Permalink/DOI: http://dx.doi.org/10.17358/jma.15.3.268
Available online at http://journal.ipb.ac.id/index.php/jmagr
by Directorate General of Higher Education (DGHE), Republic of Indonesia No 30/E/KPT/2018

ADAPTATION BEHAVIOR OF MANGO FARMERS TO CLIMATE CHANGE

Dhany Esperanza [*)1], Gilangsari Putri [*)], Elly Rasmikayati[*)], Sara Qanti[*)], and Yuyun Yuwariah[*)]

[*)] Faculty of Agriculture, Universitas Padjadjaran
Jl. Raya Bandung Sumedang KM 21, Jatinangor 45363

Abstract: The continuing climate change phenomenon causes disruption to agricultural sector including seasonal fruits such as mangoes. To anticipate the negative effects of climate change, the farmers adapt themselves in order to maintain their mango farming. The dynamics of mango farmers related to the adaptation of agribusiness strategy due to climate change occur at the level of production/cultivation and marketing. The objectives of this study are to: (1) Identify the factors that influence the behavior of mango farmers' adaptation as an effort to minimize the risks due to climate change; (2) Describe the adaptation behavior of mango farmers based on interactions among the factors that influence the adaptation by using causal loop diagrams. The results showed that the adaptation behavior of mango farmers was constructed on 37 variables from 8 categories, namely, climate change, production, marketing, income, financing, productivity, information adoption, and innovation. Adaptation behavior of mango farmers to climate change arises not only as the farmers' effort to maintain the mango farming they run but also to maintain their lives. The use of growth regulator and pesticides are shortcuts taken by farmers to increase production without realizing the side effects that can arise and accumulate in the long term. The income variable is the leverage point of the behavior pattern that is reflected in the causal loop diagram. Small changes in income will cause major changes in the overall system described.

Keywords: climate change, mango farmer, system thinking, causal loop diagram, system archetypes

Abstrak: *Fenomena perubahan iklim yang terus berlangsung menyebabkan gangguan pada sektor pertanian termasuk pertanian buah musiman seperti mangga. Untuk mengantisipasi dampak negatif perubahan iklim, petani beradaptasi demi mempertahankan usaha taninya. Dinamika petani mangga terjadi pada tingkat produksi/budidaya dan pemasaran. Tujuan penelitian ini adalah (1) Mengidentifikasi faktor-faktor yang mempengaruhi perilaku adaptasi petani mangga sebagai upaya meminimalkan risiko akibat perubahan iklim; (2) Mendeskripsikan perilaku adaptasi petani mangga berdasarkan interaksi di antara faktor-faktor yang mempengaruhinya dengan menggunakan causal loop diagram. Hasil penelitian menunjukkan bahwa perilaku adaptasi petani mangga dibangun pada 37 variabel dari 8 kategori, yaitu perubahan iklim, produksi, pemasaran, pendapatan, pembiayaan, produktivitas, adopsi informasi, dan inovasi. Perilaku adaptasi petani mangga terhadap perubahan iklim tidak hanya muncul sebagai upaya untuk mempertahankan pertanian mangga yang mereka miliki, namun juga untuk mempertahankan kehidupan mereka. Penggunaan zat pengatur tumbuh dan pestisida adalah cara pintas yang ditempuh untuk meningkatkan produksi tanpa mengetahui efek samping yang dapat timbul dari akumulasi jangka panjang. Variabel pendapatan adalah leverage point dari pola perilaku yang tercermin dalam causal loop diagram. Perubahan kecil dalam pendapatan akan menyebabkan perubahan besar dalam keseluruhan sistem yang dijelaskan.*

Kata kunci: *perubahan iklim, petani mangga, system thinking, causal loop diagram, system archetypes*

[1] Corresponding author:
Email: dhany@unpad.ac.id

INTRODUCTION

Climate change has become the most important issue in the development of policy and global governance in the 21st century. Global warming over the last century has resulted in climate change that is very influential to the agricultural sector because this sector has a high dependence on climate conditions. Recent research on climate change has noted that it shows symptoms indicating a threat to the sustainability of food production in Indonesia (Natawidjaja, 2008) and in other countries over spread continents such as China (Wang, 2010; Li et al, 2010), America (Shen et al. 2010), Africa (Gommes, 1998) and Europe (Olesen and Bindi, 2002).

Indonesia is known as an agrarian archipelago country particularly because the agricultural sector still dominates the livelihoods of the people. In February 2017, the number of agricultural workers reached 36.91 million people or 29.67% of the total Indonesian workforce. This amount increased by 0.04% from February 2016 with the total agricultural workforce of 35.27 million people. The number of agricultural laborers in February 2017 was divided into four sub-sectors, namely food crops (48.87%), plantation (30.10%), livestock (11.31%), and horticulture (9.14%) (Hasanah, 2017).

Agriculture is one of the most vulnerable sectors of the economy which gives negative impacts in climate change. The vulnerability indicates that climate change poses a risk or uncertainty to the agricultural sector. Based on the data obtained from the monitoring conducted by the Ministry of Agriculture, Republic of Indonesia, during the period of 2000–2009, drought and flood tend to increase, with the average number of drought-affected agricultural land area of 303,641 hectares and unproductive land of 58,489 hectares or equivalent to 767,589 tons of dry milled grains (gabah kering giling - GKG). Meanwhile, the flooded area reached 271,381 hectares with unproductive land of 79,846 hectares (equivalent to 774,106 tons of milled grains. Furthermore, between 2000 and 2009, there was an average of 332 occurrences of major floods per year in Indonesia causing an average of 271,381 hectares of paddy fields and other agricultural land inundated.

Indonesia as a tropical region has uniqueness in weather and climate factor which makes Indonesia highly suitable as an agricultural country. This tropical and climate conditions make most of the Indonesian population depend on their lives as farmers. One of the agricultural commodities that has a large potential of climate compatibility and economic value to be developed in Indonesia is mango.

As a horticultural commodity, mango (Mangifera indica L.) is an annual national fruit commodity, taking position as the third largest production in Indonesia (BPS, 2018). At the world level, Indonesia is the sixth largest mango producing country (Sulistyowati, 2013). The mango commodity has the potential to improve the economic welfare of farmers' families because of its high economic value and important food for people living in tropical climates (Sulistyowati, 2013; Kencanaputra, 2014).

Mango is a national superior fruit that is in great demand by the community and has the potential to improve the welfare of the farm families because of its high economic value (Natawidjaja, 2009). For that reason, West Java Province has determined to make mango as a priority commodity for development with its potential mango central areas of Cirebon, Majalengka, and Indramayu (Sulistyowati and Rasmikayati, 2014).

Majalengka Regency is a mango central region with the third largest production in West Java Province after Indramayu and Cirebon Regencies. The average mango production in Majalengka Regency was 43,523.5 tons per year (2011–2016 period). The regency consists of twenty-six districts whereas in each of these districts there is spread of mango planting and harvest area. Panyingkiran District in Majalengka Regency has the highest mango production in almost every year reaching the highest production of 24,641 tons in 2015.

Mango planting area in Panyingkiran District increases every year at around 1,800 hectares, while the amount of production fluctuates significantly from year to year, with the lowest production of 479 tons in 2013. Climate, as one of the factors that greatly affect agriculture, has contributed to the trend of this fluctuating production of mangoes.

Climatic phenomena such as erratic weather, extreme rainfall, floods, long dry seasons and drought cause disruption to the agricultural sector including seasonal fruits such as mango farming. Rainfall will affect the growth of plants and the formation of flowers or fruit. The tolerable rainfall for mango plants ranges from

1,000 to 2,500 mm with a dry season of 4 to 6 months per year. If the rainfall is very low, mango farming should be irrigated. However, flowering and fruiting season mango plants do not need excessive rain, as high rainfall can inhibit the formation of fruits and cause diseases instead.

Rainfall during mango flowering season will result in: (1) emergence of injured and loss of flowers, (2) loss of pollen grains due to rainwater, (3) inhibition of flower pollination because pollinating insects become extremely lazy to fly, (4) bloom of fungi and leafhoppers on flowers and fruits due to humid air, and (5) failure of the harvesting process because of the many fruits and flowers that fall due to dew and fog.

In addition, high rainfall also causes disturbances to the soil environment where the plants grow, and it spurs the growth of pests and diseases of mango plants (Nirdayana, et al. 2011). Likewise, the longer dry season, although the mango plants require dry season as a season to bear fruit, in fact, disturbs the fruiting season. This is due to soaring pests and diseases of plants on the leaves, stems, roots and fruits. These things cause disruption to the fruiting season cycle which leads to disruption of mango production.

The important pests and diseases of mangoes include shoot borer, branch/stem borer, fruit fly, and leaf sucking ladybug, mango leafhopper, fruit borer, fruitminer caterpillar, leaf destroyer caterpillar, leaf nodule, anthracnose, skin disease, and angled black leaf spot (Puslitbanghorti, 2006). Rasmikayati (2013) found that climate change is risking farmers' income, but the mitigation behavior of mango farmers to anticipate the impacts has made them able to maintain the productivity and maintain their welfare.

This study aims to: (1) Identify the factors influencing adaptation behavior of mango farmers as an effort to minimize the risk due to climate change; and (2) Describe adaptation behavior of mango farmers based on the interaction between the influencing factors by using a causal loop diagram.

METHODS

The objective of this study is adaptation behavior of mango farmers in order to anticipate climate change. The research was conducted in Kecamatan Panyingkiran, Majalengka Regency. The location was chosen purposively, for Panyingkiran District has the highest mango production and widest harvesting area in Majalengka Regency. Based on this, it is assumed that mango farmers in Panyingkiran District have good adaptation behavior in tackling climate change. This research used qualitative design with data analysis process based on the use of system thinking by depicting causal loop diagram. The method used in this research was a case study.

The primary and secondary data were used in this study. The primary data were obtained directly by observing the subjects of the research i.e. the mango farmers in Panyingkiran District, Majalengka Regency while the secondary data were obtained through the readings or other literature.

The respondents were determined by using purposive sampling technique and their criteria were that they were mango farmers, owners of the land, cultivators, and owners and cultivators. The data were collected by triangulation technique, a data collection technique that combines existing various data collecting techniques and data sources that already exist. This technique was used to improve researchers' understanding on the phenomena found. This technique collects and tests the data credibility (Sugiyono, 2017).

Analysis Method

Data analysis is the process of searching and compiling data systematically. The data being analyzed were obtained from the field notes, interviews and documentation organized into categories, translated into units, synthesized, and arranged into patterns, thus forming conclusions easily understood by oneself and others (Sugiyono, 2017).

System Thinking

Sweeney and Sterman (2000), the writers and researchers in system thinking, argue that it involves the ability to represent and assess dynamic complexity. According to Sweeney & Sterman (2000) in Arnold & John (2015), system thinking includes the following specific capabilities: 1)Understanding how system behavior arises from interactions between agents over time (dynamic complexity); 2) Finding and representing feedback processes (both positive and negative) that are hypothesized to underlie the system behavior patterns being observed; 3) Identifying the relationship of stock and flow; 4) Recognizing delay and understanding the consequences; 5) Identifying nonlinearity; 6) Recognizing and challenging the limitations of mental (and formal) models.

Rich Picture Diagram

Depicting rich picture is something that the researcher must do when revealing the problem situation, and this is the second stage of the Soft System Methodology (SSM) process (Checkland, 1975 in Bronte-Stewart, 1999). SSM is another approach of system thinking based on the idea that human and organizational factors cannot be separated from problem solving and decision-making (Pidd, 1996 in Cavana & Kambiz, 2007).

Rich picture diagram is created by representing a problem situation into an image diagram as richly as possible that can be collected in the time available. This image diagram can be a useful alternative to briefly describe problem situations to third party (Darzentas, 1994 in Bronte-Stewart, 1999).

Qualitative Descriptive Analysis

Qualitative descriptive analysis was carried out to find out the adaptation behavior of mango farmers in Panyingkiran District due to climate change. The steps in analyzing the data are as follows (Miles & Huberman in Sugiyono, 2017).

1) Data reduction

Data reduction is a process of summarizing information, choosing and focusing on the important things and looking for themes and patterns from the data obtained. Data reduction serves to provide a clearer picture and focus, and facilitate researchers in organizing or managing research results.

2) Data Presentation

Data presentation in qualitative research can be in the form of brief descriptions, charts, relationships between categories, flowcharts and the like. Data presentation serves to facilitate in understanding the event or information obtained.

3) Conclusion Withdrawal

Conclusion withdrawal is the last step in qualitative descriptive analysis where verification is also carried out. The conclusions may change or remain the same with the initial conclusions, depending on the data obtained during the study.

Analysis of Cause and Effect Model

Re-identification of factors that have a causal relationship in describing the adoption of mango farmers innovation as a form of adaptation to climate change, especially in the sub-system of cultivation and marketing of mango products was conducted in this phase. These factors were then developed into variables to be mapped with a causal loop diagram (CLD).

CLD is a language to define an understanding of dynamics. The CLD will reveal the causal relationship of the system variables into the image language in which the image consists of interconnected arrows forming a cause-and-effect diagram (Fortunella et al. 2015).

A positive feedback loop or a reinforcing loop is a growth process, while a negative feedback loop or balancing loop is a process for achieving a goal by balancing the interference to keep the system in a stable state (Babara, 2014).

There are some general guidelines for making CLD. According to Kim (1992), the general guidelines in making CLD are as follows.

1) Theme selection

CLD is a process of articulating a deeper insight into a complex issue. Deciding on a theme or issue that you intend to understand more deeply is essential before starting to create a CLD.

2) Time horizon (determining the time period relevant to the research)

Determining the relevant time period of the study is very important. The time interval set should be long enough to be able to see the dynamics that occur on the issue under study.

3) Behavior over time charts (identifying behavior over time)

Identifying the behavior of key variables is a very important step in understanding a system. Identifying the behavior of key variables can also provide information on the possible behavior of key variables in the future.

4) Boundary issue (determining the limitation of the problem to be studied)

Setting problem limits will help researchers focus on the issues discussed. The delineation of CLD without problem restrictions makes it possible for researchers to be inconsistent with the specified research focus.

5) Level of aggregation (determines the level of aggregation of the variables used)

A good CLD is a CLD that has a consistent level of aggregation of each variable. The determination of the level of aggregation is done during the CLD drawing process, and how much details of the CLD the researcher wants to make in accordance with the predefined time horizon were also considered.

6) Significant delays (to identify which relationships have significant delays on the overall diagram)

Delay is very important because it is often the cause of imbalance in the system. Researchers should be able to find which relationship has a significant delay on the overall diagram.

According to Sterman (2000), there are several steps to take in making CLD to conceptualize a case study. These steps are as follows: defining the problem; identifying key variables; collecting referral data; creating CLD; and limiting the depiction of CLD.

System Archetype(s)

System archetype(s) is a very effective tool for gaining insights into behavior patterns, and the system explains the basic structure of the system under study (Braun, 2002) and captures the essence of thinking in system thinking. It is very helpful in conceptualizing the model and communicating model insights by breaking the model into its basic circumference (Wolstenholme, 2004).

System archetypes can be applied in two ways: diagnostic and prospective. Diagnostically, archetypes help recognize the existing behavior patterns within the organization, functioning as a means to gain insights into the underlying structure of the system and from which the basic behavioral pattern emerges while prospectively, archetypes can serve to help determine planning. For example, a planning to adopt a new policy. Archetypes can be applied to test whether the policy has the desired effect if applied (Braun, 2002).

RESULTS

Problem mapping based on the situation occurred at the location of the study was described through the rich picture diagram of the adaptation behavior of mango farmers as presented in Figure 1. There are several actors involved in the system including farmers, government/policy-makers, researchers/academicians/ research institutes, and staff of department serving as controller in the field.

Department of Agriculture of Majalengka Regency, as an extension of the central government, realizes that climate change is a factor that is responsible for declining crop productivity. This requires the Department to find answers on how to overcome the negative impacts of climate change on the agricultural sector. In order to answer the problem, the Department and local government are always open to researchers and academics who come to conduct researches. Extension and training programs organized by the Department often involve researchers and academics from certain institutions. However, the researchers who come have limited time and costs to be able to answer problems regarding climate change issues and their impact on agriculture comprehensively.

Mango commodity, as the leading fruit commodity in Majalengka Regency, receives special attention from the government. The agency, in accordance with the direction from the central government, currently relies on regional development programs through the provision of mango seedlings and other facilities such as revamping water and road infrastructure through cooperation with other related agencies.

The Mantri Tani (staff of Agriculture Department, Fig. 1) is an extension representative of the Department of Agriculture in the field. The Mantri staff are required to collect field data related to cropping patterns while carrying out the direct assistance function to farmers. One Mantri is responsible for two districts and covers all commodities in the distric. The broad scope of responsibilities of the Mantri makes the mango farmers feel that the assistance provided by the Mantri was minimum. Lack of the assistance function was felt by them because horticultural commodities such as mangos do not have special agricultural extension agents in each village if compared with food commodities.

Mango farmers in Panyingkiran District have been assisted by the assistance and socialization of the programs from the government. However, they apparently have high expectations regarding the extension facilities they obtain, and feel that government extension is very important. They require expert figures who can be the source of answers to every question related to the problems they face in the field, and they have not found it in the official staff they often meet.

These problems then lead to the adaptation behavior of the farmers themselves. Thus, climate change, which is considered something that cannot be changed, demands farmers to change their behavior so that their farming can continue.

The adaptation behavior of mango farmers in Panyingkiran District is different, depending on the characteristics of the farmers themselves. Nonetheless, in general, the farmers realize that they must do innovation to be able to adapt but tend to delay the behavior of innovation because of constrained costs and fear of risks that may be experienced.

The adaptation of mango farmers in this study is variables that arise from various interactions among the elements which form a structure, producing behavior in a certain time context which is then referred to as a system. By using the system thinking approach that recognizes interdependent relationships and interrelation between elements in a system, the discussion in this study used a causal loop diagram (Tasrif, 2004 in Heryanto et al. 2013). The adaptation behavior of mango farmers in turn influence changes in the behavior patterns of farmers over time.

Causal Loop Diagram of Mango Production System

Changes in the behavior of mango farmers from time to time, one example of adaptation made by them particularly in Panyingkiran District, enable them to maintain their farming or, in a further context, to maintain lives. There are many variables that shape the behavior pattern. Each of these variables has a causal relationship with other variables so that a causal loop is formed which then continues over time until new variables appear that can change the relationship notation among the existing variables.

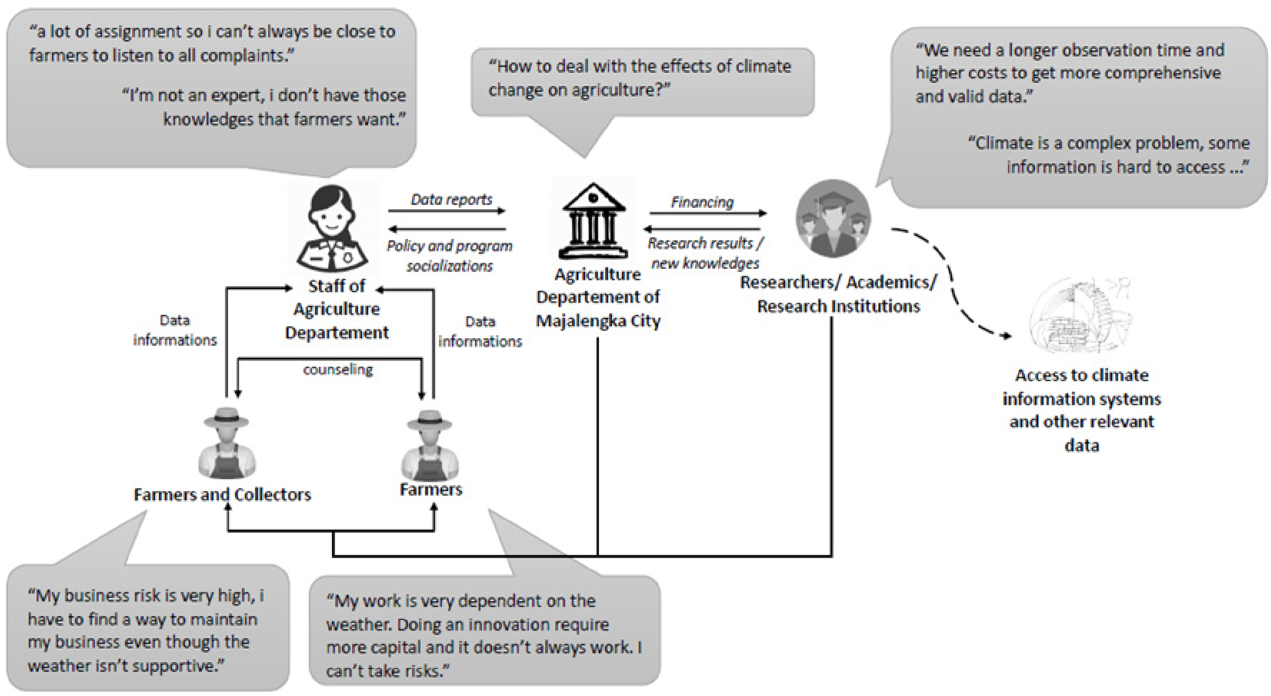

Figure 1. Rich picture diagram illustrating behavior adaptation of mango farmers

Figure 2 shows the causal loop adaptation diagram of mango farmers. The land ownership status of farmers can be in the form of land owners, land cultivators, as well as land owners and cultivators at once. Rainfall, as the indicator of climate change that is most felt by farmers, negatively affects the productivity of mangoes. The high rainfall will reduce the productivity of mango trees. This happens because mango is a plant that grows better in a dry condition with less rain.

Mango tree productivity then affects mango production. The better the productivity of the tree, the higher the production. In addition to tree productivity, the amount of mango production produced by farmers every year is also strongly influenced by the land area and number of trees owned and or cultivated by the farmers. Most farmers have mango land or trees by inheritance of their parents.

Mango production in a given year will determine the availability of mangoes in the same year. The more mango fruits produced, the more likely the availability of good quality mangoes. The quality of mango fruits will then determine the market price that applies to the mangos. The better the quality, the higher the price (Loop B1). On the other hand, an increase in the quantity of mango production will reduce the mango price (Loop B2). The greater the quantity of a product, the lower its selling price on the market. This pattern is usually reflected on the difference of mango prices during off and harvest seasons.

Mango farmers cannot easily increase mango prices just because they feel that the production costs incurred are greater than usual. If farmers immediately raise the price, the demand for mangoes they sell will decrease (Loop B1 and B2). Collectors who usually buy mangoes from farmers will not be willing to buy mangoes from farmers who sell at higher prices. As a result, farmers do not have a market to sell the mangoes they produce. Therefore, raising the price of mango unilaterally by farmers is not a good thing, except if done simultaneously by all farmers because the cost of agricultural inputs is increasingly expensive.

Prices will determine the amount of demand for the products. As with general demand and supply theory, the lower the selling price of an item, the higher the demand for the item. The quantity of the demand for mangoes will then affect the amount of revenue and income received by mango farmers. The income is used by farmers to fulfill their family's living needs, while the surplus income will be allocated to purchase agricultural production facilities and inputs so that mango farming as their livelihood can take place sustainably (Loop B1 and B2).

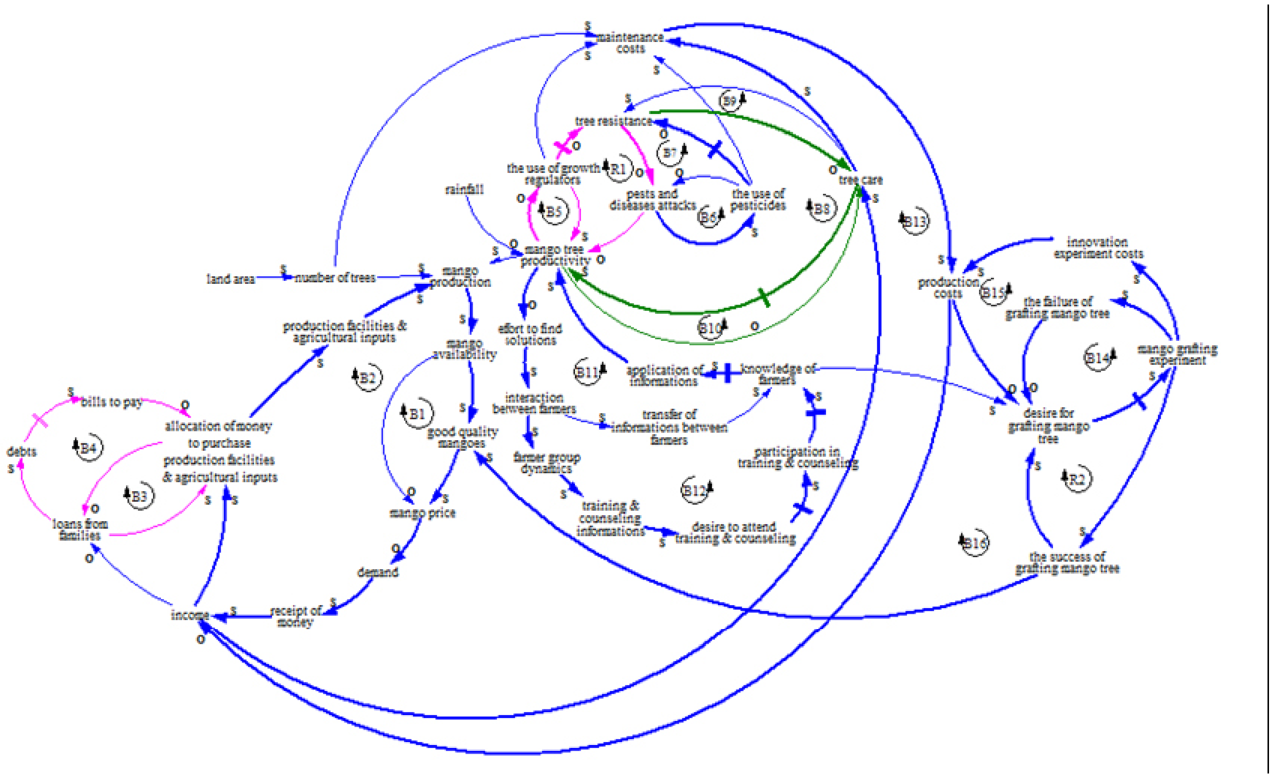

Figure 2. Causal loop behavioral diagram of mango farmers adaptation to climate change

Quality of mangoes only affect the selling price variable and do not give rise to market reach. This happens because however good the quality of the mangos is, farmers still only sell them to the collector. When farmers have quality mangoes, the additional income only comes from the price differences provided by the collector.

When a decline in income occurs, farmers are not thinking of selling all the mango trees they have and totally changing the livelihood they have engaged in. Farmers will try to find ways to continue their farming and adjust spending so as not to exceed the income they receive. This is caused by habitual factors. All informants/respondents are descendants of their farmer parents; therefore, peasant profession is a habit that has been passed down from their ascendants. The trees they manage today are mostly inherited from their parents. Urgent life needs will make them try to find other sources of livelihood, such as being teachers in madrasas and making handicrafts for sale without leaving their profession as a farmer.

Farmers who have difficulties in gathering capital for their farming will choose to borrow money from their relatives so that their farming activities continue. Farmers do not think to take loans from banks because the banks are considered having too much formality. There are certain conditions that must be fulfilled if farmers want to take loans from banks, one of which is the provision of collateral. Bank regulations that stipulate a certain amount of fine if farmers are late in paying installments are also one of their considerations in borrowing money from bank. However, taking loans from family or relatives does not necessarily free the farmers from debts and bills that must be paid in the future. This condition is described in Loop B3 and B4 (Figures 2 and 3).

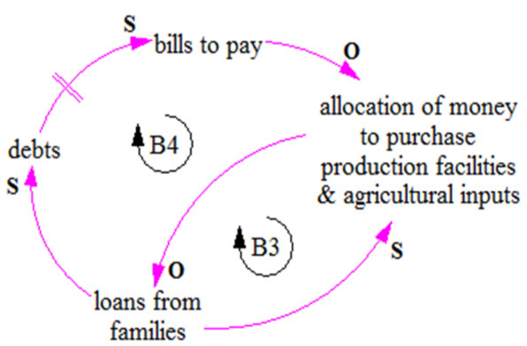

Figure 3. Fixes that fail archetype in the category of CLD farmer financing

The arrows in the B3 and B4 loops are pink marked because this pattern forms a fixes that fail archetype. This archetype describes the pattern of solving a problem which will cause other problems in the next period.

Fixes that fail archetype is also found in the productivity category (Loop B5 and R1). The low productivity of mango trees triggers an increase in the use of growth regulators/ hormones by farmers (Loop B5). The use of hormones is often regarded as an instant way out to deal with mango trees that do not produce optimally. This is then continued to be believed by most of the farmers because in short term reality mango production will be greater and quality is better when they use growth regulators than that without using the growth regulators.

However, excessive use of hormones in the long run causes overdose and makes the tree weak from the pests and diseases attack. As a result, the resistance of mango trees is reduced. Trees become more susceptible to disease and tree productivity becomes less optimal (Loop R1).

The behavior pattern in Figure 4 continues until the farmer realizes that this behavior has caused a problem. Mango trees that are weak in resistance must be treated and cared for more intensively. The emergence of this tree care variable makes the formation of another archetypes, namely, shifting the burden archetype marked with green arrows in Figures 2 and 5.

This kind of archetype describes a problem that is solved in a short-term solution, without thinking of the side effects that can occur if it is applied continuously in the long run. The application of this short-term solution usually keeps away from the fundamental solution.

In this case, mango farmers in Panyingkiran District consider the use of growth regulators to be a solution for the decline in mango tree production, thus keeping farmers from the fundamental solution they should have done in first place, namely, tree care (Loop B5, R1, B8 and B10).

The emergence of this tree care variable forms a new interaction with the tree resistance and mango tree productivity variable. The more frequent tree care is done, the better the resistance of the mango tree. Unfortunately, the farmers often ignore tree care when tree productivity is considered good (Loop B9 in Figure 2). This also occurs in the mango tree productivity. The more frequent tree care is done, the higher the mango tree productivity although it does not occur directly, the delay sign appears. However, tree maintenance is rarely done if the productivity of mango trees is considered good (Loop B10).

Weakness in tree resistance causes trees to be more susceptible to pests and diseases attack. This attack then positively affects the use of pesticides. The more the pests attack, the more doses and types of pesticides used by the farmers. Ironically, the continuous use of pesticides over a long period of time will have an impact on the tree resistance itself (Loop B6 and B7 in Figure 2).

The behavior of farmers who often use excessive growth regulators and pesticides will positively affect tree maintenance costs. The more often the hormones and pesticides are used, the greater the maintenance cost must be spent by farmers. This increase in maintenance costs will then have an impact on the increase in production costs that must be incurred. The amount of production costs will then affect the farmer income negatively (Loop B13).

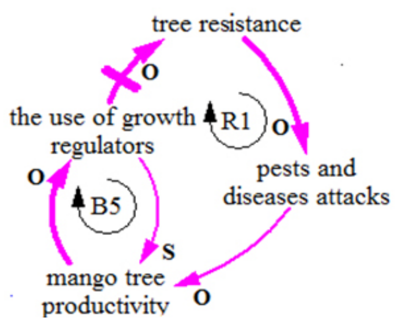

Figure 4. Archetype fixes that fail in the productivity category of farmer CLD.

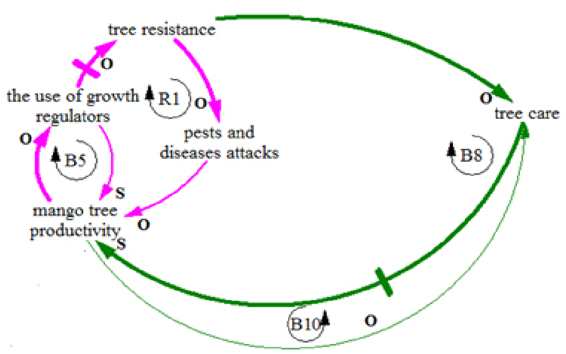

Figure 5. Shifting the burden archetype in the productivity category of farmer CLD.

Farmers' problems on mango productivity will increase farmers' efforts to find solutions. They will ask and discuss with other farmers in the hope that there will be sharing of experience of other farmers who can help them in dealing with the problems in order to increase the productivity of the mango trees. This behavior will add interaction among the farmers. The more often the farmers interact with each other, the more information transfer occurs among them. The transfer of information from one farmer to another will directly increase farmers' knowledge because information is conveyed by farmers in a language and ways that are appropriate to their habits. This way of delivering information will be more easily accepted by farmers. However, the increase in farmers' knowledge does not immediately make the farmers apply the information they receive, so it creates a delay between the knowledge of farmer's variable and application of information variable. If the information received is then implemented properly and successfully, the productivity of mango trees will increase again (Loop B11).

In Panyingkiran District, the existence of farmer group only serves as a forum for the distribution of assistance from the government and the delivery of information regarding training or counseling held by the government or other institutions. The group itself does not have a marketing function. The farmers who are members of the group do not feel that their membership helps them to market their mangoes. The farmer group also functions as a forum for the association of farmers, and this association is felt to be more dynamic when mango production decreases. This happens because when mango productivity decreases, farmers often gather and discuss to find solutions to the problems at hand.

Agriculture offices or other institutions that hold training and counseling will usually invite more dynamic groups because they are considered as active farmer groups. This means that the dynamics of farmer groups lead to obtaining more information on training and counseling by the farmers. Those who have received information on training will have the desire to attend the training. The emergence of farmers' desire to participate in the training still does not necessarily make farmers participate in training. There are several factors that prevent farmers from participating in training, including the time that is owned by the farmers themselves. In addition, the participation of farmers in training will not directly improve farmers' knowledge. Knowledge of farmers will increase according to the ability of farmers to absorb new information. Therefore, there is delay between the desire to attend training & counseling and participation in training & counseling variable, and between the participation in training & counseling and knowledge of farmers variable (Loop B12).

Knowledge of farmers variable in this study is defined by how often farmers attend training, counseling, workshops, field schools, and similar activities that discuss the cultivation or marketing of mangoes. The level of formal education is not used as a variable in CLD because it does not affect the behavior of adaptation carried out by farmers, unless the formal education pursued is special agricultural education such as vocational schools majoring in agriculture or agricultural courses, but none of the informants/ respondents has taken a formal agricultural school.

When the research was conducted, there was a widespread innovation of mango grafting by farmers. Mango grafting is conducted so that farmers can harvest Gedong Gincu fruits, albeit the primary mango tree is not Gedong Gincu variant. This is an effort to increase revenue because this type fruit has a higher market price than other types of mangoes.

The increase in farmers' knowledge in mango grafting innovation will increase the desire of farmers to innovate. Farmer A, who found out that the experiment carried out by farmer B succeeded, will certainly have the desire to try it himself although there is a delay to come to the stage of conducting the experiment himself. This is influenced by various considerations such as costs, time, and attitude of farmers who are apathetic and pessimistic about an innovation that has never been done before (Loop B15).

There are two possibilities that will occur when farmers make mango grafting experiment: this experiment is successfully carried out which in turn can increase farmers' desire to innovate again (Loop R2), or the innovation fails that will then cause farmers not to innovate anymore (Loop B14) However, the number of successful mango grafting experiments will produce more mango trees that originally is not Gedong varieties which can bear Gedong fruits. Mango grafting innovation can also be applied to mango trees that have decreased in productivity to produce better quality fruits. In the end, this mango-grafting technique will increase the availability of quality mangoes that have the potential to increase farmers' income (Loop B16).

In the CLD depiction, there is a leverage point that becomes the axis of the entire loop. Leverage point is a point of a process, which if changes are made to the point, it will lead to changes in most or the whole system.

The income variable becomes the leverage point of the 37 interrelated variables in the CLD (Figure 2). It becomes leverage point, for it has the most influence on the entire system compared to other variables. The income variable forms 28 feedback loops, with the longest feedback loop consists of 18 variables; income, tree care, tree resistance, pest and diseases attacks, mango tree productivity, effort to find solutions, interaction between farmers, farmer group dynamics, training and counseling information, desires to attend training and counseling, participation in training and counseling, knowledge of farmers, desire for grafting mango tree, mango grafting experiments, success of grafting mango tree, good quality mangoes, mango price, demand, and earning of money.

Managerial Implication

For the farmers, it is always necessary to increase their capacity to explore innovations and new ways to produce quality mangoes while maintaining productivity despite the weather uncertainty caused by climate change. They also need to look for better market that can provide better value for the mangoes they produce. The ability to look for information seems to be very crucial. The Department of Agriculture needs to equip Mantri Tani with appropriate information and utilize mango farmers who can be considered successful (influencers) in implementing sustainable technology, so that other mango farmers are interested in following and trying the technique. The current way that information diffusion occurs tends to be exploited for one-party financial benefits without taking into account its sustainability.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

There are 37 variables derived from 8 categories, namely, climate change (rainfall), production (mango production, mango availability, good quality mangoes, allocation of money to purchase production facilities and agricultural inputs, production facilities and agricultural inputs, land area, number of trees), marketing (mango price, demand), income (receipt of money, income), financing (loans from families, debts, bills to pay, maintenance costs, production costs, innovation experiment costs), productivity (mango tree productivity, use of growth regulators, pests and diseases attacks, use of pesticides, tree resistance, and tree care), information adoption (effort to find solutions, interactions between farmers, farmer group dynamics, transfer of information between farmers, training and counseling information, desire to attend training and counseling, participation in training and counseling, knowledge of farmers, application of information), and innovation (desire for grafting mango tree, mango grafting experiment, failure of grafting mango tree, success of grafting mango tree).

Mango farmers' adaptation behavior to climate change arises not only as farmers' efforts to maintain the farming they run but also to maintain their lives. The uses of growth regulators and pesticides are a shortcut conducted by farmers to increase their production without realizing the side effects that can arise in the long term. The income variable is the leverage point of the behavior pattern that is reflected in the causal loop diagram. Small changes in income will cause major changes in the overall system described.

Recommendations

The government can open access to information that is easier, complete and in timely manner for farmers. This can also be achieved through higher education institutions, research institutions, or even collaborations with private sectors to provide information and marketing platforms for mangoes. Software analysis states income as a leverage point, but to be realistic, income cannot be directly increased so that it is not feasible to be recommended as an ideal point of improvement. Therefore, in order to improve or at the very least to maintain the life of mango farmers and their farming businesses, farmers need to also increase their own capacity by being more dedicated to their farm, find better market, and start thinking about long term sustainability in maintaining their mango farms.

REFERENCES

Arnold RD, John PW. 2015. A Definition of systems thinking: a systems approach. *Procedia Computer Science* 44(2015): 669–678. https://doi.org/10.1016/j.procs.2015.03.050.

Babara M. 2014. Analisis kontroversi pembangunan pembangkit listrik tenaga sampah di Kota Bandung sebuah pendekatan systems thinking [thesis]. Bandung: Program Magister Studi Pembangunan, Sekolah Arsitektur, Perencanaan, dan Pengembangan Kebijakan, Institut Teknologi Bandung.

[BPS] Badan Pusat Statistik. 2018. *[Seri 2010] Distribusi PDB Triwulanan Seri 2010 Atas Dasar Harga Berlaku.* Jakarta: BPS.

Braun W. 2002. The System Archetypes. https://www.albany.edu/. [Februari 11, 2018].

Bronte-Stewart M. 1999. Regarding Rich Picture as tools for Communication in Information System Development. *Computing and Information Systems* 6(2): 83–103.

Cavana YR, Kambiz EM. 2007. Systems methodology. https://thesystemsthinker.com/. [Juli 15, 2018].

Fortunella A, Ishardita PT, Agustina E. 2015. Model simulasi sistem produksi dengan sistem dinamik guna memantu peencanaan kapasitas poduksi. *Jurnal Rekayasa dan Manajemen Sistem Industri* 3(2):356–267.

Gommes R. 1998. *Climate-related risk in agriculture*. Canada: IPCC.

Hasanah L. 2017. *Statistik Ketenagakerjaan Sektor Pertanian.* Jakarta Selatan: Pusat Data dan Sistem Informasi Pertanian, Sekretariat Jenderal Kementrian Pertanian.

Heryanto MA, Yayat S, Dika S. 2013. Sistem inovasi berkelanjutan dalam agribisnis: mengurai stagnasi inovasi agribisnis. *Sustainable Competitive Advantage (SCA)* 3(1):1–12.

Kencanaputra R. 2014. *Outlook Komoditi Mangga.* Jakarta: Pusat Data dan Sistem Informasi Pertanian, Sekretariat Jenderal Kementrian Pertanian.

Kim DH. 1992. Guidelines for drawing causal loop diagrams. *The Systems Thinker* 3(1): 5–6.

Li C, Ting Z, Rasaily RG. 2010. Farmer's adaptation to climate risk in the context of China: a research on jianghan plain of yangtze river basin. *Agriculture and Agricultural Science Procedia* 1: 116–125. https://doi.org/10.1016/j.aaspro.2010.09.014.

Natawidjaja JML. 2008. *Linking Mango Farmers to*

Dynamic Market Through Transparent margin partnership Model. SEARCA: Changing Agrifood Markets in Southeast Asia: Impact on Small-Scale Producers.

Natawidjaja RS, Sulistyowati L, Setiagustina L, Sulistyoningrum H, Nugraha A. 2008. *Analisis Supply dan Value Chain di Jawa Barat*. Bandung: Unpad Press.

Nirdayana K, Priminingtyas DN, Hadi HS. 2011. Dampak perubahan iklim terhadap produksi dan pendapatan usahatani mangga. *Jurnal Habitat* 22(2): 145–173 .

Olesen JE, Bindi M. 2002. Consequences of climate change for European agricultural productivity, land use and policy. *European Journal of Agronomy* 16: 239–262. https://doi.org/10.1016/S1161-0301(02)00004-7.

[Puslitbanghorti] Pusat Penelitian dan Pengembangan Hortikultura. 2006. *Pengenalan dan Pengendalian Hama dan Penyakit Penting Tanaman Mangga.* Departemen Pertanian: Badan Penelitian dan Pengembangan Pertanian.

Rasmikayati E. 2013. *Perubahan Iklim: Dampaknya terhadap Perilaku serta Pendapatan Petani.* Bandung: UNPAD.

Shen S, Basist A, Howard A. 2010. Structure of a digital agriculture system and agricultural risks due to climate changes. *Agriculture and Agricultural Science Procedia* 1: 42–51. https://doi.org/10.1016/j.aaspro.2010.09.006.

Sterman JD. 2000. *Business dynamic: systems thinking and modelling for a complex world.* United States of America: McGraw-Hill Companies, Inc.

Sugiyono. 2017. *Metode Penelitian Kuantitatif, Kualitatif, dan R&D.* Bandung: Alfabeta.

Sulistyowati L, Rasmikayati E. 2014. *Determinant of Commercialization of Manggo Farmers in West Java.* Bandung: UNPAD.

Wang J. 2010. Food security, food prices and climate change in China: a dynamic panel data analysis. *Agriculture and Agricultural Science Procedia* 1: 321–324. https://doi.org/10.1016/j.aaspro.2010.09.040.

Wolstenholme E. 2004. Using generic system archetypes to support thinking and modelling. *System Dynamic Review* 20: 341–356. https://doi.org/10.1002/sdr.302.