Development model on upstream-downstream integration of coffee agroindustry using dynamics modelling approach

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Abstract. Increasing the competitiveness of the coffee agro-industry requires integration from upstream to downstream. The problems faced by Lumajang coffee farmers are in increasing production; the limited coffee supply is not proportional to the high demand. Besides, the quality of the coffee produced is good but has not been processed properly. This research is expected to improve the performance of the coffee agroindustry in the Lumajang Regency and strengthen the institutional integration of the upstream-downstream coffee agroindustry in Lumajang. The dynamic system methodology is considered to be able to solve existing problems; the ability of dynamic systems to recognize variables and to show the influence of the relationship between the overall system behaviour in a model. The results obtained are conceptual models Causal Loop Diagram (CLD) as an effort to solve problems. It is made based on key variables to build the right dynamic system. The CLD model of upstream and downstream coffee agroindustry integration in the Lumajang Regency consists of 3 sub-models, namely the sub-model of production, quality, and agroindustry institutions.

1. Introduction
The agricultural sector has an important role in economic activity in Indonesia. The contribution to the Gross Domestic Product (GDP) is around 13.14 percent in 2017. The contribution of the plantation sub-sector is around 3.47 percent in 2017. Coffee is a plantation commodity product that has a high economic value and plays an important role as a source of foreign exchange [1]. Coffee is a plant species that belongs to the Rubiaceae family and the Coffea genus. Indonesia is the third-largest coffee producer in the world, based on data from the Indonesian Coffee Festival (ICF). Indonesia produces coffee with the proportion of robusta by 85% and arabica by 15%. [2]. This is supported by the growth consumption of processed coffee products in the country increased by an average of 7.5% per year. East Java ranks as the fifth-largest coffee-producing province at 9.73% after South Sumatra, Lampung, Aceh, and North Sumatra [3].

The coffee agro-industry consists of several actors ranging from farmers, middlemen, large traders, and the coffee processing industry. In the supply chain, the involvement of other parties in the flow of goods/services and information is important for the availability of goods/services for consumers [4].
The complexity and high linkages of the supply chain network make it more vulnerable to problems [4,5]. Based on previous research in identifying and mitigating risks in the coffee agro-industry, the risks that often arise in the farming and processing sector are in the forms of production and institutional risks. The first step to identify agro-industrial supply chain risks is to map the characteristics and sources of risk that trigger supply chain performance [6]. The production risk indicates a lack of standard operating procedures for planting and processing coffee beans. The institutional risk was identified by the lack of a strong integrated relationship in the coffee agro-industry to support the market demand fulfillment. Institutions play an important role that is to bridge the role of the supply chain structure in an integrated manner from upstream to downstream [7]. Institutions must be able to become a forum for equitable access to factor inputs to achieve efficiency and effectiveness in resource management [8]. The key to success in the supply chain for agricultural commodities is to be able to apply key success factors (trust building, coordination, cooperation, and government support) as a foundation in the institution [9].

The integration from upstream to downstream is analyzed from the flow of agricultural commodities from the upstream to the downstream process subsystem [10]. Integrated means the business linkages upstream and downstream (vertical integration) synergistically and productively, and there are links between regions, between sectors, and even between commodities [11]. Supply integration is demonstrated by reliable suppliers [12]. The support of harmonized upstream-downstream policies is expected to create a conducive business climate, increase productivity, quality, and continuity of coffee production, increase the volume and quality production of the coffee processing industry [13]. The basis of integration is characterized by cooperation, collaboration, information sharing, trust, partnership, technology deployment, a shift from individual processes to integrated chain [14, 15, 16].

The development of upstream-downstream integration of the coffee agro-industry is carried out by simulating the system in a model based on the recommended risk mitigation [17]. System dynamics is used as an analytical tool in this study to determine the variables in the coffee agroindustry to be directed towards sustainable development. Dynamics systems are very useful for formulating future policies for conducting business in complex environments over time. Dynamics system models are used to understand the causes of industrial behavior, detect early changes in agro-industry, estimate system performance, provide alternative policy scenarios and serve as a reference for improving long-term performance [18]. There are two ways to analyze the dynamics system: first, the causal loop diagram (CLD) and second, the stock-flow diagram (SFD). CLD can be used to show the relationship between different variables using a feedback loop [19].

The general objective of this study are to determine the system modeling for the development of upstream-downstream integration of the coffee agro-industry in East Java and to determine the variables that affect the development of upstream-downstream integration of the coffee agro-industry in East Java, especially Pasrujambe, Lumajang Regency. Furthermore, the specific objectives are to (1) determine the variables that affect the development of upstream-downstream integration of the coffee agroindustry, (2) improve the performance of the coffee agroindustry.

2. Materials and methods

In this study, a dynamic system method was used to determine the development model for integrating upstream-downstream coffee agroindustry using dynamics system approaches. This research was conducted in Pasrujambe, Lumajang Regency. Dynamics system is modeling the system in agro-industry with the addition of formulations to make it easier to simulate the policies that need to be done. This dynamic system methodology is based on the ability of the dynamics system to recognize the elements and relationships between variables in a system and show the effect of the overall relationship in a model. Dynamics system interprets the real system into a computer simulation model that simulates how the structure and policy decision making in the system [20]. The stages in dynamics system modeling are: (1) identification of problems, (2) identification of variables and determination of modeling variables, (3) compile a conceptual model, (4) compile a causal loop diagram (CLD).
2.1 Identification of problems
Problem identification is carried out based on problems in the upstream and downstream supply chain of the coffee agroindustry in the Pasrujambe District, Lumajang Regency. Lumajang coffee farmers often face the problem of increasing production since the limited coffee supply is not proportional to the high demand. Though the quality of the coffee produced is good, but it has not been processed properly. Therefore, there is a need for integration between upstream and downstream to improve coffee quality and productivity to meet consumer demand, both locally and globally.

2.2 Identification of variables and determination of modeling variables
The identification of variables is carried out based on the relationship between actors in the upstream and downstream supply chain of the coffee agroindustry in Lumajang Regency. The variables that affect the system will be identified. Variable identification is obtained based on secondary data and first-year reports. The actors in the upstream and downstream supply chain of the coffee agroindustry are farmers, middlemen, large collectors, processing industries, and end consumers. There are three sub-models in system dynamics, and these three sub-models are in the form of a production sub-model, a quality sub-model, and an institutional sub-model. Each sub-model consists of variables and constants that make up the model. The production, the quality, and the agro-industry institutional sub-models consist of 16, 29, and 27 variables, respectively. The variable written in the causal loop diagram is variable in general as an illustration to form a model.

2.3 Construct a conceptual model
The conceptualization of a model is a concept formation process that is expected to describe the real situation and explain the variables involved in the upstream and downstream supply chain of the coffee agro-industry. The first step that must be taken is the identification of the components or variables involved in modeling. The conceptual model is made to determine variables that affect the production, quality, and institutionalization of the coffee agro-industry. This model’s conceptualization makes it easy for readers to bring up a deeper understanding of the system [21]. Conceptual model design is carried out through a literature study and previous research. The development of the model used Vensim 7.2 software.

2.4 Construct causal loop diagram

![Causal Loop Diagram](image)

Figure 1. (a) Regular CLD arrow shape, (b) Circle CLD arrow shape (reinforcing feedback loop) and (c) Circle CLD arrow shape (balancing feedback loop).

The conceptual model variables are searched for their interrelationships with each other using the causal loop diagram method. CLD is based on variables that affect and are influenced, building a dynamic system with information feedback theory (redundant). The causal loop diagram is excellent for (1) capturing hypotheses about the causes of dynamics, (2) capturing the individual/group model, (3) communicating feedback as responsible for a problem [22]. The arrow shape of the CLD is shown in Figure 1. Figure 1 showed that the variable in CLD is placed on the tail of the arrow (A) will affect the variable on the arrowhead (B). It is given a "+" sign if the two variables have a positive effect on each
other (unidirectional correlation) and a "-" sign is given if the two variables have a negative effect on each other (opposite correlation).

3. Results and Discussion

3.1 Dynamics system modeling

This section outlines the conceptual model of the dynamic system of integration upstream and downstream of the coffee agroindustry in the Lumajang Regency, especially the Pasrujambe District. The conceptualization of the model is by making the causal loop diagram show the causal relationship of the variables. This section describes the supply chain consisting of farmers, processing agroindustry, middlemen, and consumers have been assumed as follows is shown in Figure 2.

![Figure 2. Supply chain in the dynamic system model of Lumajang Regency.](image)

In the dynamic system conceptual model, the area of coffee land is influenced by the rate of extensification and the rate of conservation. Coffee production is influenced by the amount of productivity, land area, and agroindustrial institutions. Coffee production will affect the amount of coffee bean supply. Coffee bean supply is divided into processing agroindustry and direct selling by farmers. Furthermore, coffee bean processing techniques will affect defects and storage. The existing defects will affect every processing of coffee beans and affect the quality of coffee beans according to the specified quality specifications. The storage of coffee beans is classified into green beans and roasted coffee beans. Total sales of green beans and roasted coffee beans have been assumed. Selling green beans and roasted coffee beans will influence consumers (exporters, retail and café industries) and influence agro-industrial institutions (farmers, middlemen, large collectors, and processing industries). A large number of processing agroindustries, quality, consumers, and agro-industrial institutions will affect coffee demand. The CLD consists of three sub-models that are production, quality, and institutional sub-models. The production sub-model is formed from the extensification rate, conservation rate, land area, coffee production, productivity, supply, demand, production costs, sales, and profits. The quality sub-model is formed from agro-industrial processing, processing techniques, defects, storage, quality, roasted coffee beans, and selling green beans. The institutional sub-model is formed from consumers and agro-industrial institutions.

3.2 Causal loop diagram

Causal loop diagram (CLD) is a mapping diagram that shows the causal relationship between variables with arrows from cause and effect [23]. The interactions between variables are depicted with arrows. The arrows on the causal loop diagram are marked (+) and (-) depending on the interaction between variables. The sign (+) is used for the interaction between two variables and has a unidirectional relationship, while the sign (-) is used for the interaction between two variables that have an opposite relationship with the characteristic red arrow. Based on the integration variables upstream and downstream of the coffee agro-industry in Lumajang District as presented in Figure 3.
Figure 3. Causal loop diagram of supply chain integration upstream and downstream of coffee agro-industry in Lumajang Regency.

The production sub-model is formed from the extensification rate, conservation rate, land area, coffee production, productivity, supply, demand, production costs, sales, and profits. The production sub-model consists of several loops. The first loop states the relationship between land area, extensification rate, and conservation rate. The higher the extensification rate, the higher the land area used for coffee cultivation. The higher the conservation rate, the lower the land area, and vice versa. The second loop is the relationship between productivity, coffee production, supply, and demand. Higher productivity will increase coffee production and coffee supply. Coffee production will increase along with the increased productivity and level of coffee supply. High demand also affects the level of coffee supply to a higher level. The third loop is sales, production costs, and profits. The higher the sales and the lower the production costs, the higher the profit. Likewise, the higher cost of coffee production, the lower the profit. Production costs increase along with the increase in handling and operational costs. Profits will decrease when production costs are greater than the sales value [24].

The quality sub-model is formed from processing agroindustry, processing techniques, defects, storage, quality, roasted coffee beans, and selling green beans. The first loop in the quality sub-model is a relationship between processing agro-industry, processing techniques, and storage. The high processing agro-industry will increase demand for coffee. The high demand for processing agro-industry improves processing techniques. The higher coffee beans are processed, affect more coffee beans are stored. The second loop states the relationship between defect processing techniques and quality. The effect of high processing techniques can increase the defect. When the defect of coffee beans is low, the resulting quality is high and conversely. The high quality will increase demand for coffee, so high-quality increases the number of selling green beans and roasted coffee beans. The third loop states the relationship between storage, selling green beans, and roasted coffee beans. The increased storage of coffee beans affects the high availability of selling green beans and roasted coffee beans, so this relationship is directly proportional.

The institutional sub-model is formed from consumers and agro-industrial institutions. This sub-model only consists of one loop it is between consumers, agro-industry institutions, and demand. The more consumers will affect the size of demand, and the demand increases the proportion to increasing consumer [25]. The increase of consumers (exporters, retail industry, and cafes) will increase industrial institutions, and increased industrial institutions increase demand for coffee beans. Furthermore, agro-
industrial institutions will affect coffee production; the increase of agro-industrial institutions will increase coffee production.

4. Conclusions
Dynamics system modeling with CLD is a systemic approach to the integration of the upstream-downstream coffee agroindustry in the Lumajang Regency, especially the Pasnujambe District, which consists of three sub-models, namely the sub-model of production, quality, and agro-industrial institutions. From the variables of the three subsections, it is used to determine system modelling and determine variables that affect the development of upstream-downstream integration of the coffee agroindustry in the Lumajang Regency, improve the performance of the coffee agro-industry and strengthen institutional integration the coffee agro-industry in Lumajang Regency. From the analysis of CLD sub-models, seven loops are consisting of four positive loops and three negative loops.

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