 | 3 | 2 |
| 3 | 3 | 3 | p2 | p2 | p2 | 3 | 3 | 3 | 2 |
| 3 | 3 | 3 | p2 | p2 | p2 | 3 | 3 | 3 | 2 |
| 3 | 3 | 3 | 3 | 3 | 3 | p2 | 2 | 2 | 2 |
| 2 | 2 | p2 | 3 | 3 | 3 | 2 | 0 | 0 | 0 |
| 0 | 0 | 2 | 3 | 3 | 3 | 2 | 0 | 0 | 0 |
| 0 | 0 | 2 | 2 | 2 | 2 | 2 | 0 | 0 | 0 |

**Figure 14.** Management of SCM using forest fire model in third step.

Stock condition that simulated using serious game SCM using concept as discussed above can be shown as in **Figure 5**. Stock condition in **Figure 5** shows that the supply of tobacco from tobacco farmers to cigarette factories C1, C2 and C3 in stages.

### 4.3. The result of forest fire model in serious game real time gross settlement (RTGS)

Cells in this model represent banks that can be in three positions: (1) not forming a network for the settlement process that causes the net worth value does not change; (2) the value of net worth is decrease that influenced by saving agent and loan agent greater than other agent; (3)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2 | 3 | 3 | 3 | 3 | 3 | 2 | 0 | 0 | 0 |
| p2 | 3 | 3 | 3 | 3 | 3 | p2 | 2 | 2 | 2 |
| 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 3 | 3 | 3 | 3 | 3 | 3 | 3 | p2 | 2 | 2 |
| 2 | p2 | 3 | 3 | 3 | 3 | 3 | 2 | 0 | 0 |
| 0 | 2 | 3 | 3 | 3 | 3 | 3 | 2 | 0 | 0 |

**Figure 15.** Management of SCM using forest fire model in fourth step.

the value of net worth is increase that influenced if deposit agent and reverse agent. Banks will only be in position 2 for one time round, after being in position 2 they will only be in position 3. Bank in position 3 cannot return. Each round consists of a bank analysis at position 2 to see if the bank will relate to its neighbors. The systematic way to analyze the cell will begin at the peak and then the process goes again clockwise around, the tested cell once again randomly generated to run the model with the specified probability.

Behavior of agents with varying probability values indicates that agent that affects net worth increases, agent that affects net worth decreases and the agent not form a network with probability 0.1 in the same time has a range of 90% as shown in **Figure 16**.

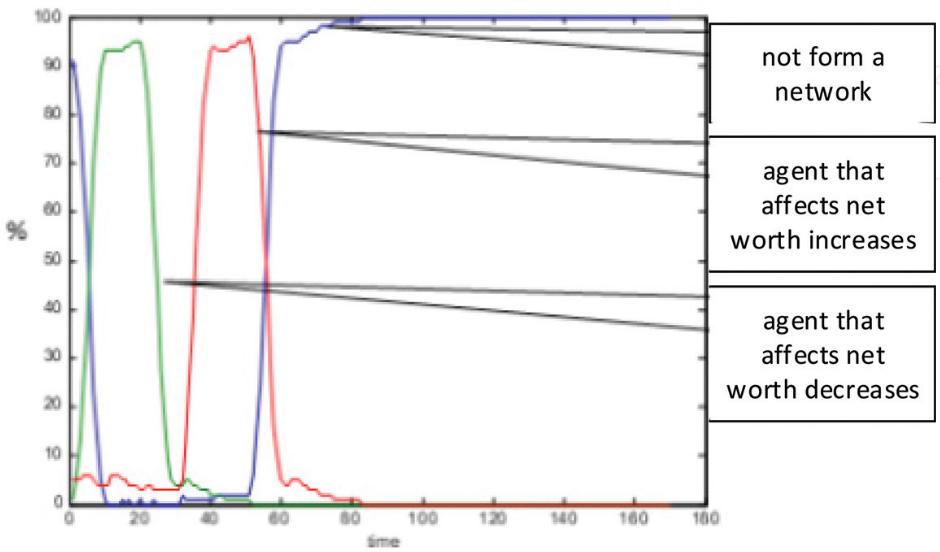


**Figure 16.** Behavior of agent with probability 0.1.

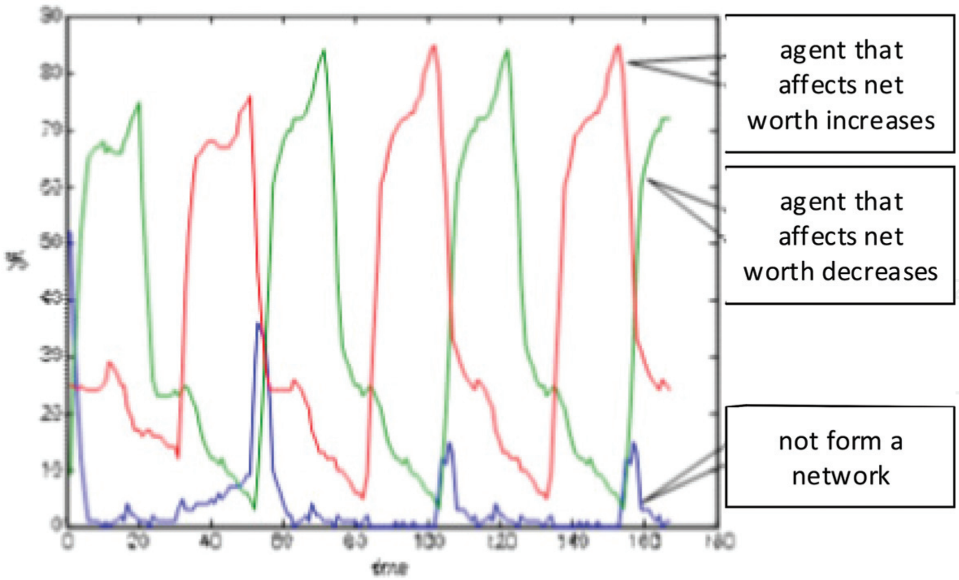


**Figure 17.** Behavior of agent with probability 0.5.

Agents that affect to increase the value of net worth and agents that affect to decrease the value of net worth with a probability 0.5 in the same time have a range of 60%. Agents that influence does not form networks with agents that affect to increase net worth and agents that affect to decrease net worth with a probability of 0.5 in the same time have a 35% range as shown in **Figure 17**.

Agents that affect to increase the value of net worth and agents that affect to decrease the value of net worth with a probability 0.7 in the same time have a range of 35%. Agents that influence does not form networks with agents that affect to increase net worth and agents that affect to decrease net worth with a probability of 0.7 in the same time have a 15% range as shown in **Figure 18**.

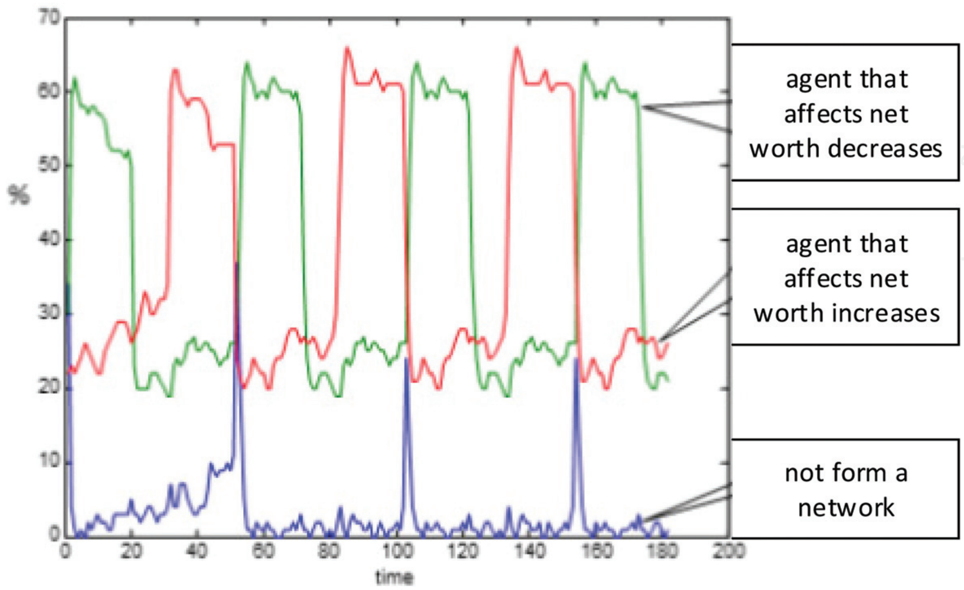


**Figure 18.** Behavior of agent with probability 0.7.

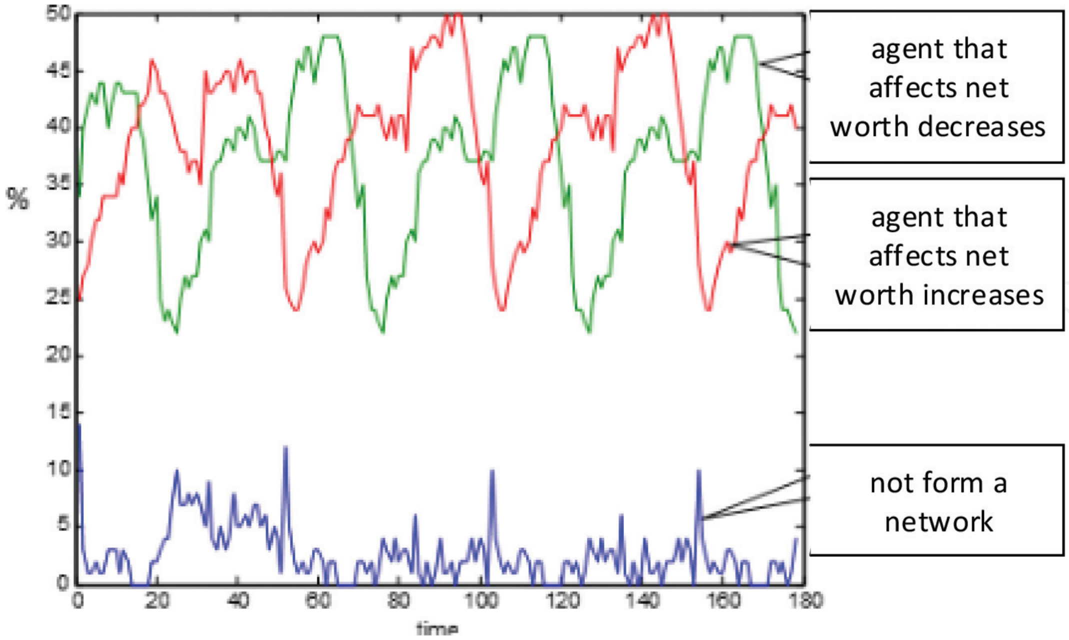


**Figure 19.** Behavior of agent with probability 0.9.

Agents that affect to increase the value of net worth and agents that affect to decrease the value of net worth with a probability of 0.9 in the same time have a range of 15%. Agents that influence does not form networks with agents that affect to increase net worth and agents that affect to decrease net worth with a probability of 0.9 in the same time have a 15% range as shown in **Figure 19**.

The flow of funds to the RTGS, particularly in the clearing house using the forest fire model, with a probability of 0.7 is shown in **Figure 20**.

**Figure 21** shows that using probability 0.7, the flow of funds ends at step t to 150 to keep the net worth value in the RTGS at a stable value.


**Figure 20.** The flow of funds in the settlement process.

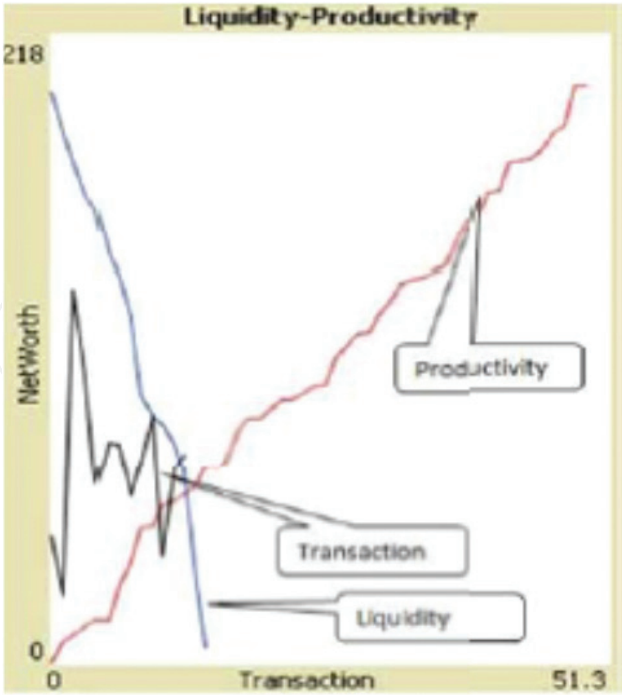


**Figure 21.** Efficiency in liquidity and productivity.

The efficiency of liquidity and productivity by using probability 0.7 with 15 banks transaction is shown in **Figure 21**.

### 4.4. Result of forest fire model in serious game supply chain management agroindustry

The intercompany network on supply chain management can be categorized as follows: (1) mutual independence, (2) unbalanced independence, (3) mutual dependence and (4) unbalanced dependence. The four networks formed are influenced by the capacity of companies that make up their networks and environments based on relational analysis of vertical, horizontal and other relationships as shown in **Figure 22**.

**Figure 22** shows that each condition requires different handling and strategies. In conditions with mutual dependence, categories requires a strategic approach by network management to maintain network balance. In conditions with the category of mutual independence, it is necessary to maintain a degree of independence rather than maintain network integrity. In conditions with the category of unbalanced dependence required a strategy approach to manage networks that can create balance. Conditions with the category of unbalanced independence need a strategy to strengthen the company's independence.

**Figure 22** shows that each condition requires different handling and strategies. In conditions with mutual dependence categories requires a strategic approach by network management to maintain network balance. In conditions with the category of mutual independence, it is necessary to maintain a degree of independence rather than maintaining network integrity.

http://dx.doi.org/10.5772/intechopen.72591

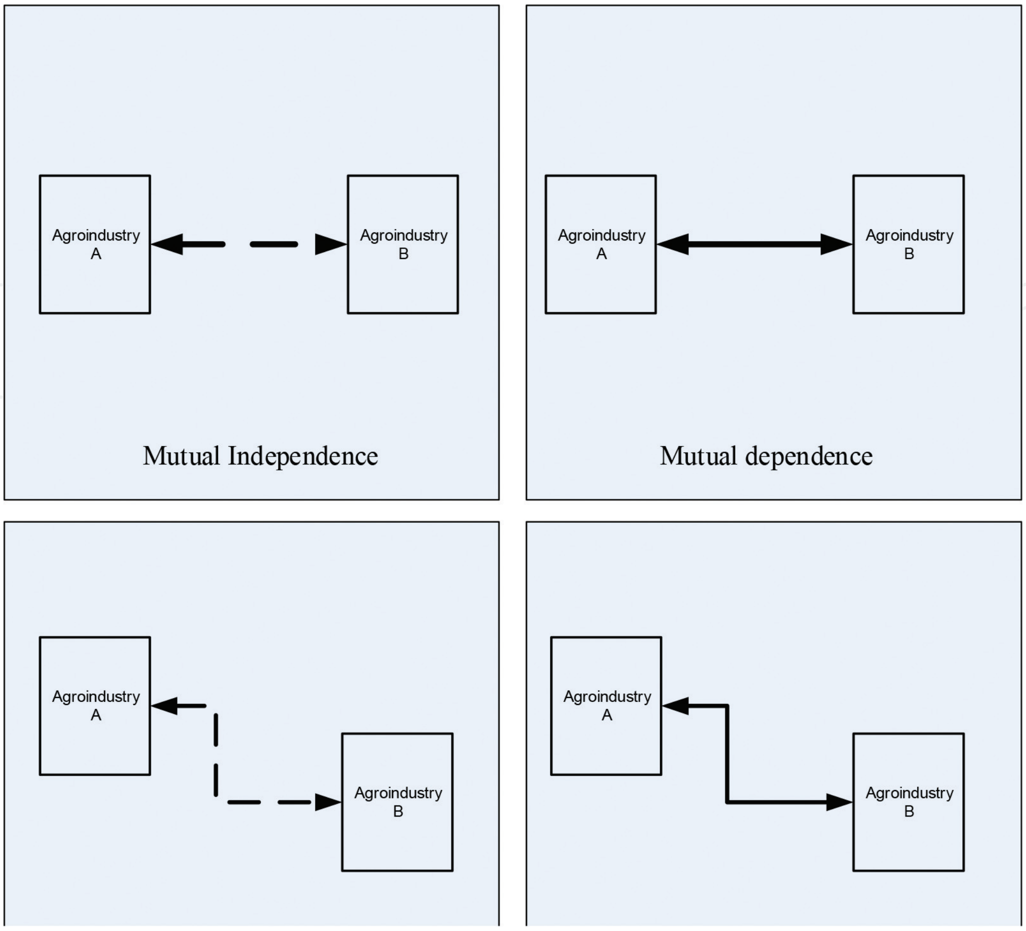


**Figure 22.** The probability of intercorporate network.

**Figure 22** shows that each condition requires different handling and strategies. In conditions with mutual dependence categories requires a strategic approach by network management to maintain network balance. In conditions with the category of mutual independence, it is necessary to maintain a degree of independence rather than maintain network integrity. In conditions with the category of unbalanced dependence required a strategy approach to manage networks that can create balance. Conditions with the category of unbalanced independence need a strategy to strengthen the company's independence. The four categories of networks between agribusiness management (mutual independence, unbalanced independence, mutual dependence, and unbalanced dependence) can be detected by using a serious game agribusiness management by first modeling agribusiness network management and modeling data related to the agribusiness network as in **Figure 23**.

The result of modeling in the form of a serious game shows that the condition of the interdependence represented by x values starts with drastic degradation from the initial value close to a stable value that is in the range of value 0. This change of data gives an overview to agribusiness management to perform a strategy that can depress the network be balanced.

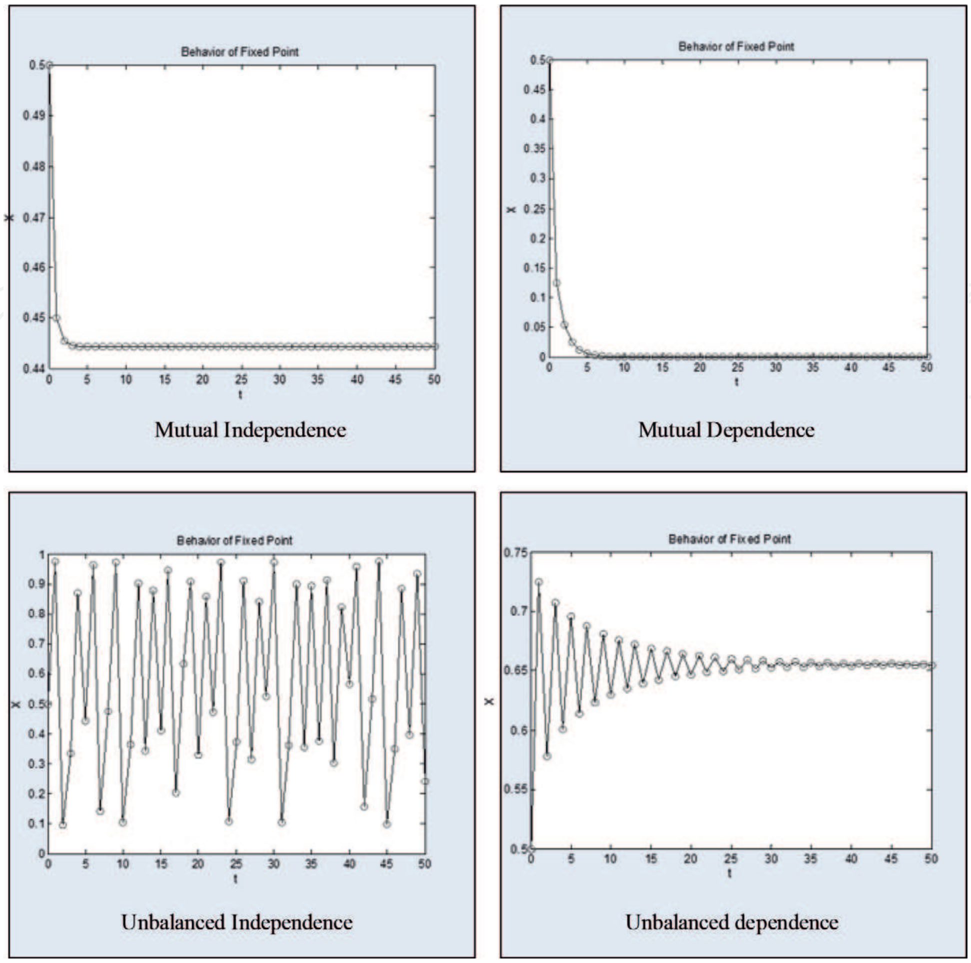


**Figure 23.** The fourth condition of intercorporate network.

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