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University of Applied Science North-western Switzerland

# Application of System Dynamics in the International Development Cooperation

Analysis of decision taking among cocoa farmers in Flores, Indonesia

Thesis --1 -T-2302-DA/06-PA -- Business Process Management

Written by

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Submitted to

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## List of Abbreviations

| | |
|---|---|
| BDS | Business Development Services |
| BOT | Behaviour over Time Graph |
| CLD | Causal Loop Diagram |
| CPB | Cacao Pod Borer |
| ICCO | International Cocoa Organization |
| LED | Local Economic Development |
| MFS | Management Flight Simulator |
| NTT | Nusa Tenggara Timur |
| SC | Swisscontact |
| SLA | Sustainable Livelihood Approach |
| SLF | Sustainable Livelihood Framework |
| SNI | Standar Nasional Indonesia |
| Veco | Vredeseilanden Country Office |

## Management Summary

This thesis is going to look at how cocoa farmers on Flores make their decisions. Flores is a beautiful island in the district of Nusa Tenggara Timur (NTT) in the south eastern part of Indonesia. Swisscontact – as the contractor of this thesis – has already decided to plan an intervention in the cocoa sub sector in this region; therefore, Swisscontact needs further information about the existing system's inherent impacts.

The methodologies used for the system analysis in this thesis are tools of the wide area of systems thinking. Systems' thinking focuses on recognizing the interconnections between the various parts of the system and synthesizing them into a unified view of the whole. The cocoa farming system in Flores, with its dynamic processes like the farmers' problem awareness and decision making, is highly complex. Consequently, a tool is required to evaluate the dynamics of particular situations instead of a methodology that represents only a snapshot of the system.

As the low productivity of Flores' cocoa production is not a new phenomenon in Indonesia, there is a great deal of research available conducted in other major cocoa-producing regions. Previous works, including the PhD thesis by Roger K. Day (1985), have shown already twenty years ago solutions for the fight against the main limiting factor in the Indonesian cocoa production: the cocoa pod borer (CPB). The thesis in hand focuses more on how Flores' cocoa farming system reacts to impacts and changes in general, rather than on one specific situation.

The idea of the analyst is - by creating a management flight simulator (MFS) which bases on a computer model especially developed for this system - to help every party involved in an intervention to understand the existing real world system. By following all the necessary steps of the system dynamics process – from the system description to the design and implementation of sustainable strategies and policies – the analyst was able to pick out the elements in the system with the greatest impacts on the numerous existing feedback structures.

The resulting strategy of the system analysis targets the farmers' huge lack of knowledge - either the know-how concerning their cash crops and appropriate farming management know-how:

> *"Constitution of a farmer field school, where the farmers can acquire the knowledge of how to maintain their cacao trees, become aware of time delays in the trees lifecycle, learn about the urgent need to integrate pest management, and obtain know-how required to make specific decisions."*

Bearing in mind, that there are common patterns of behaviour like the limit to success – nothing can grow without limits – the intervention must implement effective ways so the farmers can use the knowledge gained to reduce their limited working capacities.

Interventions in the cocoa farming system of Flores need not just a written down strategy, on the contrary, it is mandatory that every party involved in an implementation understands the system in question. For this reason the analyst conducted a first learning laboratory – using the MFS and other systems thinking tools - in which the Swisscontact team could gain necessary insight into the cocoa farming system. Every individual has mental models in mind, which reflect his or her view of the systems as well as their reasoning processes. Therefore, further learning laboratories carried out with possible partners for an intervention will force everyone to share their mental models and conclude on one generalized new mental model.

*„It is not knowledge, but the act of learning,*
*not possession but the act of getting there,*
*which grants the greatest enjoyment.“*
*Carl Friedrich Gauss*

Developing computer simulation models – also known as micro worlds or virtual worlds – is an effective way to analyse social-economical-systems behaviour and to share those insights with others. A MFS is not a tool for forecasting and it has not the ability to predict, but it can anticipate how the system will behave if and when certain changes occur.

Despite the fact that virtual worlds are useful foresight tools, there are also weak points, as almost nothing is perfect. Most problems occur in the description of the decision rules, the quantification of soft variables, and the choice of the model boundary. As all these points are based on the analyst's assumptions, the model itself is only as accurate as these assumptions are. Most of the real cocoa farming system is descriptive, qualitative, difficult to quantify, and has never been recorded. To make the computer simulation as correct as possible, those soft variables are crucial and they have to be evaluated as accurately as feasible.

However, the limiting factors, the analyst recommends the use of the system dynamics methodology and systems thinking in general for the analysis of every new system, before interventions are taken into action. Furthermore, the analyst recommends that system dynamics is used to create and test sustainable interventions, strategies and policies before they are put into place in the real world.

With a proper application of systems' thinking and system dynamics in the international development cooperation, chances that today's solutions become tomorrow's problems will decline.

## Acknowledgments

First and foremost, I would like to thank my wife Simone for her patience and support.

Thanks to the University of Applied Science North-western Switzerland for having such an interesting field of study - business process management - and very special thanks to **Robert Schäfer** for being the couch of this thesis.

I would like to thank Swisscontact's staff in the headquarter in Zurich for having given me the opportunity to write my thesis in one of their projects, and especially **Ruedi Nützi** for choosing me to carry out a system analysis in Indonesia.

Special thanks go to **Peter Bissegger** for determining the very interesting LED-NTT project in the beautiful island Flores for my thesis, and giving me the liberty to use and decide on the appropriate methodology.

Particular thanks to **Etih Suryatin** for having me in the rural development project in Flores.

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Last but not least all Swisscontact staff in Jakarta and Ende, who made my stay as enjoyable as possible and reading all my wishes from my lips.

# 1 Introduction

## 1.1 Background

In March 2004, Swisscontact launched the LED-NTT project in Flores. LED stands for Local Economic Development and defines the project goal, namely to facilitate economic development in specific areas in the Province of Nusa Tenggara Timur (NTT). The project focuses on income generation and job creation through an integrated approach on sector development such as cashew nuts, cacao and ginger. Likewise, the project aims to contribute to the reduction of poverty in selected areas of NTT.

Bearing in mind that 29% of the people in NTT are poor, the creation of decent employment is widely seen as a major route out of poverty. The LED-NTT project has already selected the cashew nuts sub sector as the first field of intervention.[1] Swisscontact identified the cacao sub sector with high potential for achieving high impact on farmer level for future interventions.

**Box 1-1: Cocoa farming: Fast facts**

Number of cocoa farmers, worldwide: 5-6 million. → Number of people who depend upon cocoa for their livelihood, worldwide: 40-50 million. → Annual cocoa production, worldwide: 3 million tons. → Annual increase in demand for cocoa: 3 percent per year, for the past 100 years. → Current global market value of annual cocoa crop: $5.1 billion. → Length of time required for a cacao tree to produce its first beans (pods): five years. → Duration of "peak growing period" for the average cacao tree: ten years (World cocoa foundation, 2005).

Cocoa is one of the main cash crops in Flores, making up between 20% and 90% of the farmer's income, depending on the location. However the potential, the main problem in Flores' cacao sub sector is the low productivity. Like most of Indonesia's cacao production, Flores' cacao trees have a high infestation of the Cocoa Pod Borer (CPB) pest. Beside the problems arising because of CPB, the cocoa sub sector in Flores is suffering more problems caused by a considerable lack of farming knowledge.

## 1.2 Specific Task

This thesis shall support the LED-NTT project through a system analysis of the environment of cocoa farmers and a model for decision taking among cocoa farmers in Flores. To develop a systemic model, the analysis must generate a deeper insight into livelihood, economic, social and environmental system of the farmers. With this systemic model for decision

[1] Source: Swisscontact brochure for the LED-NTT project

taking, the analyst shall compare the interventions proposed by the LED-NTT project and provide recommendations on how to improve the proposed strategies. What are key elements of decision taking among cocoa farmers and to whom do they listen? These key questions will guide the research in order to find out how cocoa farmers make decisions and what makes them act.

**Box 1-2: Decision making**

Decision making is the cognitive process leading to the selection of a course of action among alternatives. Every decision making process produces a final choice. It can be an action or an opinion. It begins when we need to do something but we do not know what. Therefore, decision making is a reasoning process which can be rational or irrational, and can be based on explicit assumptions or tactic assumptions. (Definition: www.wikipedia.org)

## 1.3 Structure of the thesis

In this thesis, the researcher uses the tools of systems thinking to get to the core problem of Flores cocoa farmer system. The specific used tools and the system dynamics[2] methodology are described below, in chapter 2. The steps of this methodology also determine the outline of this thesis, as each step represents one chapter.

**Box 1-3: Systems thinking**

At its broadest level, systems' thinking encompasses a large and fairly amorphous body of methods, tool, and principles, all oriented to looking at the interrelatedness of forces, and seeing them as part of a common process. The guiding idea is that behaviour of all systems follows certain common principles, the nature of which are being discovered and articulated. (Senge, 2005)

As an additional chapter, a critical analysis of the applied methodology in the context of the international development cooperation is also part of this thesis. Since every analysis requires some fundamental research into the topic and all the actors involved, all the additional data is collected and put in appendix 1 and 2. Appendix 3 contains a large documentation of the developed systemic model, in order to make the model accessible to those interested and, furthermore, to prove the correctness of all the assumptions taken by the modeller and the team.

[2] System dynamics is a field of study that includes a methodology for constructing computer simulation models to achieve better understanding of social and corporate systems. It draws on organizational studies, behavioural decision theory, and engineering to provide a theoretical and empirical base for structuring the relationships in complex systems.

# 2 Methodology

The iterative process in Figure 2-1 shows the seven steps in system dynamics necessary to analyze a social system. A reflection of the preliminary findings, following every step in the process, must be conducted by the workgroup or team with the analyst. Each step of this iterative process is described below.

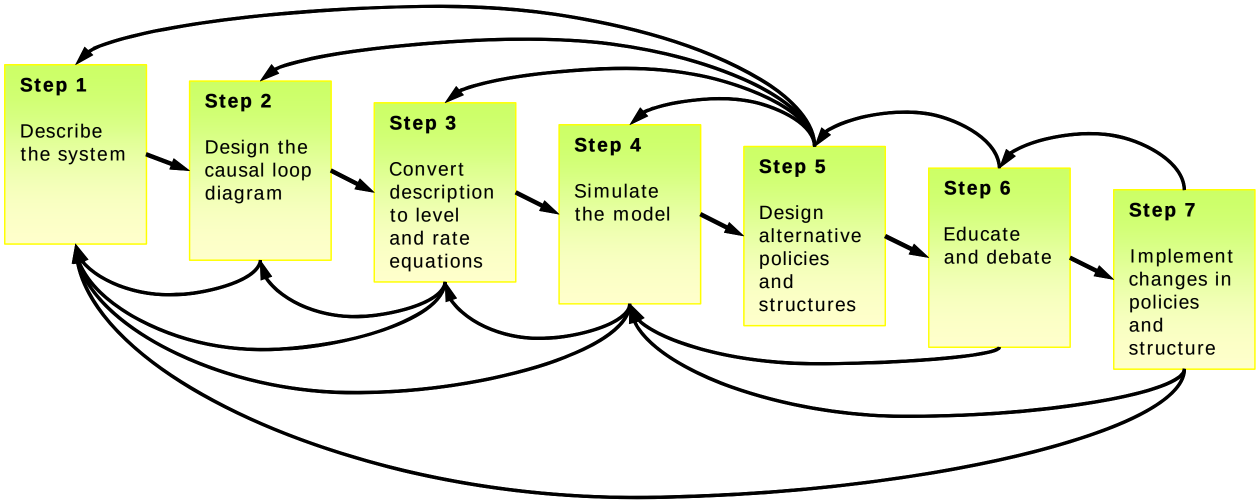


**Figure 2-1: System dynamics process[3] (cf. Forrester, 1961)**

## 2.1 System Description[4]

Every system analysis begins with the system description, which is constantly updated during the development of the model according to the current findings. Every system is always open, touching others; closed systems do not exist in reality. Every system is always part of a larger system and contains several smaller subsystems.

From there, a collection of key variables with extensive descriptions have to be evaluated. The resulting variable set is the "gene pool" of the system and, at the same time, its fingerprint. If necessary, the variables can be improved or updated at any time.

Groups of at least two people check the variable set with the "Impact Matrix" on its interactions. For this purpose all variables appear in a cross-impact matrix where the effect of every variable upon any other will be asked for, including its latent possibilities. This step will get everybody involved to consider the system from a new point of view.

Every variable gets an "Index of Influence" according to its pattern of influence and will be displayed in the "Systemic Role Graph". Because of its position on the graph, each variable can be explained and further described by a net of 50 fields with different meanings.

[3] This process is slightly modified by the analyst: The original process lacks the second step, which is very important for the understanding of a social economic system.

[4] Procedure according to the Vester Sensitivity Analysis ® (Vester, 2005)

## 2.2 Systems Archetypes and Causal Loop Diagram's

Systems archetypes are one of the ten tools of systems thinking. Systems archetypes are the "classic stories" in systems thinking — common patterns and structures that occur repeatedly in different settings.

> *A good systems thinker, particularly in an organizational setting, is someone who can see four levels operating simultaneously: events, patterns of behaviour, structure, and mental models.*

According to this statement (Senge, 2005: p.97), a system analysis should start with the understanding of the ongoing situation – events – this normally starts with the phrase: "The problem is…" By applying all the techniques to develop systems archetypes, the analyst and the team involved are capable of sharing their mental models,[5] which leads to a deeper understanding of the system in question.

Causal loop diagramming uses the same "language" as the archetypes - causal links from one element to another. However, the structure is more flexible; causal loop diagrams do not presume a pre-existing template into which you have to force-fit the situation. Causal loop diagrams also show the character of the relationship between each pair of concepts; for example, they indicate whether an increase in one variable causes the other to increase or decrease (John Sterman in: Senge, 1997).

## 2.3 System Modelling

The virtual model of the system of Flores cacao farmers will be developed by the modeller using the stock and flow diagram[6] techniques with the Vensim PLE Plus software.[7]

Formalizing a conceptual model often generates important insight even before it is ready to be simulated. Formalization helps the modeller to recognize vague system descriptions and resolve contradictions that went unnoticed or undiscussed during the previous steps. Formalization is where the real test of the analyzer's/modeller's understanding occurs: computers accept no hand-waving arguments.

Modelling is, like the system dynamics steps, iterative. Modelling is a continual process of iteration among problem articulating, hypothesis generation, data collection, model formulating, testing and analysis. Effective modelling continually cycles between experiments in the virtual world of the model and experiments and data collection in the real world (Sterman, 2000: 89pp).

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[5] In cognition, a mental model refers to both the semi permanent tacit "maps of the world" which people hold in their long term memory, and the short-term perceptions which people build up as part of their everyday reasoning process. (Art Kleiner in Senge, 1997)

[6] This is the traditional modelling technique of system dynamics. For more information see Sterman, 2000.

[7] Ventana Systems Inc., Harvard, MA 01451, http://vensim.com

## 2.4 System Simulation

Simulation of the model is fully integrated in the Vensim software. The developed model will simulate automatically all the proposed strategies between the defined boundaries. When beginning with the simulation, it is necessary that the model is fully tested for its robustness and sensitivity.

In order to test the model, the analyst will use the Monte Carlo method, a widely used class of computational algorithms for simulating the behaviour of various physical and mathematical systems. Because of the repetition of algorithms and the large number of calculations involved, Monte Carlo is a method suited to calculation using a computer. This functionality to test the model with hundreds of possible inputs is integrated in the Vensim software.

The team consider and decide together with the modeller for the outcome graphs of the simulation. The modeller can create specific outcome graphs which are insisted by the team.

## 2.5 Policy Making

*"When one tugs at a single thing in nature, he finds it attached to the rest of the world."*
*John Muir (1838-1914)*

In this step, the model is used to create new sustainable policies and strategies, by involving the team into the simulating process to make them see the actual impact of every policy the team decides on.

## 2.6 Learning Laboratory

The term learning laboratory refers to an innovation in infrastructure: a “practice field” where all those involved (the team, partner, or actors) can surface, test, and improve their mental models. Learning laboratories represent a natural context within which the simulation model seems to have the greatest impact – as a tool for learning, rather than a tool for predicting.
Therefore, with the simulation model the team can discuss, debate, and learn about the already proposed strategies, as well as about the new policies developed by the analyst.

## 2.7 Implementation

The implementation of the proposed interventions due to this system analysis is not part of this project. The future will show the impacts of the proposed interventions in the real world. To finish a system analysis, those impacts and outcomes in the real world should be compared with the simulations outcomes in the virtual world to verify the model.

# 3 System Description of Flores Cocoa

Flores is an island in the most eastern province of Nusa Tenggara Timur (NTT), which is part of Indonesia's archipelago.[8]

> **Box 3-1: What is a system**
>
> A System is a group of interacting, interrelated or interdependent elements, forming a complex whole. This is almost always defined with respect to a specific purpose within a larger system. The word descends from the Greek verb *sunistánai*, which originally meant "to cause to stand together".

The system of Flores Cocoa - more specific the four regencies Ngada, Ende, Sikka and Flores Timur – is embedded in the larger system of the Indonesian cocoa as well as in the huge system of world cocoa production. Flores' share of the world coca production is not significant, even though, the production of cocoa is one of the main sources of income among farmers on Flores.[9]

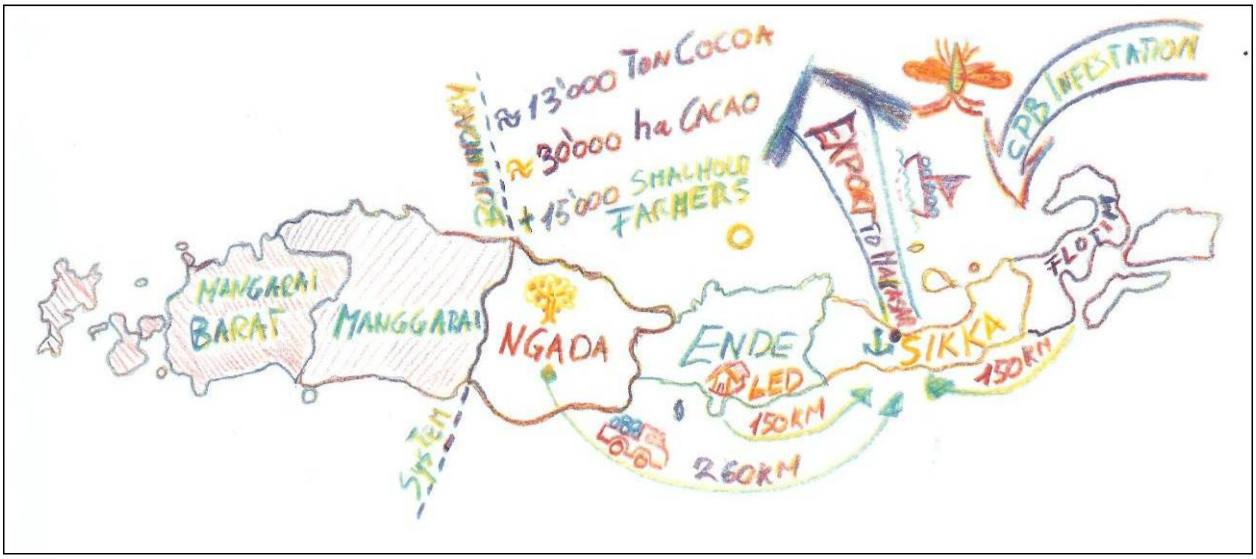



**Figure 3-1: System illustrating of the region of intervention**

About 90% percent of the cocoa bean production is exported to Makasar (Sulawesi). The inland transportation from the farmers to the exporters in Maumere is organized by collectors and traders – who play an important role in the market chain – with cars and trucks on road.

In the region of intervention, about 15'000 smallholder farmers cultivate about 30'000 hectares of cacao trees and produce slightly more than 13'000 tons of cocoa beans.

[8] For more information about the region of intervention see Appendix 1, Chapter 10

[9] For more information about Flores cocoa production see Appendix 1, Chapter 12.2

The main problem in the system of Flores cocoa sub sector is the low productivity. Like most of Indonesia's cocoa production, Flores' cacao trees have a high infestation of the Cocoa Pod Borer (CPB)[10] pest. In addition to the problems arising because of CPB, the cocoa sub sector in Flores is suffering further problems caused by a considerable lack of farming knowledge.[11] Figure 3-2 shows the average annual productivity of all Indonesia compared to the productivity of NTT farmers, most of whom are located in Flores. Almost every farmer contacted by the analyst claims a huge decrease in cocoa production compared to the last two years. The data for 2006 reflects the farmers' assumptions in Flores

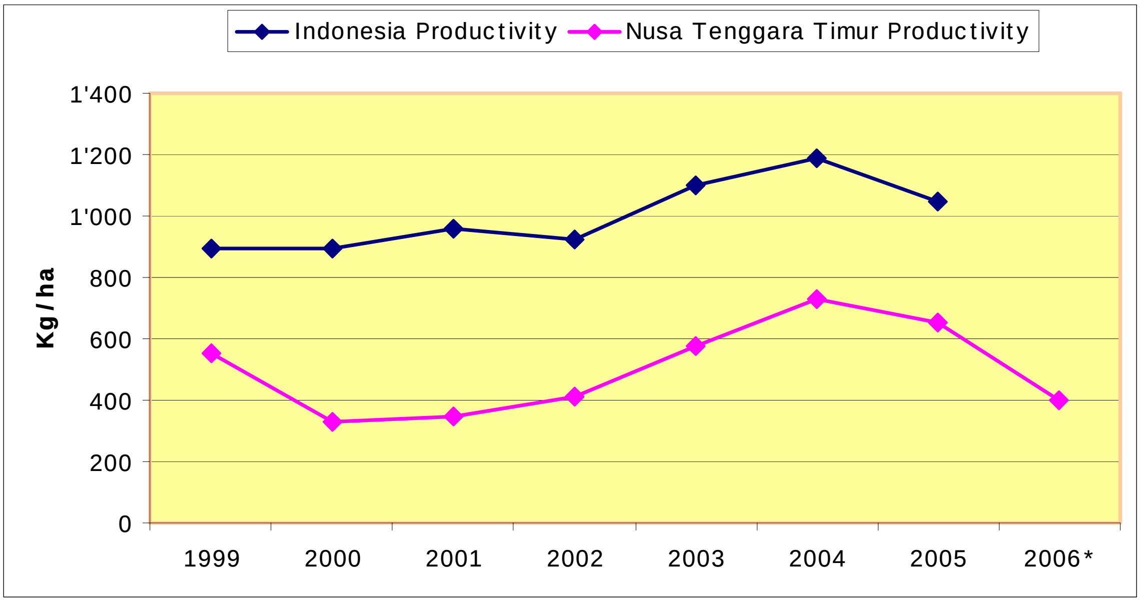



**Figure 3-2: Cocoa productivity comparison in Indonesia (cf. Deptan, 2006[12])**

## 3.1 The Systems relevant Variable Set

A variable is a specific element of the system in question. Variables are, as the name suggests, variable and they are intersections in the system. The variables show the system's cybernetic interaction/interdependency and are either quantitative or qualitative. Every variable is a key variable of the Flores cocoa system, which often represents further subsystems. The system's relevant variable set in Table 15-1 in Appendix 2, summarizes the identified variables of the system with the affiliated descriptions. In total, 27 variables are identified to analyse the systems inherent impact. The created Excel spreadsheet (see Appendix 2, chapter 15.2) calculates the active, respectively the passive sum of every variable, as well the "Impulse Index" (*Q* - quotient of the active and the passive sum) and the "Dynamic Index" (*P* - the product of active and passive sum). With the impact matrix, every variable gets a role in the system which determines their effects after changes.

[10] For more information about CPB see Appendix 1, chapter 12.3

[11] See Figure 12-2 in Appendix 1, about the multiplication effect of lack of knowledge on CPB infestation

[12] Departemen Pertanian Republik Indonesia; http://www.deptan.go.id

## 3.2 The Roles in the System

Figure 3-3 shows the position of every variable (element) in the system. The elements are dispersed according to their *Q* (on the graph the straight lines out of the zero point) and *P* (the hyperbola) value. The *Q* reaches from reactive to active, and the *P* reaches from absorber to critic. Both indexes together determine the role of each element and anticipate their system behaviour either in a critical, absorbing, active or reactive form. This leads to a first interpretation of the appropriateness of each variable for an intervention in the system. I.e. critical elements can be identified which can be inappropriate for an intervention, because the whole system or some specific parts of it could react unpredictably.

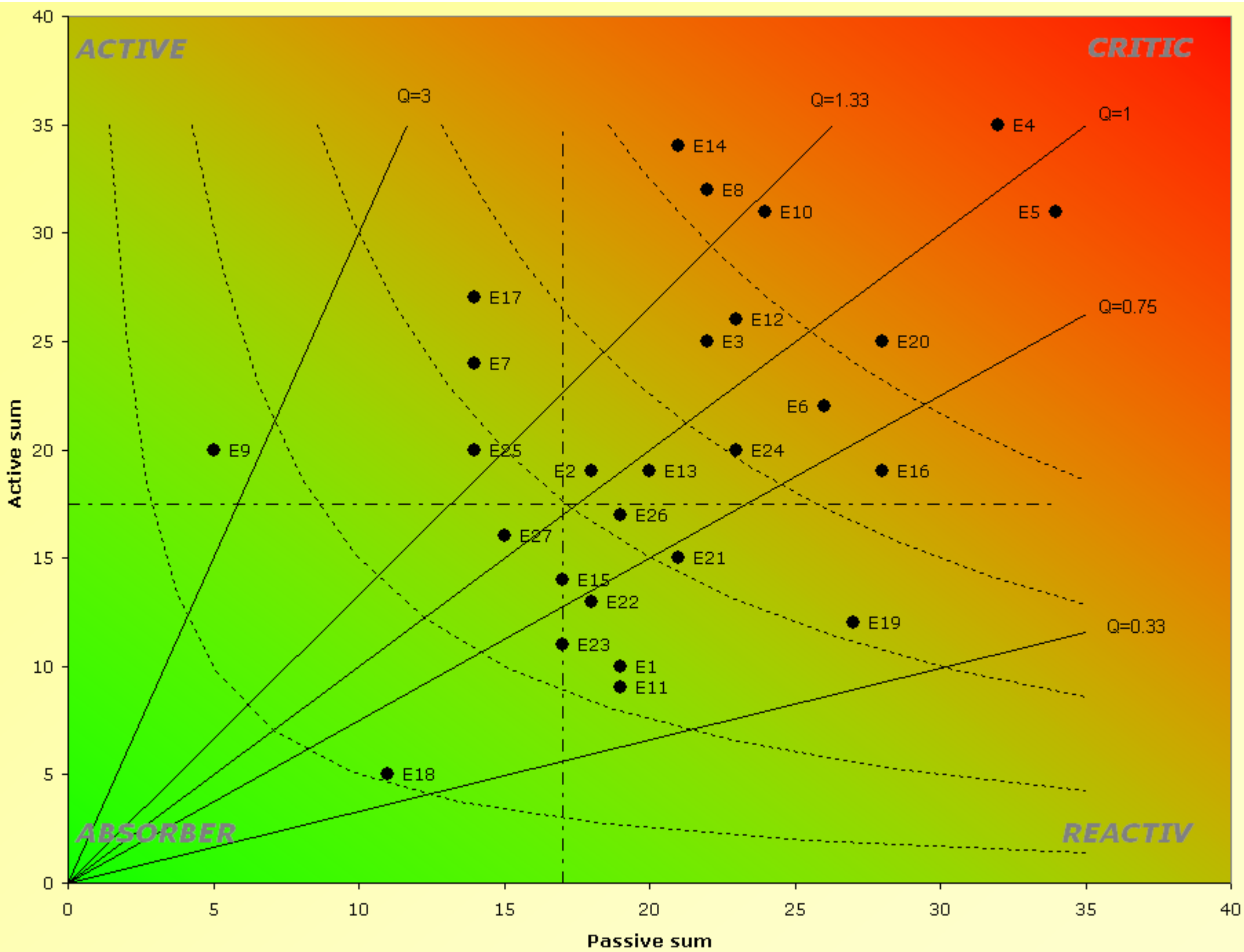



**Figure 3-3: Roles in the system**

### 3.2.1 Elements with active Effects

Highly active and active elements are effective control levers and they can move the system to a desired level and stabilize it after alterations. The element with the highest *Q* is “Drought and bad weather” (E9), but with its low *P* value, E9 is also absorbing, which means that this variable is not controllable through interventions. “Business environment” (E17) and “Demand for cocoa beans” (E7) are also active in the system. Exogenous changes in E7 and E17 have big influences on the system. The “Transport infrastructure” (E25) is slightly active and *P* neutral, therefore, an intervention in the transport infrastructure is helpful for the system's self regulation.

### 3.2.2 Elements with absorbing Effects

The scope of absorbing elements is not suitable for interventions or controlling of the system behaviour. "Farmers' health" (E18) has no impact on the system behaviour but reacts very sensitively to specific changes in the system.

### 3.2.3 Elements with reactive Effects

An intervention in the strong reactive scope only leads to some cosmetic modification and is just like a symptom treatment. Nevertheless, those elements are primarily system indicators. The elements "Quality of cocoa beans" (E19) and "Farmers' expenses" (E11) have the lowest *Q*; therefore, those elements are the most reactive in the system. "Livelihood of farmer" (E16) is a slightly reactive element which can response considerable critic after interventions. The other elements "Availability of suitable land" (E1), "Input suppliers' action/support" (E21), and "Schooling in agriculture" (E22) are only slightly reactive with some absorbing characteristics. Because of the almost neutral *P* value, the system's self regulation can be triggered by "Financial institutes intervention" (E23), but these are more symptom treatments and only limitedly/restrictedly controllable.

### 3.2.4 Elements with critical Effects

Elements in the critical scope of the model are accelerators and catalysts, which can be used as a booster detonation in the system. These elements must be treated very carefully, because of the risks of uncontrolled growth, known as "Overshoot and Collapse". Strong intervention in the elements "Cacao tree stock/holdings" (E4) and "Cocoa bean production" (E5) are liable to overshoot because of their very high *P* values. Considered system interventions with those elements must be measured out carefully. Action in "Diseases and pests" (E8) can move the system to a desired level. Despite the fact that this element has a high *P* it must be treated very carefully. Because of his high active sum, E8 could move the system easily out of bound – positively or negatively. "Farmers' crop know-how" (E10), "Agriculture agency intervention" (E14), and "Farmer group intervention" (E20) are less critical. Nevertheless, they are able to boost the system to a desired level, with E14 having the most active effect.

### 3.2.5 Elements with neutral Effects

Neutral elements are the triggers for the self regulation of the system and they are only restrictedly controllable. A neutral effect with absorbing tendency have the elements "Labour force (employees)" (E15), "Farmers' income" (E26), "Farmers' management know-how" (E27), "Church/NGO/NPO intervention" (E2), and "Farm gate price for cocoa" (E13).

These elements help to stabilize the system, but cannot be used for large scale shifts. The elements with neutral effects and critical tendencies are “Collectors and middlemen” (E6), “Farmers' capacity” (E12), “Soil and environment” (E24), and “Availability of information” (E3). Interventions in those elements have a greater impact on the system’s self regulation because of the higher P value which adds some accelerating effects to them.

### 3.2.6 Overall Variable Set Effects

The socioeconomic system of Flores cacao farmers appears like a relatively stable system with many self-regulating mechanisms with a share of about 33% neutral elements. With 15% the active elements provide a considerable amount of effective control levers, and with further analysis most of them can be used for sustainable policies and intervention strategies. In addition, the critical elements with 22% are highly active in the system, but they must be handled very carefully. The relatively high share of reactive elements (26%) provides many elements reflecting the actual system status, but only a few opportunities for intervention.

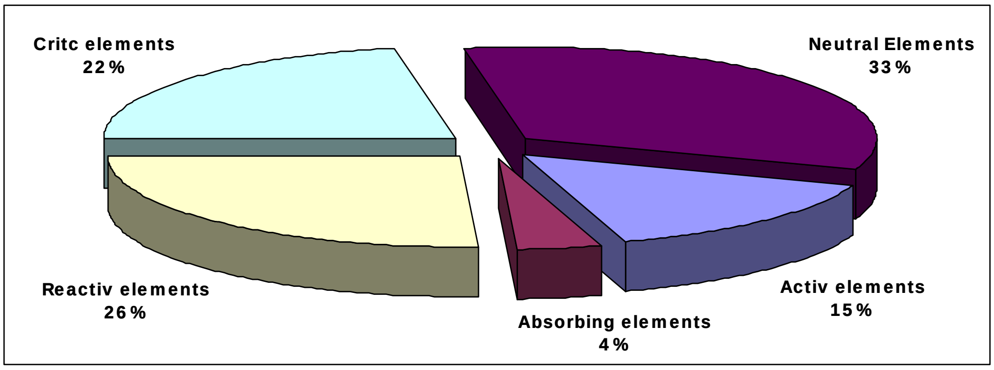



**Figure 3-4: Allocation of the systems behaviour**

## 3.3 Conclusion

This first step in the system dynamics methodology provides the analyst with a large number of system insights. Through this methodical procedure, the whole system, including all actors influenced, had to be taken into account. In addition, by discussing every possible interaction between the selected 27 key variables, the analyst and the team got more sensitive about the whole system. As a result of the analysis of the system’s inherent impact, the three variables “Cacao tree stock/holdings” (E4), “Diseases and pests” (E8), and “Agriculture agency intervention” (E14) reflect, on the one hand, the cash crop in question and the source of the low productivity of it, and, on the other hand, a possible partner for an intervention with high influence.

Due to this extensive system description, the analyst was able to grasp all the relevant data, elements and actors to get a clear picture of the whole cocoa farming system in Flores. This first step is crucial when developing a correct working simulation model to show the complex real world in a smaller context in a virtual (computer) world.

# 4 Causal Loop Analysis and Systems Archetypes

*"The unapparent connection is more powerful than the apparent one." Heraclitus, 500 BC*

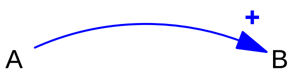
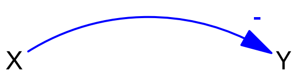
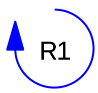
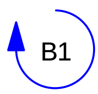
## 4.1 Causal Loop Diagrams

After the first step of the iterative system dynamics process is completed, the relevant variable set is determined and their roles in the system are known. In the real world a complex framework consisting of mutual relations exists, hence, we cannot just look at elements in isolation.[13] With the causal loop diagrams (CLD) a tool exists, with which the analyst can determine all feedback loops in the entire system. As the variable set consists of 27 elements, the CLD is – for a better understanding – divided into three parts. Every part is still connected to the other parts, so as to prevent double definition of existing feedback loops in the entire system.

### 4.1.1 Notification in Causal Loop Diagrams

For a clear understanding of the following CLD the interpretation of the used symbols is necessary. Table 4-1 shows all the symbols used.

**Table 4-1: Notification in CLD (cf. Sterman, 2000; own depiction)**

| Symbol | Interpretation |
|---|---|
|  | Short-term interrelation: A change in the source element has an immediate effect on the target element. |
|  | Medium term interrelation: A change in the source element has a slight time delay effect on the target element. |
|  | Long term interrelation: A change in the source element has a huge time delay effect on the target element. |
|   | All else equal, if A increases (decreases), then B increases (decreases) above (below) what it would have been. |
|   | All else equal, if X increases (decreases), then Y decreases (increases) above (below) what it would have been. |
|   | Loop identifier: Positive (**R**einforcing) Loop. Each positive loop gets a unique number, and perhaps an appropriate name. |
|   | Loop identifier: Negative (**B**alancing) Loop. Each negative loop gets a unique number, and perhaps an appropriate name. |

[13] While the impact matrix takes every latent possibility into account, the CLD considers only active interrelations.

### 4.1.2 Identified CLD from the variable set

By analysing the actual interrelations between the elements of the variable set, an uncountable number of feedback processes are noticed. The three following figures illustrate some particular feedback processes which are crucial to the understanding of how the system works. In total, 14 reinforcing- and 11 balancing feedback processes are taken into account for further description. As the system analysis with the impact matrix already has shown, the element “Diseases and pest” is highly unpredictable and has a big influence on almost every possible intervention. With “drivers” like the element just mentioned, the system looks a lot more unstable than the systems role analysis concluded.

All three CLD parts are still connected over their boundaries to variables in the other parts. In Appendix 2, chapter 16 every identified feedback loop is described further.

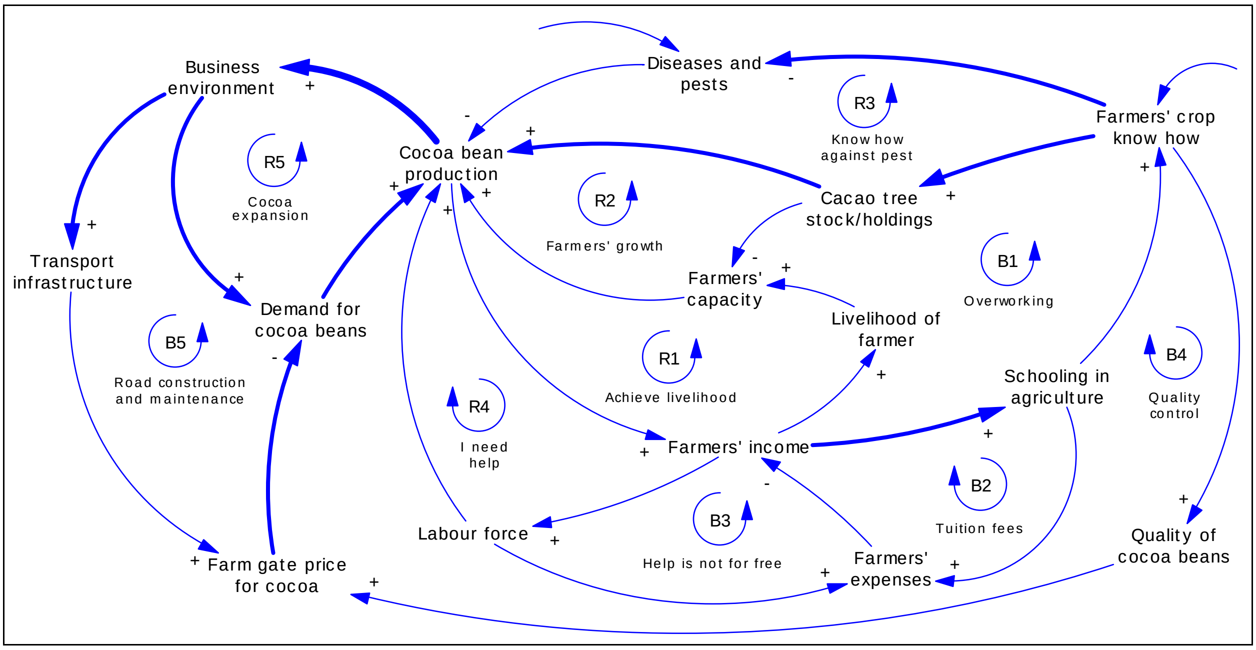



**Figure 4-1: CLD Part 1**

The CLD in Figure 4-1 contains five reinforcing and five balancing feedback processes, including the expansion of cocoa and farmers’ capacity, knowledge and livelihood. In this CLD an identified loop is for example the reinforcing R2- loop – “Farmers’ growth” - which can be read as follows:

> *When “Schooling in agriculture” is available and attended by the farmer, the “Farmers' crop know-how” will increase, therefore, a higher amount of “Cacao tree stock/holdings” is possible which leads to a higher “Cocoa bean production” and higher “Farmers' income” which again leads back to more “Schooling in agriculture” to get even more “Farmers' crop know-how” again.*

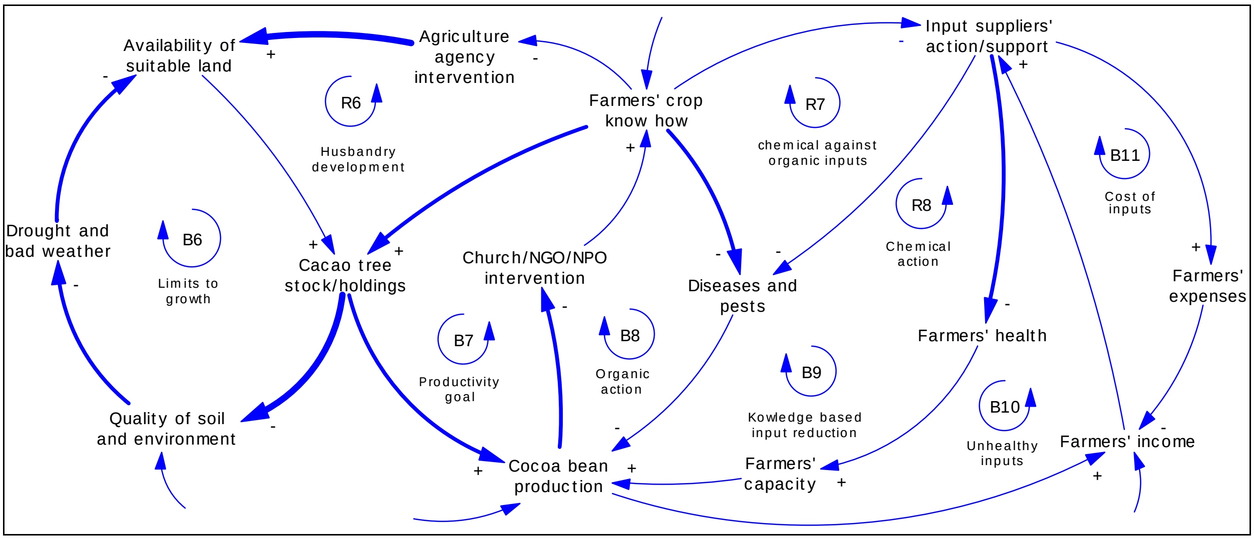



**Figure 4-2: CLD Part 2**

The CLD in Figure 4-2 contains three reinforcing and six balancing feedback processes, including government, private and input suppliers intervention, and balancing feedbacks caused by the diseases and pests. As an example, B10 which is the balancing loop because of “unhealthy Inputs”:

> *More action against CPB with “Input suppliers' action/support” through pesticides, results in bad “Farmers' health” which results in lower “Farmers' capacity”. Subsequently, the “Cocoa bean production” drops and “Farmers' income” declines, therefore, this leads to lower “Input suppliers' action/support”.*

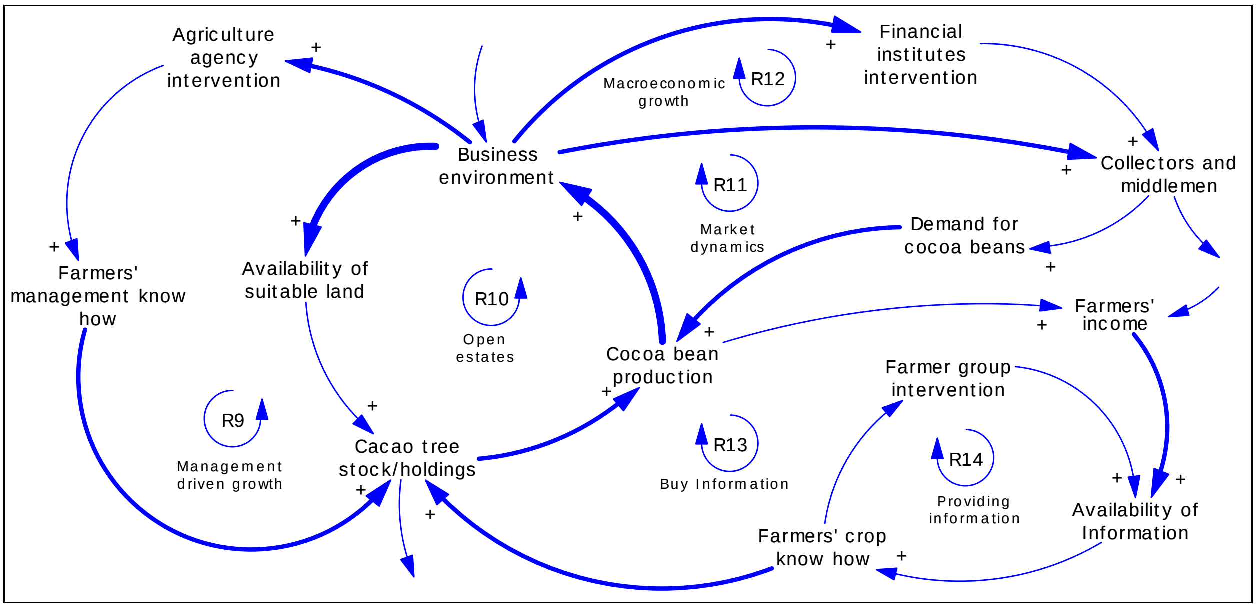



**Figure 4-3: CLD Part 3**

The CLD in Figure 4-3 contains six reinforcing and no balancing feedback processes, as there are no balancing factors, such as “Diseases and pests”, included in this particular CLD. This CLD shows the overall macroeconomic view, as well the availability of information and know-how. One of these reinforcing feedbacks can be read like the following R10-loop, “Open estates”:

> *If there is more “Availability of suitable land”, then “Cacao tree stock/holdings” rises as well as the “Cocoa bean production”, and this is beneficial to the overall “Business environment” which triggers more “Availability of suitable land”.*

The CLD analysis offers the analyst a deep insight into the system and provides the basic structure for the intended simulation model. Further CLD will be developed continually, for example the livelihood CLD in chapter 5.1.5.

## 4.2 Systems Archetypes

Successful systems’ thinking is about being able to see the whole picture or context of a situation and its interconnections with its environment. With the knowledge gained from the causal loop analysis, the analyst is now able to recognize specific patterns and structures in the system.

**Box 4-1: What are systems archetypes**

Systems archetypes are the "classic stories" in systems’ thinking — common patterns and structures that occur repeatedly in different settings. It is important to recognise that systems archetypes are first and foremost a communication device to share dynamic insights.

The system of Flores’ cocoa production most outstanding patterns are “Out of Control” (e.g. “fixes that fail” and “shifting the burden”), as well as the “Underachievement Archetype” (e.g. “limits to success” and “tragedy of the commons”).

### 4.2.1 Shifting the Burden Archetypes

A “shifting the burden” story situation usually begins with a problem symptom that prompts someone to intervene and solve it. The solutions are obvious and immediate and they relieve the problem symptom quickly. However, those “quick fixes” divert attention away from the real or fundamental source of the problem, which becomes weaker as less attention is paid to it. This reinforces the perception that there is no way out except the symptomatic solution. Furthermore, those “quick fixes” trigger once more unintended consequences that compound the problem. Those additional reinforcing loops degrade the system into a so called “addiction”. The addiction becomes worse than the original problem, because of the devastation it wreaks on the fundamental ability to address the problem symptom.

### Low Productivity

The identified problem symptom is the low productivity among cacao farmers in Flores. Because of the lack of knowledge and the inability to gain know-how immediately, farmers are looking for a fast symptom-correcting process. Such a quick fix is the application of extensive inputs like pesticide, insecticide, fungicide and hormones. It is widely known that a more fundamental solution is required to tackle the source of the problem[14]. But the corrective action - increase the level of farming and crop management know-how – would take much longer, so it has less effect on the problem symptom. However, in the long term, it will be a better way to fight diseases and pests.

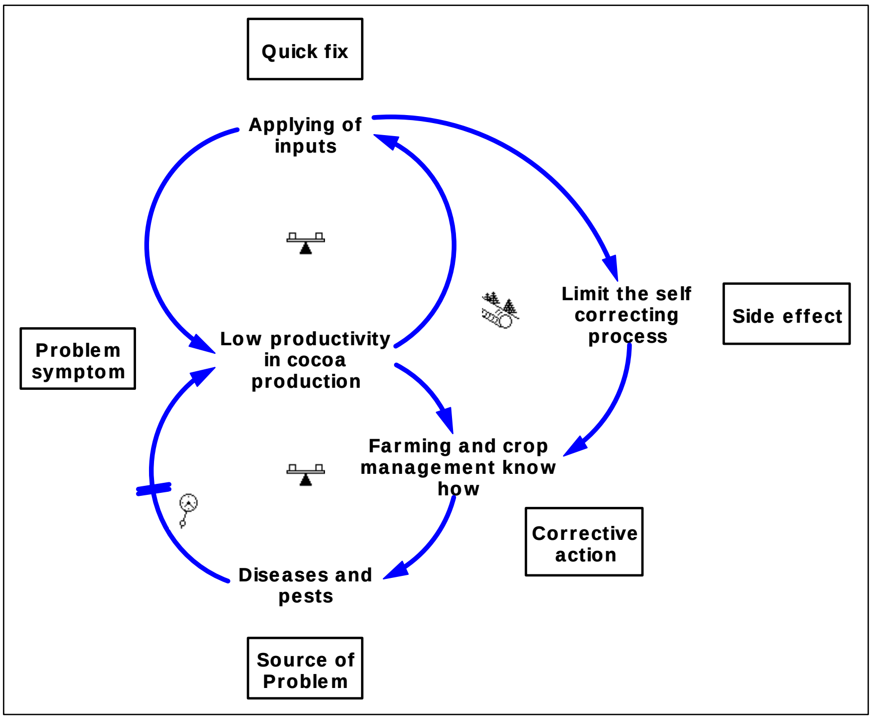



**Figure 4-4: Low productivity archetype**

By only fighting against the problem's symptom the farmer creates "fixes that backfire", because of the addictive side effect. The farmer gets accustomed to the use of inputs, and therefore, does not need to care about further know-how development. Gradually, the farmer becomes addicted to apply inputs, creating a financial crisis at the expense of fundamental long-term changes.

### Cash Flow bottleneck

Another problem symptom is the constant shortage of cash among smallholder cacao farmers. Widespread quick fixes for this problem are selling the cocoa beans for a fixed price to the collector even before they are harvested to get the money immediately, and deliver them later. The even worse quick fix is the selling of not yet dried or only partially dried cocoa beans to get the money a few days earlier than for fully dried beans. Figure 4-5 shows this particular pattern in a classic "shifting the burden" archetype with two unintended side effects with both having reinforcing impacts.

[14] e.g.: Wood, Brian J. (2004): *Pest control in Malaysia's perennial crops: A half century tracking the pathway to integrated pest management*. Netherland: Kluwer Academic Publishers.

There are three reasons as to why the farmers do not dry their beans: firstly, they need the money immediately, secondly, they hope for a higher yield because the weight of the beans is higher when they are un-dried and, thirdly, they do not have the capacity to dry them.

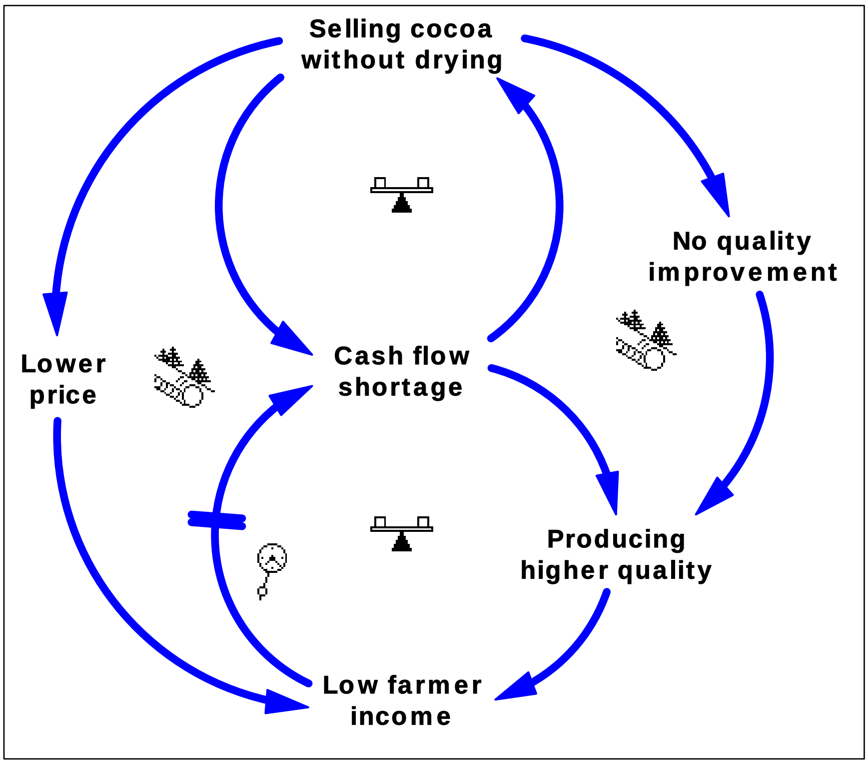



**Figure 4-5: Cash flow shortage archetype**

The practice to sell the beans un-dried triggers a lower price. The farmers manoeuvre themselves into bargaining positions where they cannot negotiate a proper price. Often the farmers get only half of the official farm gate price for their beans. If they do not break out of this addiction, they are not able to solve the fundamental problem, the permanent shortage of cash. As a result, their income drops even further.

If the farmers are not willing or able to produce a higher quality because of the constant shortage in cash, they confine themselves in the long-term with no quality improvement. The farmers get addicted to the habit of selling un-dried beans and, hence, there is no motivation to produce a higher quality.

The lack of knowledge, combined with the limited physical capacity of the farmers, suppresses a fundamental solution – a corrective action like producing higher quality for a better farm gate price – to lift the farmers' income to a desired level. The farmers need the know-how to produce a higher quality, and the possible incentives for a higher cocoa bean quality.

### 4.2.2 Underachievement Archetype

A further term that is often used in connection with cocoa production in Flores is underachievement. One speaks of underachievement when intended achievement fails to be realised. Nothing can grow without limits, in every aspect of life, patterns of growth and limits come together in various combinations. Sometimes growth dominates; other times limits dominate; and often the degree of influence shifts back and forth between them (Senge, 2003).

The history of Indonesia's large expansion of cocoa farming over the last twenty years has been driven by a large number of growth factors (Figure 4-6). Every growth factor has a limit or constraint; consequently, a large number of "limits to growth", "limits to success" and even some "tragedy of the commons" behaviour exist in the system.

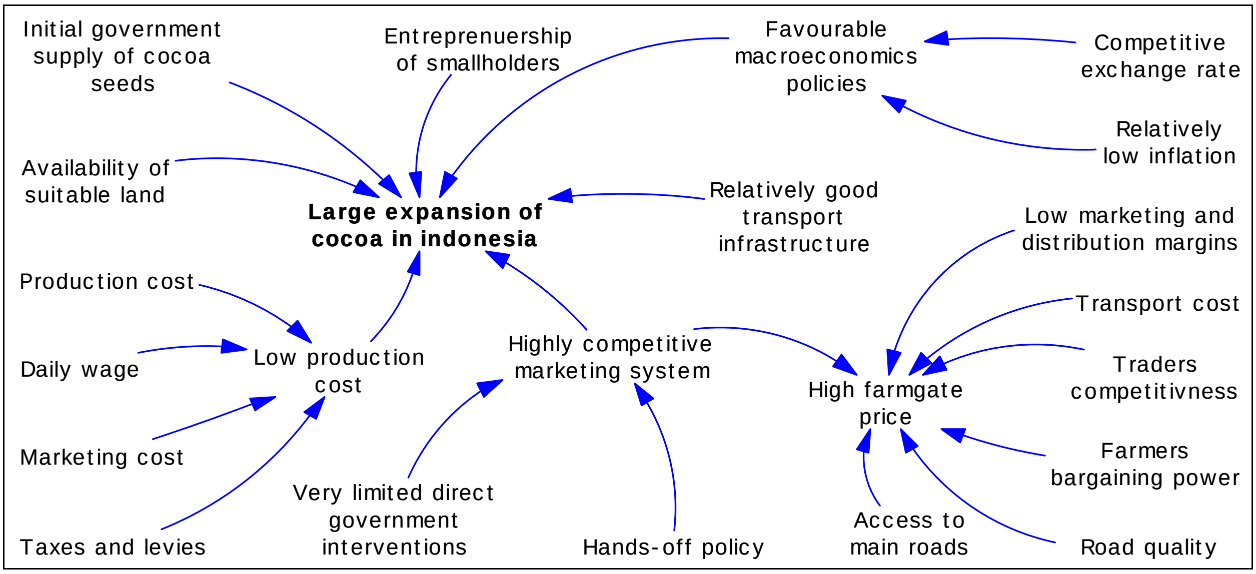



**Figure 4-6: Indonesia's cocoa expansion**

Indonesia's government announced an expected annual growth in the cocoa sector of 2,5% until 2010, afterwards a 1,5% annual growth up to 2020. To further the expansion, the following aims are announced: Extension cocoa planting area, pest and disease control, quality increase, integrate farming management, increase the income of the cultivators, strengthen the input suppliers, and to establish local processing.[15]

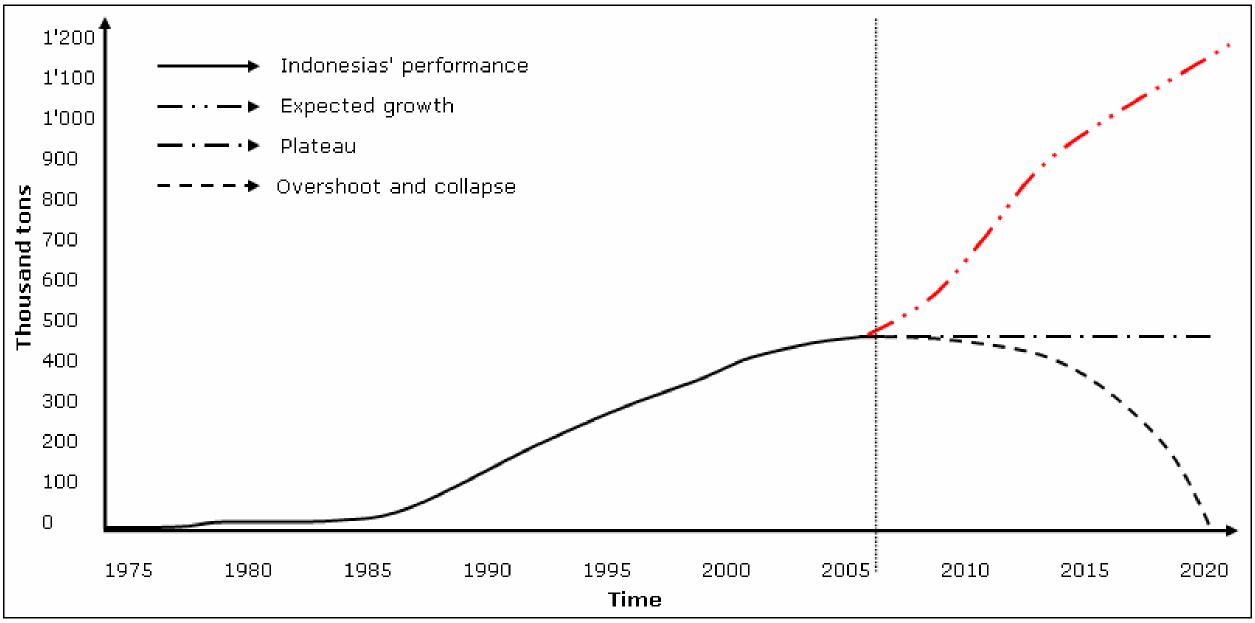



**Figure 4-7: Patterns of behaviour in the Indonesian cocoa production**

[15] Agriculture Department of Indonesia: Agribisnis Kakao; Prospek dan Arah Pengembangan (2005)

The graph in Figure 4-7 shows the possible patterns of behaviour. If everything is working as proposed, the expected growths will double the annual production until 2020 (red line in the graph). However, if the growth levels off, the system has reached some source of resistance which prevents further improvements. Even though every actor in the system works harder, the earlier boom does not return; in addition, the harder they push, the harder the system seems to push back. At this point, instead of the expected growth, there are two potential patterns of behaviour:

The performance either reaches a plateau, after which it remains in equilibrium; or the system zooms past its natural constraints and crashes completely.

With the following two archetypes, the analyst shows two possible feedback structures to influence the system's behaviour; one including the farmers' capacity and knowledge, and the other one including the limits of the environment.

**Limits to Success**

In the "limits to success" case a reinforcing loop is created with the intention to convert farmers crop and management know-how into a higher production of cocoa within the knowledge based sector of the cocoa production (blue reinforcing loop). However, an unintended, balancing consequence of this effort is that the farmers' limited capacity in the physical sector of the cocoa production is exceeded, actually reducing the production.

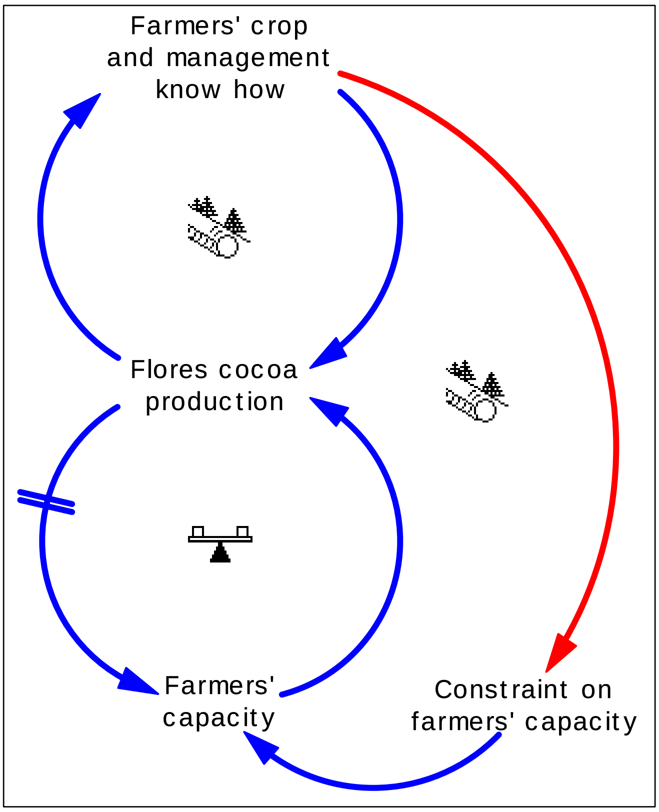



**Figure 4-8: Limits to success archetype**

A weak solution would be to simply add a second balancing loop by using the farmers' capacity to reactively trigger new capacity additions. The stronger closed-loop solution (depicted with the red arrow) takes the form of more management know-how - like efficient time management and motivation techniques - to control the constraints on the farmers' capacity.

**Tragedy of the Commons**

In the "tragedy of the commons" case a reinforcing loop is created by the activity of the government to expand the cocoa production with the intention to increase the numbers of cacao trees on Flores. However, an unintended consequence is that this large expanding strategy results in an overuse of and damage to the environment. This reduces the magnitude of the outcome for all other cash crops too. Here the unintended, balancing loop results in an unsustainable environment to the detriment of everyone’s livelihood.

In the usual representation of this archetype, two reinforcing loops are shown representing the separate activities of two groups of people. The side effects of the two groups are then combined in a resource constrained balancing loop. In reality n groups are often present in a “tragedy of the commons” situation and it is argued here that it is equally justifiable to limit the representation to the combined effect of all groups as it is to restrict the representation to two groups (Wolstenholme, 2003).

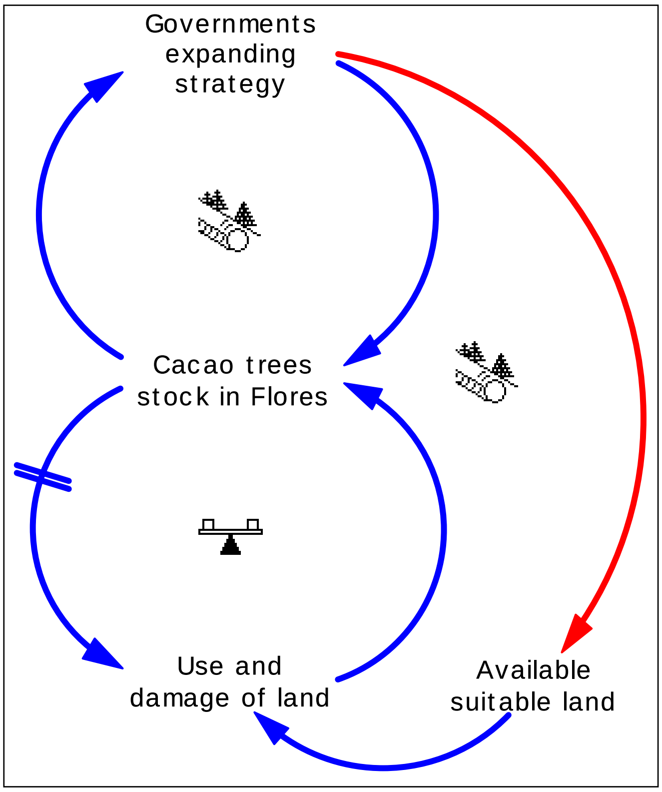



**Figure 4-9: Tragedy of the commons archetype**

In the case of the “tragedy of the commons” a closed-loop solution depends on whether the constraint can be unblocked. If more land can be made available, then this should be realised in proportion to the demand of each cash crop and their kickback on the land in question. If this is not possible, planting must be constrained, perhaps by density rules in line with defining and achieving acceptable damage limitation.

## 4.3 Conclusion

The causal loop analysis and the definition of archetypes have shown many patterns of behaviour and the inherent impact of the variable set determining the system’s performance. The mental models of every member of the team concerning the cocoa intervention are widening by debate and discuss the archetypes as well as the common collection of all the system’s cross linking. The CLD have shown a large number of feedback loops in the system. It is not possible to draw them all in a single CLD, this would not reduce the real world’s complexity – this would be as complex as the real system itself. All the interrelations and the understanding of crucial patterns of behaviour are important to develop a virtual world of the system.

Step 2 of the methodology is thereby completed and all the findings have to be converted into stock and flow diagrams as described in the next chapter. Yet, the findings of the CLD and the archetypes are not only to create a functional simulation model. Here on can say that the saying: “the way is the goal” is well placed - by analysing the system, finding the relevant feedback loops and searching for existing patterns of behaviour, the analyst and the team involved gained experience in the system’s inherent impact as well as the ability to talk about the behaviour of the system in case of changes.

# 5 System Dynamics; Modelling of Farmers’ Behaviour

*“The only thing constant is change. To do nothing is to do something too.”*
*Heraclitus, 500 BC*

Action – following a decision - always includes risk and uncertainty. Risk suggests measurable probability. Uncertainty is when the likelihood of future events is simply incalculable. Furthermore, uncertainty is when you are not even aware of what you do not know. Therefore, a simulation model is more for foresight and policy design than prediction. Foresight is the availability to anticipate how the system will behave if and when certain changes occur. It is not forecasting, and it does not depend on the ability to predict.

This chapter clarifies the modellers approach to grasp the decision making processes among cocoa farmers, and the conviction of the findings from the system description and feedback analysis into a virtual model.

## 5.1 Decision Making

### 5.1.1 The Concept of Mankind of the Farmers

Given the information available to the farmers, do they make rational, optimal decisions or is their behaviour naïve and mindless? Do farmers make systematic errors? How and how quickly do learning and adaptation occur? Human decision making generally falls in between the extremes of mindless rote behaviour and the perfect rationality of economic theory. The evidence suggests that the rationality of human decision making is bounded (Simon, 1957).

**Box 5-1: Bounded rationality**

Bounded rationality results from limitations on our knowledge, cognitive capabilities and time, our perceptions are selective, our knowledge of the real world is incomplete, [...], and our powers of deduction and inference are weak and fallible. Emotional, subconscious, and other non-rational factors affect our behaviour. Deliberation takes time and we must often make decisions before we are ready (Sterman, 2000).

For Flores' cocoa farmers, optimal decision making is impossible. To do so requires assessing all relevant system actors' behaviour and predicting the market's dynamics and further developments, as well as fundamental knowledge of crop and farming management.

If there is bounded rationality among decision making, how then do farmers make decisions? Extensive field interviewing by the analyst has shown that the farmers are not eager to make decisions. They mostly wait until solutions to their problems appear, often in the hope that someone is simply providing an answer. Another finding is that the farmers are often not aware of the problem, or worse, they do not care.

> *To support farmers in decision making, their problem awareness must be supported first. To get the farmers aware of the real problems, they must first have the chance to gain the needed know-how to handle their bounded rationality.*

### 5.1.2 The Farmers' biases in decision making

Biases can creep into farmers' decision making processes, calling into question the correctness of a decision or even block the decision making process. Common cognitive biases observed in farmers' decision making processes are:

- Wishful thinking and optimism – farmers tend to want to see things in a positive light, which can distort their perception and thinking. Even if the trees are highly infected by the CPB – they still have a tree, which suggests saved income.
- Experiential limitations – unwillingness or inability of the farmers to look beyond the scope of their past experiences; they often reject the unfamiliar.
- Unwillingness or inertia to change thought patterns that farmers have used in the past in the face of new circumstances.
- Source credibility bias – farmers often reject information from groups, organizations or government, if they have a bias against their credibility.
- Peer pressure to conform the opinions held by the farmer group, the community or other influencing actors.
- Decisions are influenced by initial information.

### 5.1.3 Available Information and the Cocoa Value Chain

Unlike several other Indonesian commodity sectors, the government's involvement in the cocoa industry has been minimal. Minimal intervention combined with Indonesia's infrastructure has created a highly efficient marketing system, making Indonesia the most competitive producing country in the world cocoa market. Whilst the development of a free-market trading system in Indonesia's cocoa value chain[16] had earlier been congratulated for its efficiency and transparency, it is currently unable to transmit appropriate quality signals

[16] For further information about Indonesians Value Chain, see Appendix 1, Chapter 13

to farm-level decision makers. Furthermore, there have been few incentives to improve the quality of cocoa exports, in part because of the limited knowledge of many Indonesian middlemen with respect to cocoa handling, quality and storage. Thus, the existing cocoa value chain system does not provide a ready structure for managing social responsibility. No single powerful driver exists. The following short description of the value chain actors beside the cocoa producing farmers are described below.

**Associations**

In the past a major role has been played by the industry association, ASKINDO (the Indonesian Cocoa Association), but in the past few years the role of ASKINDO has diminished and it is seen as increasingly weak and ineffective. Currently, there are no effective growers associations in Indonesia.

**Collectors**

Smallholders have a variety of options when selling their crop. Normally there are several collectors and middlemen in each area and, consequently, strong competition exists.

**Middlemen / traders / exporters**

Middlemen acquire beans from collectors and arrange the transportation to the exporters or to local grinders. Many of the internal traders are of Indonesian Chinese origin. Exporters buy primarily on a "back to back" basis from small village traders i.e. the buying price and the selling price are fixed simultaneously. As in the case of producers, exporters are exposed to large price risks and invariably need to hold stocks to meet forward physical commitments. [17]

> *Out of the value chain analysis, one can say that there is no helpful information available for the cocoa farmers. The value chain actors themselves lack knowledge and information, therefore, they are not in a position to further information to the farmers, and are themselves targets for possible training.*

### 5.1.4 Farmers' Livelihood

Modelling farmers' livelihood is a task for itself, which needs specific empirical research to get all the data needed in order to provide a powerful tool to evaluate the dynamics within particular communities, the likely effect of outside influences (e.g. climate change, commodity price fluctuations, policy changes, introduction of new technology, etc.), and the range of livelihood strategies that may be adopted to cope with these. The farmers' decision simulation model has to take into account feedback from changes in the livelihood of the farmers, and modelling of the livelihood in a simplified way. Carney (1998, p.4) defines the term livelihood as follows:

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[17] Source: Bedford A., et al.: *In Focus Report. Cacao.* Natural Resource Institute: 2006.

> *„A livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base".*

Often observed is the laziness of the farmer. Almost every farmer the analyst and the team visited was sitting around near his house or on the road – no matter what time of the day. This behaviour not only occurred on smallholder farms, but also in larger plantations where paid labour force works. Even there the workers were sitting under the cacao trees. The questions now arise: where does this "laziness" come from? Is it just the European sight of the analyst? Is this behaviour actually laziness?

> *Laziness probably evolved out of the survival advantage of conserving energy whenever possible. By avoiding unnecessary energy outputs, the individual lowers his food needs and conserves his energy reserves for escaping from predators and other unavoidable demands (Kort E. Patterson).*

This saying is profound in the cocoa farmers' pattern of behaviour. Laziness among farmers is not talking about doing nothing, they simply realize that they do not need a lot of money to be happy and, hence, only work for what they need. Furthermore, as is the cocoa growing estate not just around their houses, but often a few kilometres away and up the hills, they just have not enough energy to go to their plantations every day.

The cocoa farmers are only superficially lazy; they constantly attempt to minimize their activity level, doing only as little as necessary to sustain life. They remove just enough of the rocks from just enough of their land to grow just enough food to stay alive. As they go through life farmers attempt to find ways to expend the minimum effort at that particular moment, and only do what can not be avoided. For example, when faced with the unavoidable need to fetch water they only fill as many pails as they need at the moment.

### 5.1.5 Livelihoods influence on decision making

As most cocoa farmer are aware of the fact that they have to work for their food security. However, they are seldom conscious of the fact that they have to maintain their plantations – not only get seedlings from government, plant them, and harvest until eternity – to secure a sustainable source of income. The poor maintenance of the cacao trees is not only a problem of their unawareness, it is also strongly connected with their capacity. The farmers' capacity to work is bounded by health, energy resources, intrinsic as well extrinsic motivation, and the financial pressure to work – all this is determined by the farmers' livelihood.

*Therefore, to level up the awareness of the farmers' need of maintaining their trees, they must get the capacity to do so, and this is only possible with a higher livelihood level, which has to be reached first.*

Hence, there are many key intermediate variables to be considered before the livelihood impact on the farmers' decision making can be assessed. The modeller takes a CLD approach to grasp the farmers' livelihood assets to create the important feedback loops. Livelihoods assets are the means of production available to a given individual, household or group that can be used in their livelihood activities. These assets are the basis on which livelihoods are built. In general, the greater and more varied the assets base, the higher and more durable the level of social security. Carney (1998) suggests that there are five dominant forms of livelihood assets arranged in a pentagon:

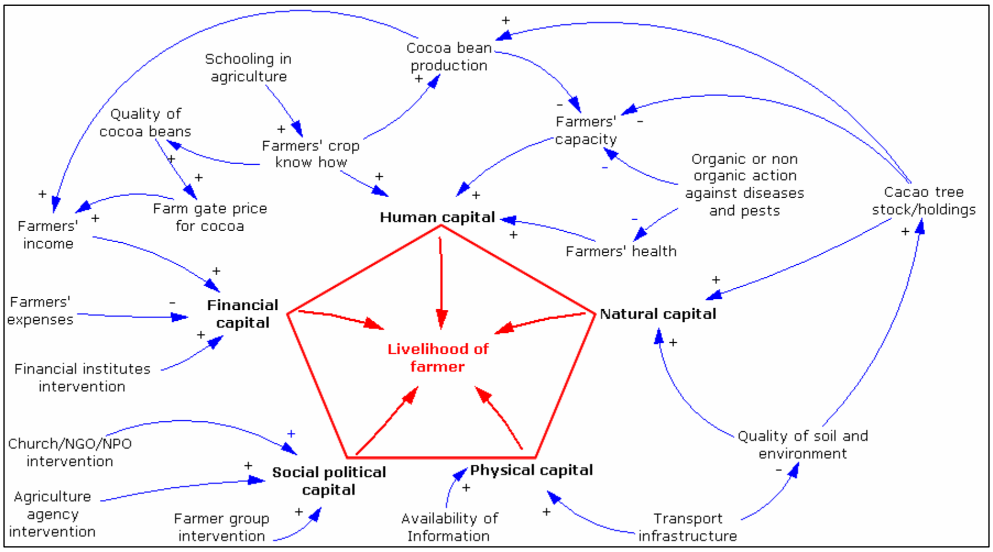


**Figure 5-1: Livelihood assets CLD**

### Natural Capital

Natural capital is the natural resource stock from which resource flows useful to livelihoods are derived.

### Social-political Capital

The horizontal and vertical social resources (networks, membership of groups, relationships of trust, access to wider institutions of society) upon which people draw in pursuit of their livelihood.

### Human Capital

The skills, knowledge, ability to labour and good health important to the ability to pursue livelihood strategies determine the human capital.

### Physical Capital

The physical capital is the basic infrastructure (transport, shelter, water, energy, and communications) and production equipment and means which enable people to pursue their livelihoods.

**Financial Capital**

Financial capital is financial resources which are available to people (whether savings, supplies of credit, or regular remittances or pensions) and which provide them with different livelihood options.

## 5.2 Problem Articulating

The model to be developed must be a representation of the decision taking among cocoa farmers in Flores. In order for it to be useful, the model addresses a specific problem, and simplifies rather than attempts to mirror the entire system in detail. Every decision taken by farmers influences the system around them; therefore, to show the impacts of particular decisions and interventions, the entire system must be modelled in a simplified way. In addition, the model must represent the physical world, dynamic processes, feedback relationships, soft variables and unmeasured quantities, as well as the delays between actions and results.

To determine the appropriate object detail level, the system has to be delimited according to the next steps.

### 5.2.1 Purpose of the Model

The purpose of the model is to reflect the impacts of the various possible decisions taken by the farmers. The model has furthermore the purpose to serve as a learning laboratory for the LED-NTT project team as well as for potential partners for interventions.

By developing a simulations model within a local project team, the model gives an opportunity to develop the skills of the team and widens the mental models of every team member involved.

### 5.2.2 Time Horizon and -Delays

The lifecycle of the cacao tree is one of the major components which determine the timeframe of the model. When looked after carefully, most cacao trees begin to bear fruit in the fifth year. A cacao tree reaches peak production in approximately ten years after planting and will continue to produce pods at a high level for an additional 12 - 13 years. It is not uncommon to find trees 30 - 40 years old, still producing pods. Other time delay defining components are the time to become aware of a problem, the time to decide, the time to act, and the time it takes until the actions get effective. Figure 5-2 depicts the summarized time delays from the first appearance of declining production until new planted trees become old trees. The curved line shows how cocoa production might evolve in the future, under the assumption that the farmers rejuvenate their plantation once. This expected behaviour, called reference mode, will be used later in the modelling process as a reference to check the simulations outcome.

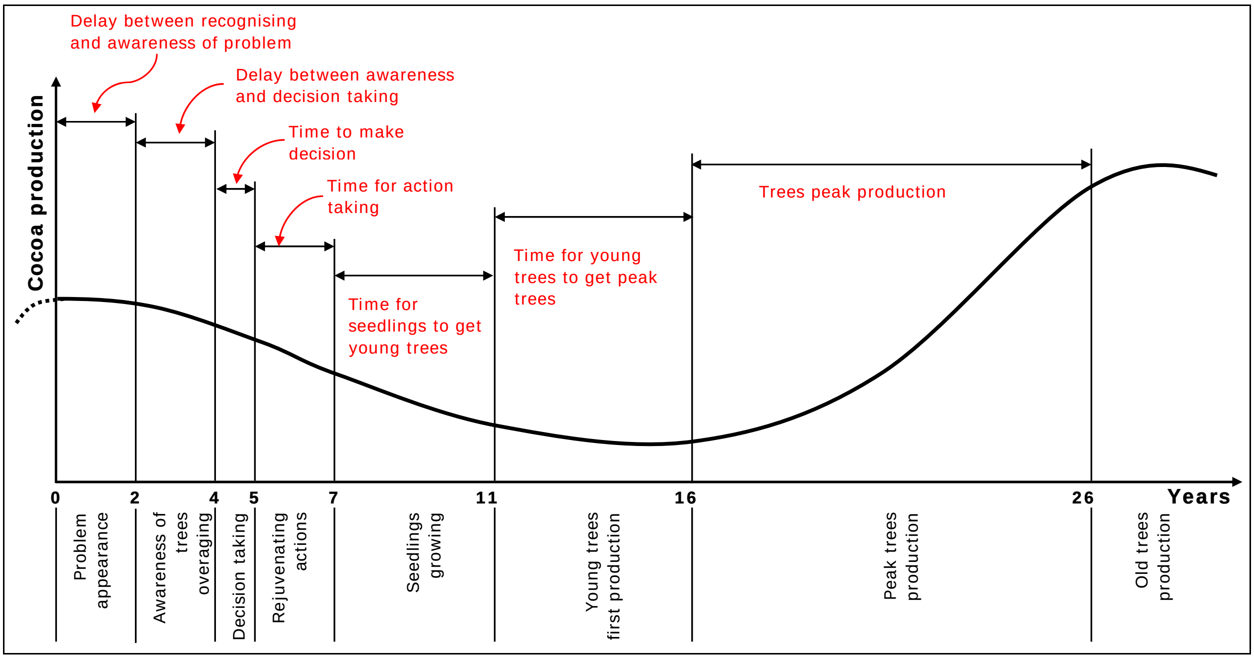


**Figure 5-2: Time delays in the tree over-aging problem**

In dynamically complex systems, cause and effect are distant in time and space. Most of the unintended consequences (see chapter 4.2) of decisions leading to policy resistance involve feedbacks with long delays, far removed from the point of decision or the problem symptom. A long time horizon is a critical antidote to the event-oriented worldview, so crippling to our ability to identify patterns of behaviour and the feedback structures generating them (Sterman, 2000). Therefore, the modeller suggests a time frame of 30 years,[18] starting in the year 2005.

The time dimension is especially troublesome in decision making. Every decision takes some time, which creates delays in the problem solving process. Therefore, one of the various model inputs must be the possibility to change decision times between problem awareness and acting.

### 5.2.3 Model Boundaries

The system's model boundary must be wide enough to include every important feedback, but as narrow as possible to keep the model in a handy complexity. The model's boundary determines which element of the variable set is endogenous, exogenous, or even excluded. Endogenous variables are calculated by the model itself. They are the variables explained by the structure of the model, the ones for which the modeller has an explicit theory, and the ones that respond to feedback. On the other hand, exogenous variables are ones that influence other variables in the model but are not calculated by the model (Sterman, 1988).

[18] According to a role of thumb (Sterman, 2000: 94), the time horizon should be set several times as long as the longest time delay in the system.

Whilst in the impact matrix every variable of the variable set is seen as endogenous, this approach is not possible when modelling a specific problem of the whole system. In a decision taking model, the focus lays on the possible decisions for an action – and as we know that every decided action needs basic knowledge to do so – the source of knowledge will not be modelled. Therefore, the possible partners for interventions to level up the farmers' know-how are not included as endogenous variables in the decision taking model. Table 5-1 shows how the previously developed variable set is used in the model, therefore, sets the model's boundary.

**Table 5-1: Model boundary chart**

| Endogenous | Exogenous | Excluded |
|---|---|---|
| Availability of suitable land | Agriculture agency intervention | Business environment |
| Cacao tree stock/holdings | Availability of information | Collectors and middlemen |
| Cocoa bean production | Church/NGO/NPO intervention | Drought and bad weather |
| Diseases and pests | Demand for cocoa beans | Input suppliers' action/support |
| Farmers' capacity | Farmer group intervention | Labour force (employees) |
| Farmers' crop know-how | Financial institutes intervention | |
| Farmers' expenses | Schooling in agriculture | |
| Farmers' health | Transport infrastructure | |
| Farmers' income | | |
| Farmers' management know-how | | |
| Farm gate price for cocoa | | |
| Livelihood of farmer | | |
| Quality of cocoa beans | | |
| Quality of soil and environment | | |

### 5.2.4 Model Subsystems

The subsystems diagram in Figure 5-3 shows the overall architecture of the model. The simulation model itself is divided into several subsystems. The farmers' system is the main system, while the markets' system and the interventions' system only provide outside inputs which are not involved in the modelled farmers' system feedback processes. Shown along with the subsystems are the flows of information, material, goods, and money, to point out the systems inherent feedback processes which the analyst has already revealed. Every subsystem (depicted as the pale brown rectangles in the figure) represents one view (screen-page) in the simulation model.

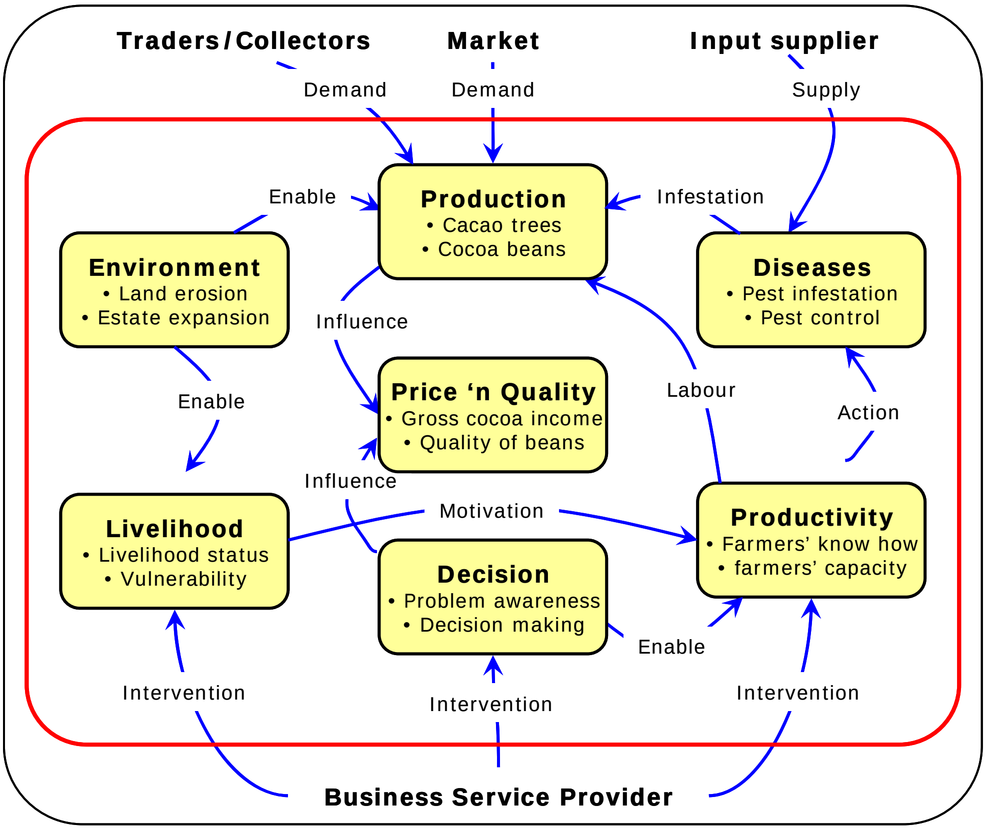


**Figure 5-3: Model subsystems diagram**

## 5.3 Formulating the Simulation Model

After the development of the initial dynamic hypothesis, model boundary, and conceptual model, they must be tested. Since it is impossible for the analyst to conduct the real world experiments, the tests and experiments must be carried out in the virtual world. To do so, the analyst must now move from the conceptual realm of diagrams and models to a fully specified formal simulation model complete with equations, parameters, and initial conditions.

The documentation of all the simulation models, equations, initial values, parameter description, and stock and flow diagrams can be found in Appendix 3.

## 5.4 Tests

To test the model, the analyst will use the Monte Carlo method, a widely used class of computational algorithms in order to simulate the behaviour of various physical and mathematical systems.

Specific parameter values can change the appearance of the graphs representing the behaviour of the system. But significant changes in behaviour do not occur for all parameters. System dynamics models are generally insensitive to many parameter changes. It is the structure of the system, and not the parameter values that has most influence on the behaviour of the system.

Therefore, 13 parameters (decision times and possible decisions) -excluding the exogenous elements which only have influence on the livelihood rate but do not have direct influence on the decision making simulation - are chosen for the sensitivity test. For the values of the parameters “Potentially estate for cocoa beans” and “Desired new tree planting” the “RANDOM UNIFORM(min,max)” function is used, which takes values from a uniform random distribution as sensitivity test inputs. For the other parameters the “VECTOR(min,max,increment)” function is used. This generates a sequence of numbers from min to max by increment, as the possible inputs only vary between two values: 0 or 1.

The sensitivity analysis has shown that the cocoa farmers’ decision making model reacts significantly to the random combination of values in model inputs. 200 simulation runs with random inputs have been calculated. The graphics below show the results for three selected outputs of the system.

The colours below, and in the following graphs, indicate the certainty of appearance:

sensitivity
50% 75% 95% 100%

The first simulation run (with the values of the constants contained in the model) is plotted as a blue line indicated by the run name “sensitivity”.

Figure 5-4 depicts possible outcomes for the cocoa bean production over the next 30 years. The initial value is approximately 0.6 kg per tree and year. Farmers predicted the value for 2006 to about 0.4 kg (compare Figure 3-2; divided by an average of 1’000 trees per hectare).

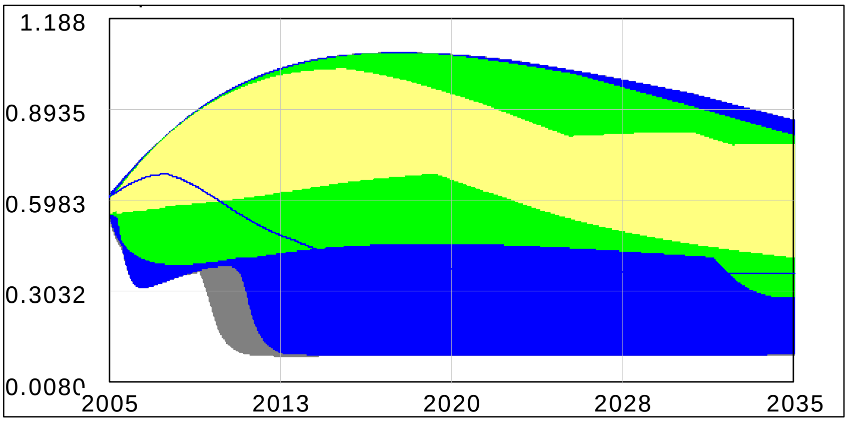


**Figure 5-4: Cocoa bean production (kg/tree/year)**

This predicted value lies within 95% of the entire outcome of the tests. However, the sensitivity test points out that in 50% of the runs higher productivity rates result. It can be interpreted that there are many possible improvement opportunities in the farmers system. In addition, the sensitivity test proves that the modelled system’s behaviour is within possible values for the cocoa bean production. It also shows that in the worst case, with possibilities up to 100%, a cocoa bean production results which is far below the farmers’ prediction.

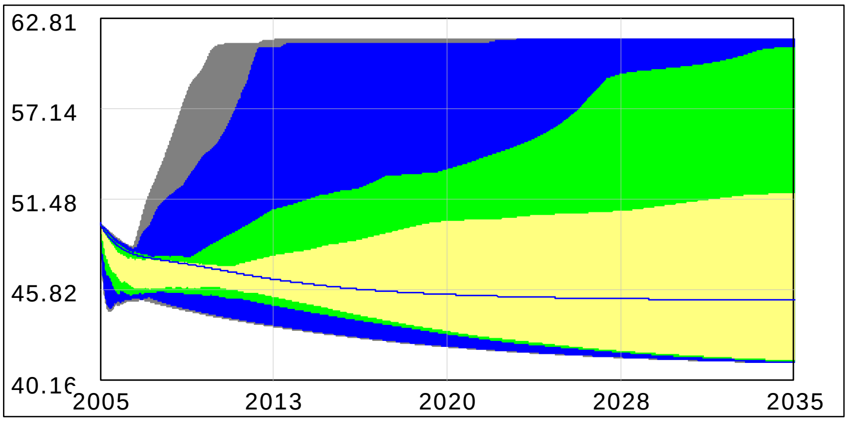


**Figure 5-5: Farmers' livelihood (fraction)**

The livelihood outcome, affected by the farmers' decision making – except the exogenous inputs – is depicted in Figure 5-5. Livelihood is quantified by values between 0 and 100, where the maximum value is the most possible, reachable outcome for smallholder farmers. As initial value, the value of 50 for the actual situation is assumed by the analyst. The sensitive analysis shows that possible outcomes with almost 100% certainty range from approximately 40 up to 60 livelihood fraction points. Specific, optimised runs combined with the optimised changes in the exogenous parameters have shown that the livelihood could rise nearly to the optimum. Cocoa farmers' livelihood will not change significantly in 50% of the outcomes, with only a few being above the initial value. However, by finding the right combination of decisions, much higher values for the livelihood outcome are possible.

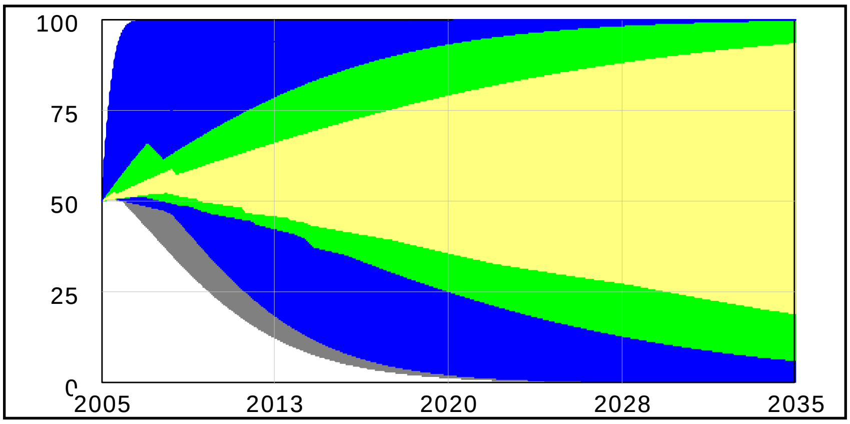


**Figure 5-6: CPB infestation (percent)**

For the outcomes of the CPB infestation, everything is possible. With the right decisions, the CPB infestation can be eliminated in the next 15 years. Yet, if there are no more actions the infestation will raise to 100% with a 95% certainty in the very near future. This possible high infestation, among other worst case values, is responsible for the lowest possible outcomes in cocoa bean production in Figure 5-4.

# 6 System Dynamics; Simulation of the Framers' System

If the farmers do not decide anything else apart from the decision to wait for a solution, presented by either the government or other possible intervention groups, the farmers' system will behave as described in this chapter. The simulation of the model starts in the year 2005 with the initial values that are described in appendix 3. This basic run simulates only over 20 years, as the last ten years show no significant difference in behaviour.

Provided that the farmers do plant 1.6 million (m) cacao seedlings every year - this is the average of the last five years -, Flores' cacao tree stock will behave like Figure 6-1 suggests. The amount of cacao trees will reach a peak in 2012 by 24.4 m trees, which are just 2.2 m trees more than the initial value due to rising tree loosing rates. If there is no awareness of planting new trees and replacing those that have been damaged or lost, the cacao stock will shrink to just 5.7 m trees in 2025. Possible interventions target the awareness and the need of tree replacement, felling trees, to fill the gap between the necessary trees reaching peak and the young trees, as well as the tree adjustment time by knowing the cacao trees specific lifecycle.

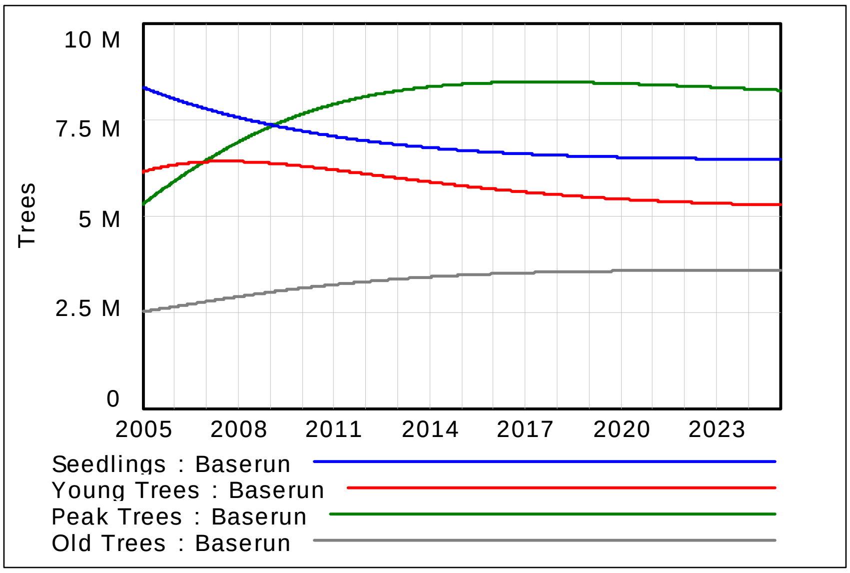


**Figure 6-1: Development of Flores cacao trees**

As it is assumed that the farmers plant the desired new cacao trees on newly developed land, the estate for cocoa will raise by every cacao tree planted until the estates reaches the limit of the available land suitable for cacao trees. Therefore, the tree density rate will decline, because it is assumed that the farmers do not replace lost trees in the existing estate. The percentage of trees lost due to density, pest, and poorer land fertility, will rise by almost two percent over the simulated timeframe (the grey line in Figure 6-2). Because the planted estate for cacao trees is crucial due to tree density and soil condition, the amount of land available is one changeable input in the model. The land fertility degradation rate, caused

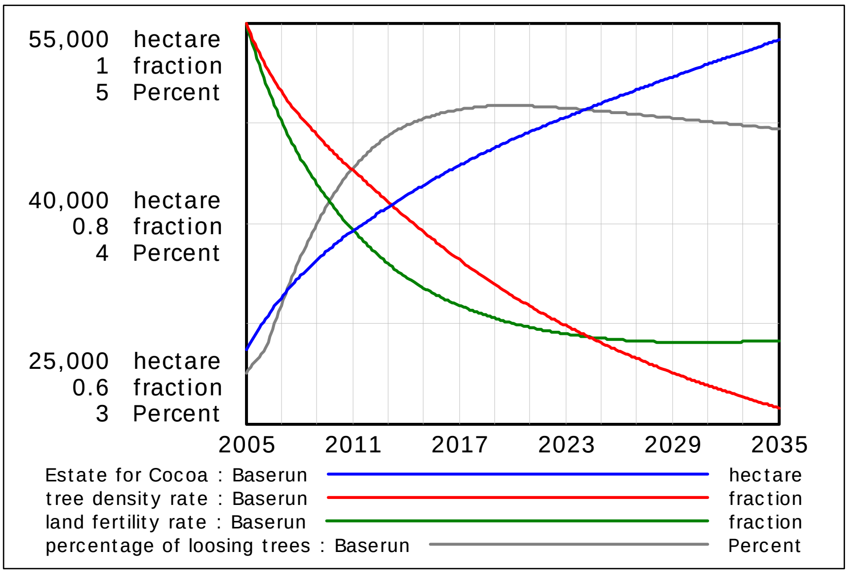


**Figure 6-2: Soil and environment condition**

by the cacao trees (density), can be countered by levelling the farmers' awareness of the need of sanitation and fertilisation of their land.

The soil condition not only influences the rising number of lost trees, but it is also linked to the cocoa bean production (blue line in Figure 6-3). The cocoa bean production is the amount of beans resulting when multiplying the cacao trees stock by the effective productivity rate. While the normal productivity rates of young-, peak- and old trees vary and are influenced by the CPB infestation and the farmers' know-how and capacity, combined with the changing distribution of the trees over time in those categories, the effective cocoa bean production is highly unpredictable. The cocoa bean production will reach a peak within two years and an increase of approximately 3'000 tons can be expected. This is the result of the government's efforts of planting new trees over the last decade.[19] The sharp fall following this peak is mostly caused by the uncontrolled growth of the CPB infestation, which will put the cocoa production in Flores, as well as the effective yield per produced kilogram into conditions which are simply not bearable for the farmers. In order to avoid this unfavourable development, the farmers must have immediate access to know-how to act effectively against diseases and pests.

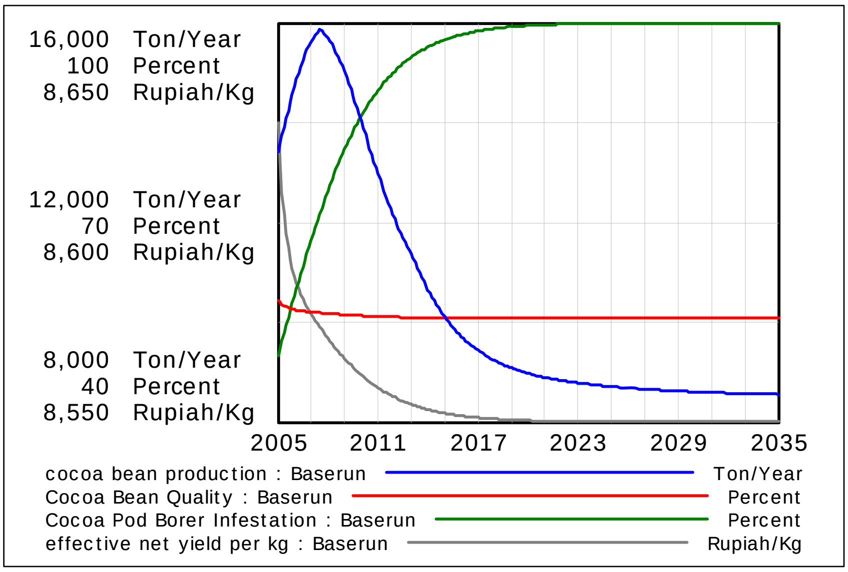


**Figure 6-3: Cocoa bean production**

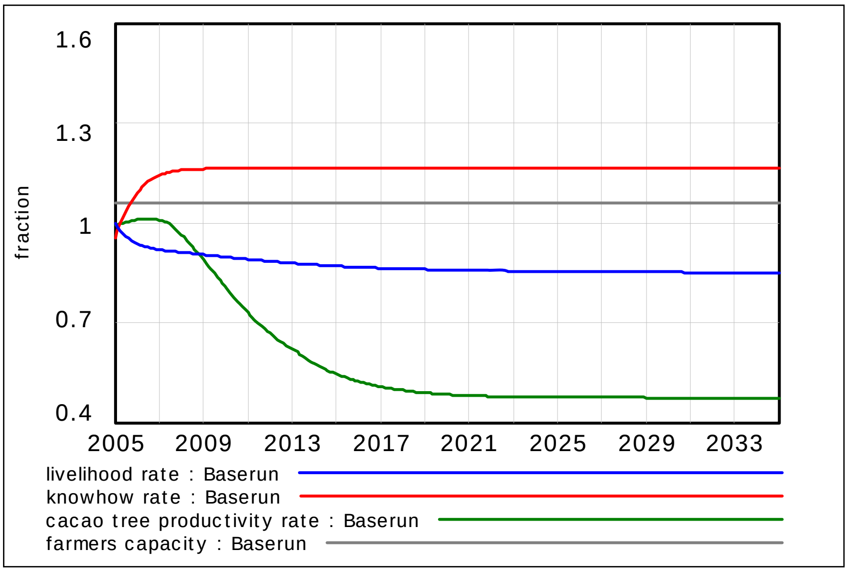


**Figure 6-4: Farmers' livelihood**

In the farmers' system all the limiting factors in the cacao trees productivity have to be targeted by

[19] Departemen Pertanian Republik Indonesia; http://www.deptan.go.id

interventions. As it is visible in Figure 6-4, besides the overshadowing effect of the CPB infestation, the farmer's knowledge, his physical capacity, and his overall livelihood outcome are also tightly connected with the cacao tree productivity rate. The farmers' desired know-how will increase with every decision made to act. Therefore, if schooling is available to get the know-how required to do so, his capacity will decrease. The question arises now why this is the case. With every new activity, the farmers' work exploitation rate will mount and cause more fatigue, which is the main limiting factor in the farmers' capacity.

In the virtual farmers' system simulation, five decisions concern the cacao trees stock and the estate available, another five decisions concern crop maintenance and fighting CPB, and a further four concern time delays and decision times. In addition to those farming concerning control levers, five exogenous interventions with direct influence on the farmers' livelihood are integrated for simulation. Every possible combination of changing the control levers' values - the farmers' decisions - can be simulated and the impacts of the decisions are visible immediately.

As it is necessary to simulate the farmers' system over 30 years to show at least one lifecycle of a planted cacao tree, the short-term impacts of decisions and interventions must be highlighted for immediate interventions. Therefore, the next chapter focuses on policies and strategies following the findings of this basic simulation, with the centre of attention in the years up to 2011. But by depicting the outcomes and impacts in graphics with a proposed timeframe of 30 years, the long- and middle-term impacts are not being ignored.

# 7 Policies and Strategies

*The complexity of the system's cause and effect are distant in time and space while we tend to look for causes near the events we seek to explain. Our attention is drawn to the symptoms of difficulty rather than the underlying cause. High leverage policies are often not obvious (Sterman, 2000).*

## 7.1 Recommendations on the Proposed LED-NTT Interventions

As it is one task of this thesis, the analyst shall compare the interventions proposed by the LED-NTT project with this systemic model for decision taking, and provide recommendations on how to improve the proposed strategies. To test the proposed strategies, summarized in Table 7-1, the cocoa farmers' system will be simulated over 30 years, to show the long-term impacts.

**Table 7-1: SC LED-NTT proposed interventions**

| Strategy | Description | Modelling approach |
|---|---|---|
| **Strategy 1** | Better access and use of quality inputs. | The two levers "Awareness of need of land fertilisation and decision to do so" and the "Awareness of CPB infestation and decision to act non organic against CPB" will be set. |
| **Strategy 2** | Sustained productivity through improved knowledge of quality inputs and farming techniques. | The same as strategy 1, because there are no other impacts of input suppliers. |
| **Strategy 3** | Access to higher market segment by improving quality of cocoa beans | The levers concerning the cocoa bean quality – "Drying of cocoa beans" and "Fermentation of cocoa beans" and "Church/NGO/NPO intervention" will be fully set. |
| **Strategy 4** | Availability of necessary financial resources and maximization of the available financial resources | The lever "Financial institutes' intervention" in the livelihood subsystem will be set. |
| **Strategy 5** | Improving conducive policy and business environment | This strategy targets the physical- and the social political capital in the livelihood's subsystem: "Availability of information", "Church/NGO/NPO intervention", "Farmer group intervention", and "Transport infrastructure". |

To depict the simulated impact of the proposed strategies, two graphs are selected as exposed in Figure 7-1. The graph on the left side shows the financial outcome in terms of the yield per cultivated hectare (Rupiah per year per hectare), and the graph on the right side shows the cocoa bean production per tree (kg per year per tree).

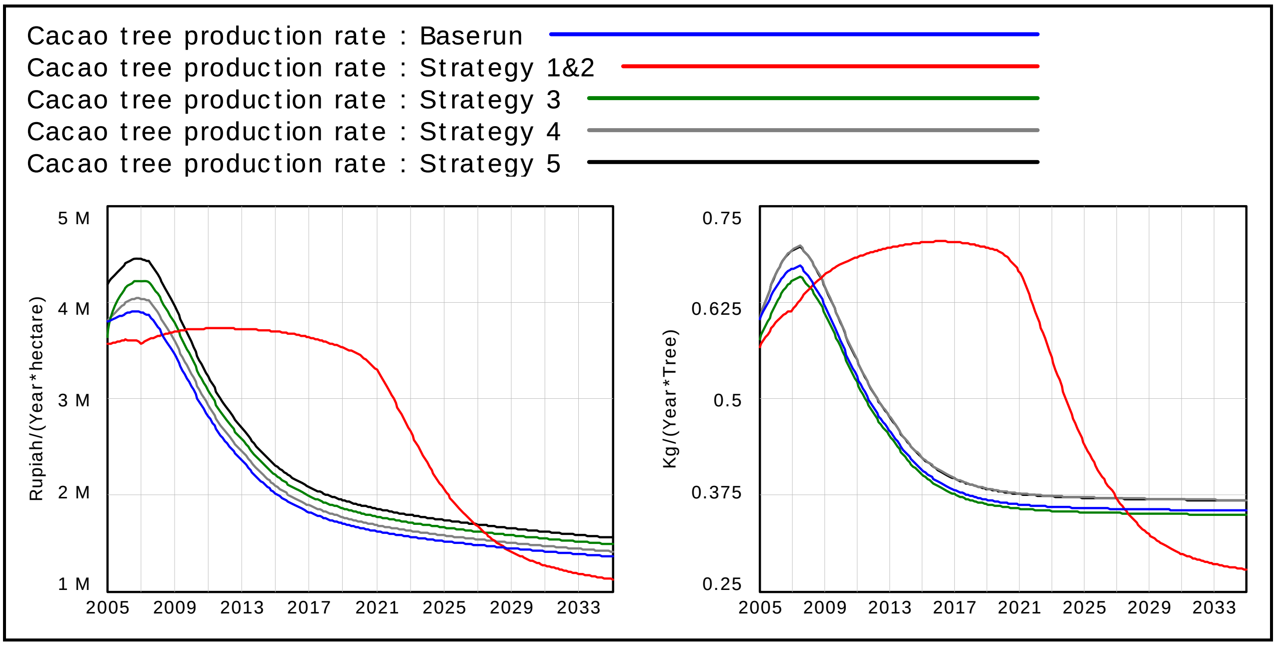


**Figure 7-1: Outcome of the LED-NTT proposed strategies**

The proposed strategies are intended to implement by a single chosen intervention:

> *"Provision of - and access to affordable and recommended - inputs to the farmers to ensure better farm practice (appropriate application of technology and inputs)."*

The proposed intervention targets, on the one hand, the access to inputs and, on the other hand, the appropriate use of inputs. This intervention leads to the outcome in Figure 7-1, depicted with the red line (Strategy 1&2). It is obvious that this intervention has only a short- or middle-term effect and, hence, does not lead to significantly better results in both the productivity and the yield. The decline after the year 2017 is due to the adaptive behaviour of the CPB to chemical inputs after approximately eight years.[20]

Strategies 4 and 5 target only the farmers' livelihood. The livelihood is more a system indicator than a possible input lever in the modelled farmers' system. Only the two assets human- and natural capital, which are part of the farmers' livelihood, are involved in the complex feedback processes in the observed system. Therefore, those interventions will cause only slightly different effects – if there are no further interventions – than the "Base run" has shown.

Strategy 3 will lead to a better cocoa bean quality and, thus, to a better farm gate price, assumed that there is a demand for higher quality. This strategy alone is also not at all sustainable and leads simply to a lower productivity (green line in the right-hand graph).

[20] See also chapter 12.3 for further information about the pests' resistance on pesticides and other inputs.

## 7.2 Resulting Strategy of the System Analysis

> *"Although the stability of systems is not explicitly contained in current definitions of sustainability, it has proven to be an elementary requirement for competent behaviour: future generations will only be able to fulfil their needs if the ecological, economical, and social systems are stabile, adaptable, and capable of surviving."*

As the system's stability is a very important part in competent behaviour, Vester (2005) points out that a profound system analysis is needed to create sustainable policies and strategies. However, Box 7-1 delivers a current definition of sustainable development,[21] which contains a hint on the system's ability of dealing with limits and constraints.

**Box 7-1: Sustainable development**

Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:

- The concept of *needs*, in particular the essential needs of the world's poor, to which overriding priority should be given.

- The idea of *limitations* imposed by the state of technology and social organization on the environment's ability to meet present and future needs.

Both key concepts for sustainable development were already targeted and depicted graphically in chapter 4.2 by the "Shifting the burden archetypes" and the "Tragedy of the common archetype". Out of these basic recognitions, the analyst was able to implement identified patterns of behaviour into the cocoa farmers' system simulation model. The process of formulating and simulating this model immediately uncovered every attempt to establish short-term solutions and pointed out the importance of time delays.

The aim of an intervention in the cocoa farmers' system must be clear; every single intervention must aim at the core problem – and this is not the low productivity or the lack of access to inputs or finance; **the core problem is the lack of knowledge!**

Farming methods that minimize reliance on expensive inorganic fertilizers and pesticides must be supported. This can be done by using these inputs as efficiently as possible, or by replacing them with inexpensive organic fertilizers, biological pest control, and ecological knowledge. The currently high CPB infestation could be fought with inputs, but results of research i.e. in Sulawesi (Day, 1985) have shown, that only organic pest control leads to a sustainable containment of this threatening pest. In addition, the cocoa farmers in the area of research do not have the financial resources needed to fight the CPB efficiently.

[21] Definition: International Institute for Sustainable Development. http://www.iisd.org/sd/.

For farmers to become aware of the immediate need to act against diseases and pests, they, first and foremost, must understand what attacks their cocoa bean production. Most farmers do know that their low production is caused by CPB, but they do not know about the lifecycle of CPB, its symptoms, and how that pest causes their declining cocoa bean production. This lack of knowledge cannot be dealt with by enabling them access to finance and to inputs. This deficit must be handled with the only way running: **Field schooling!**[22]

For the farmers it is not important who provides the information they need, as long as they get the information immediately and, preferably, for free. As mentioned before, farmers are aware of the existing problem, but they are still awaiting a solution from someone before making the decision to act in whatever way possible.

Bearing these findings, the extensive system analysis and the simulation model in mind, the analyst suggests the following strategy:

> *"Constitution of a farmer field school, where the farmers can acquire the knowledge of how to maintain their cacao trees, become aware of time delays in the trees lifecycle, learn about the urgent need to integrate pest management, and obtain know-how required to make specific decisions."*

This strategy - implemented by appropriate intervention partners -aims at the core of the problem of the low productivity in the cocoa sub sector: the lack of knowledge. Figure 7-2 depicts certain possible outcomes of the intervention to raise the farmers' awareness for tree replacement and efficient crop management techniques like pruning, grafting, sanitation, and harvesting. The blue line depicts the base run, and the red line depicts the optimum strategy's outcome. The average productivity could rise up to 0.9 kg per tree (including not yet yielding trees), which could provide the farmers an income of up to 12 million Rupiah per hectare and year for fully dried, fermented cocoa beans.

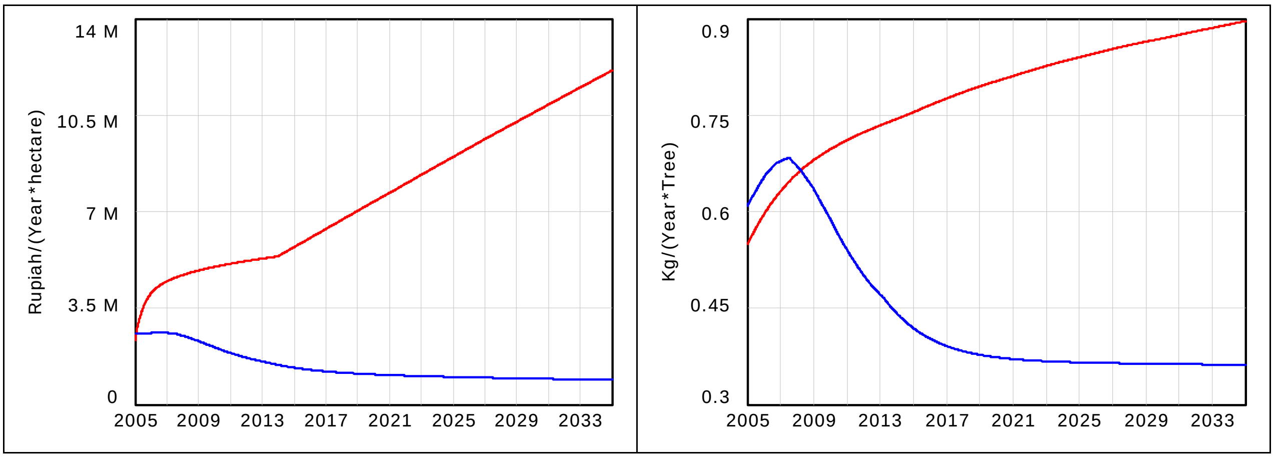


**Figure 7-2: Possible outcomes of the analysts' proposed strategy**

[22] A farmer field school is an effective approach to technical education and capacity building, where the farmers generate knowledge that is functionary and necessary to improve their production and livelihood potential. All learning is based in the field - supported by a facilitator - using a "learning by doing training approach".

## 7.3 Implementation

However the possible higher outcome for the livelihood of the farmers by implementing this strategy, one must bear in mind that the farmer field school is not restricted to the farmer's crop know-how, but it must also target his capacity to work. The analyst depicted this already with Figure 4-8: Limits to success archetype", and in context with the findings described below Figure 6-4. It has to be clear for every partner involved that providing the farmers with more know-how in crop management and techniques for better maintenance of their trees, the farmers' capacity will suffer. Why this? The farmers' work exploitation rate will rise, because they will have the knowledge required to make the decision to act and to work. The more they know the more they must work. But the farmers' capacities are limited by their physical ability, health and nutrition.

Therefore, an implementation of the mentioned strategy – access to know-how - must also include the provision of know-how to target the farmers' constraints and limits of their working capacity.

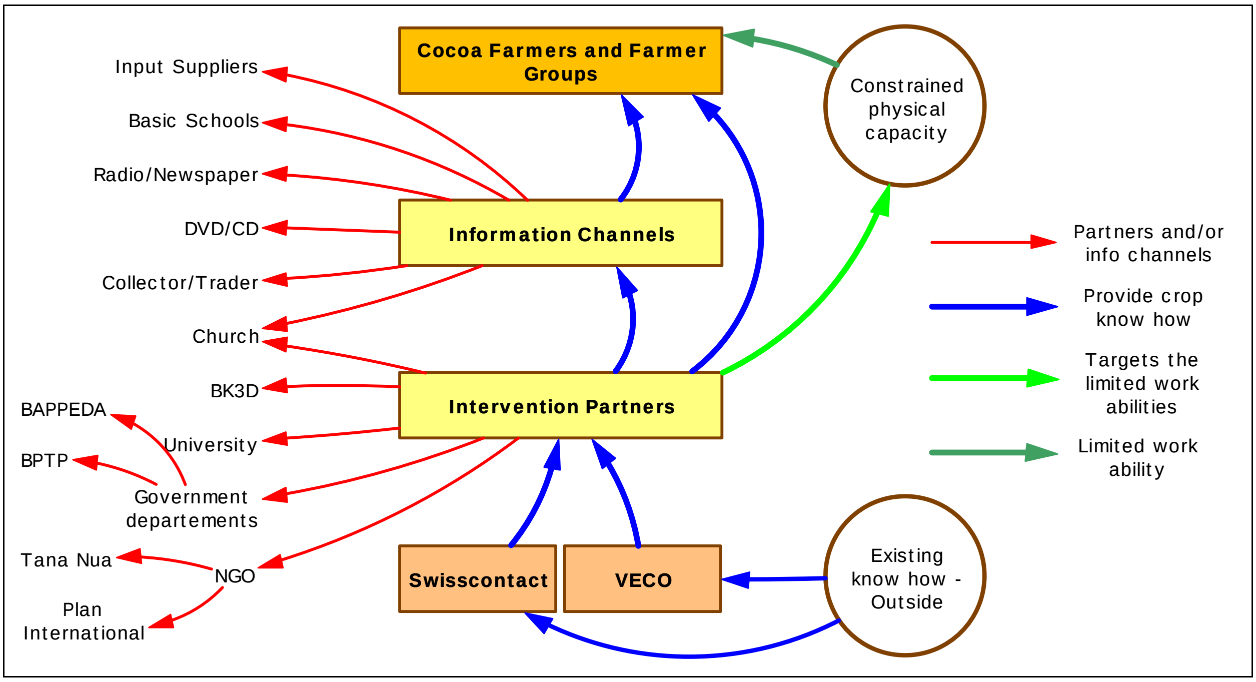


**Figure 7-3: Intervention flow chart**

The chart in Figure 7-3 shows the information flows from possible know-how sources outside Swisscontact or Veco to the farmers. This chart is just an overview of a possible implementation of an intervention in the cocoa farmers' system with appropriate partners. There are many possibilities of how to implement the strategy mentioned above; but the field school can be considered the most effective one. Everything the farmers need to know already exists somewhere. Swisscontact and Veco can act as a link between the sources of know-how and the chosen intervention partner. The support of an intervention partner must lead to a better access to know-how and higher working capacities for the farmers targeted.

# 8 Learning Laboratory

To find sustainable solutions for an intervention in the cocoa farming system, the LED-NTT project team and possible partners can gain experience by taking part in a learning laboratory (learning lab).

## 8.1 Learning laboratory design precepts

There is an innate tendency for people to abdicate their responsibility as a decision maker and to accept the "answer" given by the computer when running a simulation model. Therefore, the analyst decided to organise a learning lab for the LED-NTT team to bring them together to talk about the conclusions and assumptions drawn from the model. The simulation model itself is simply an explicit set of assumptions, and its principal value is in helping to make implicit assumptions explicit.

**Box 8-1: Learning laboratory**

A learning lab embeds a management flight simulator[23] (MFS) in a learning environment as a tool for learning, rather than for predicting. It is a "practice field" where teams can surface, test, and improve their mental models. Groups of team members or intervention partners use a combination of systems thinking tools to explore the dynamics of the particular system and inquire into their own understanding of that system.

In the learning lab, which has to last at least one full day, the participants learn to interpret what is happening on the computer screen in terms of the real world. But only less than half the time is spent working with the MFS. In order to understand how the MFS works and to comprehend the results that emerge from it, participants must first gain insight into a framework which observes why events unfold as they do. Therefore, more time is spent on work with causal loops, archetypes, and other systems thinking tools that relate to the system's underlying model. The lab is designed in such a way that the participants pay attention to all four levels of systems thinking: *events, patterns of behaviour, structure, and mental models*. As in the real world, discipline is needed to keep the participants' attention to structural relationships and their own patterns of thinking. To keep the participants in an inquiry-oriented mode, the lab is equipped with "before and after" exercises, in which they have to mentally simulate a new strategy and to draw and explain what they expect will happen without the help of the computer. After the simulation, the participants have to compare their prediction with the simulated results. The lab's intention is to focus a team on the dynamics which they should be thinking about.

[23] A management flight simulator is based on a system dynamics computer model that has been changed into an interactive decision-making simulator through the use of a user interface (Senge, 1997).

## 8.2 Results from the team learning laboratory

The learning lab and the staff helped the analyst to see the analyzed system once more from another point of view; furthermore, the learning lab was also the final test for the MFS and the correctness of the proposed strategy.

The staff involved should now be able to chair a learning lab with some possible partner for an intervention. Every conducted learning lab will be helpful not only for the partner's understanding of the cocoa farmers system; it will also produce some new and deepen existing mental models for the staff.

The LED-NTT staff, concerning the cocoa sub sector, is now able to explain the reason for the MFS and how the simulation work. The staff can explain some basic skills, such as reading existing CLD and archetypes.

## 8.3 Recommendation for further learning laboratories

The analyst recommends that the LED-NTT team members conduct a learning lab, like the one they partook in, with possible partners for an intervention. The first learning lab with an intervention partner will be in Denpasar, Bali. This first learning lab is part of the final presentation of this thesis and will be chaired by the analyst. Therefore, everyone present from Swisscontact staff can take part in another learning lab and gain insight into some new mental models, as well as consolidate their knowledge in basic systems thinking and in the use of the MFS.

Working with the staff in the learning lab have shown that it is very important to point out the importance of recognizing events, patterns of behaviour, structure, and mental models right in the beginning. Working with CLD and archetypes helps everyone involved to understand the system in question in a short time.

# 9 Reflection of the System Dynamics Methodology

Systems' thinking is a powerful problem-solving-tool. Furthermore, it is an effective language, which augments and changes the ordinary ways of thinking and talking about complex issues. The specific form of systems' thinking language used in this thesis - systems dynamics - is particularly valuable to describe how to achieve fruitful changes in the farmers' system. By creating a management flight simulator – which bases on the system dynamics insights in the system – and sensitize the project team in a learning lab, systems' thinking is applied in a practical way.

Well-designed simulation models – in this case the farmers' decision making management flight simulator - can be valuable tools for foresight and policy design.
Foresight is the availability to anticipate how the system will behave if and when certain changes occur. It is not forecasting, and it does not depend on the ability to predict.

> *[…,] at present we are far away from being able to predict social-system behaviour except perhaps for carefully selected systems in the very short-term. […,] much can be learned from models in the form of broad, qualitative, conditional understanding – and this kind of understanding is useful (and typically the only basis) for policy formulation. (Meadows et al., 1982)*

Despite the limitations of modelling, there is no doubt that computer models can be extremely useful foresight tools. It should be remembered that we all use models of some sort to make decisions and to solve problems. The alternative to continued reliance on mental models is computer modelling.

No one can (or should) make decisions on the basis of computer model results that are simply presented, “take ‘em or leave ‘em”. In fact, the primary function of model building should be educational rather than predictive.

The modeller agrees that models probably do not offer much to smallholder farmers directly, as many of the problems that this group is faced with are not problems that can be addressed by models. Farmers have a set of rules of thumb which are more than adequate in the majority of cases, and the extra precision that simulation models give would usually not justify the costs of their use. However, the role of models is more that of a tool to help researchers (and possibly policy makers) to understand the complexity of the farmers’ system, and to test ways that might be improved before interfering in the real system.

Other analytical tools like the sustainable livelihood approach (SLA) and its framework (SLF), which may be used in a diagnostic sense (i.e. to identify the real constraints of a particular system) to determine a course of action, or to test out the likely outcomes of particular strategies, only represent a snapshot of the system and do not capture dynamic processes such as decision-making. Therefore, the usefulness of the SLF could be enhanced by simulating modelling of systems, which would then have the potential to provide a powerful tool to evaluate the dynamics within particular situations, the possible effect of outside influences (e.g. climate change, commodity price fluctuations, policy changes, introduction of new technology, etc.), and the range of livelihood strategies that may be adopted to cope with these. Such an approach could be particularly useful, for example, in understanding the processes of decision making among the actors in the system, time delays in cash crop planting, as well as understanding pests’ lifecycles and their long-term influence on the productivity.

Consequently, the analyst recommends the use of the system dynamics methodology and systems thinking in general for the analysis of every new system, before new interventions are taken into action. Furthermore, the analyst recommends that system dynamics is used to create and test sustainable interventions, strategies and policies before they are put in place in the real world.

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# Glossary[24]

Systems thinking can serve as a language which is used to communicate about complexity and interdependencies. To be fully conversant in any language, you must gain some mastery of the vocabulary, especially the phrases and idioms unique to that language. This glossary lists many terms that may come in handy when you are faced with a system's problem. Additionally, this glossary list is expanded with terms of the international development cooperation, and specific cacao related terms.

**Accumulator**

Anything that builds up or dwindles. For example, water in a bathtub, savings in a bank account or inventory in a warehouse. In modelling software, a stock is often used as a generic symbol for accumulators. Also known as *Stock* or *Level*.

**Balancing Process/Loop**

Combined with reinforcing loops, balancing processes form the building blocks of dynamic systems. Balancing processes seek equilibrium: They try to bring things to a desired state and keep them there. They also limit and constrain change generated by reinforcing processes. A balancing loop in a causal loop diagram depicts a balancing process.

**Balancing Process with Delay**

A commonly occurring structure. When a balancing process has a long delay, the usual response is to overcorrect. Overcorrection leads to wild swings in behaviour. Example: real estate cycles.

**Behaviour Over Time (BOT) Graph**

One of the ten tools of systems thinking. BOT graphs capture the history or trend of one or more variables over time. By sketching several variables on one graph, you can gain an explicit understanding of how they interact over time. Also called *Reference Mode*.

**Cacao Tree**

The cacao tree is a tropical tree that produces cocoa beans. Its botanical name, *Theobroma cacao*, means "food of the gods."

**Causal Loop Diagram (CLD)**

One of the ten tools of systems thinking. Causal loop diagrams capture how variables in a system are interrelated. A CLD takes the form of a closed loop that depicts cause-and-effect linkages.

[24] Source of the glossary: for systems thinking related terms, http://www.thesystemsthinker.com/tstglossary.html and for the cocoa related terms http://www.worldcocoafoundation.org/.

**Cocoa**

Cocoa is the dried and partially fermented fatty seed of the cacao tree from which chocolate is made.

**Chocolate Liquor**

The liquid chocolate produced by grinding the cocoa nibs. It is the basic ingredient in all chocolate products. There is no alcohol in chocolate liquor.

**Cocoa Bean**

The seed of the cacao tree. It is only called a cocoa bean once it has been removed from the pod in which it grows.

**Cocoa Pod**

The cocoa pod is the leathery oval pod (husk) that contains cocoa beans.

**Donor**

In this thesis, the term ‚donor' includes bilateral and multilateral donor organisations, development agencies, NGOs implementing on behalf of a donor agency, consultants, etc.

**Farmer Field School**

A farmer field school is an effective approach to technical education and capacity building, where the farmers generate knowledge that is functional and necessary to improve their production and livelihood potential. All learning is based on the field - supported by a facilitator - with a "learning by doing training approach".

**Feedback**

The return of information about the status of a process. Example: annual performance reviews return information to an employee about the quality of his or her work.

**Flow**

The amount of change something undergoes during a particular unit of time. Example: the amount of water that flows out of a bathtub each minute, or the amount of interest earned in a savings account each month. Also called a *Rate*.

**Generic Structures**

Structures that can be generalized across many different settings, because the underlying relationships are fundamentally the same. Systems archetypes are a class of generic structures.

**Graphical Function Diagram (GFD)**

One of the ten tools of systems thinking. GFDs show how one variable, such as delivery delays, interacts with another, such as sales, by plotting the relationship between the two over the entire range of relevant values. The resulting diagram is a concise hypothesis of how the two variables interrelate. Also called *Table Function.*

**Learning Laboratory**

One of the ten tools of systems thinking. A learning laboratory embeds a management flight simulator in a learning environment. Groups of managers use a combination of systems thinking tools to explore the dynamics of a particular system and inquire into their own understanding of that system. Learning labs serve as a manager's practice field.

**Level**

See Accumulator.

**Leverage Point**

An area where small change can yield large improvements in a system.

**Management Flight Simulator (MFS)**

One of the ten tools of systems thinking. Similar to a pilot's flight simulator, an MFS allows managers to test the outcome of different policies and decisions without "crashing and burning" real companies. An MFS is based on a system dynamics computer model that has been changed into an interactive decision-making simulator through the use of a user interface.

**Policy Structure Diagram**

One of the ten tools of systems thinking. Policy structure diagrams are used to create a conceptual "map" of the decision-making process that is embedded in an organization. It highlights the factors that are weighed at each decision point.

**Rate**

See Flow.

**Reference Mode**

See Behaviour Over Time Graph.

**Reinforcing Process/Loop**

Along with balancing loops, reinforcing loops form the building blocks of dynamic systems. Reinforcing processes compound change in one direction with even more change in that same direction. As such, they generate both growth and collapse. A reinforcing loop in a causal loop diagram depicts a reinforcing process. Also known as vicious cycles or virtuous cycles.

**Simulation Model**

One of the ten tools of systems thinking. A computer model that lets you map the relationships that are important to a problem or an issue and then simulate the interaction of those variables over time.

**Stock**

See Accumulator.

**Structural Diagram**

Draws out the accumulators and flows in a system, giving an overview of the major structural elements that produce the system's behaviour. Also called *flow diagram* or *accumulator/flow diagram*.

**Structure-Behaviour Pair**

One of the ten tools of systems thinking. A structure-behaviour pair consists of a structural representation of a business issue, using accumulators and flows, and the corresponding behaviour over time (BOT) graph for the issue being studied.

**Structure**

The manner in which a system's elements are organized or interrelated. The structure of an organization, for example, could include not only the organizational chart but also incentive systems, information flows, and interpersonal interactions.

**System Dynamics**

A field of study that includes a methodology for the construction of computer simulation models to achieve better understanding of social and corporate systems. It draws on organizational studies, behavioural decision theory, and engineering to provide a theoretical and empirical base for structuring the relationships in complex systems.

**System**

A group of interacting, interrelated or interdependent elements, forming a complex whole. Almost always defined with respect to a specific purpose within a larger system. Example: An R&D department is a system that has a purpose in the context of the larger organization.

**Systems Archetypes**

One of the ten tools of systems thinking. Systems archetypes are the "classic stories" in systems thinking—common patterns and structures that occur repeatedly in different settings. Defined Archetypes are the following (Senge 2005):

**- Fixes That Fail**

In a "Fixes That Fail" situation, a fix is applied to a problem and has immediate positive results. However, the fix also has unforeseen long-term consequences that eventually worsen the problem. Also known as "Fixes That Backfire."

**- Escalation**

In the "Escalation" archetype, two parties compete for superiority in an arena. As one party's actions put it ahead, the other party "retaliates" by increasing its actions. The result is a continual ratcheting up of activity on both sides. Examples: price battles, the Cold War.

**- Drifting Goals**

In a "Drifting Goals" scenario, a gradual downward slide in performance goals goes unnoticed, threatening the long-term future of the system or organization. Example: lengthening delivery delays.

**- Growth and Underinvestment**

In this situation, resource investments in a growing area are not made, owing to short-term pressures. As growth begins to stall because of lack of resources, there is less incentive for adding capacity, and growth slows even further.

**- Limits to Success**

In a "Limits to Success" scenario, a company or product line grows rapidly at first, but eventually begins to slow or even decline. The reason is that the system has hit some limit—capacity constraints, resource limits, market saturation, etc.—that is inhibiting further growth. Also called "Limits to Growth."

**- Shifting the Burden**

In a "Shifting the Burden" situation, a short-term solution is tried that successfully solves an ongoing problem. As the solution is used over and over again, it takes attention away from more fundamental, enduring solutions. Over time, the ability to apply a fundamental solution may decrease, resulting in more and more reliance on the symptomatic solution. Examples: drug and alcohol dependency.

**- Success to the Successful**

In a "Success to the Successful" situation, two activities compete for a common but limited resource. The activity that is initially more successful is consistently given more resources, allowing it to succeed even more. At the same time, the activity that is initially less successful becomes starved for resources and eventually dies out. Example: the QWERTY layout of typewriter keyboards.

**- Tragedy of the Commons**

In a "Tragedy of the Commons" scenario, a shared resource becomes overburdened as each person in the system uses more and more of the resource for individual gain. Eventually, the resource dwindles or is wiped out, resulting in lower gains for everyone involved. Example: the Greenhouse Effect.

**Systems Thinking**

A school of thought, that focuses on recognizing the interconnections between the parts of a system and synthesizing them into a unified view of the whole.

# Truthfulness

Hereby, I declare that I wrote this thesis in hand by myself, without help of a third party, and by using of only the declared references.

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Lieu, date

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Signature

## Appendix 1; Background Information

# 10 The Region of Intervention

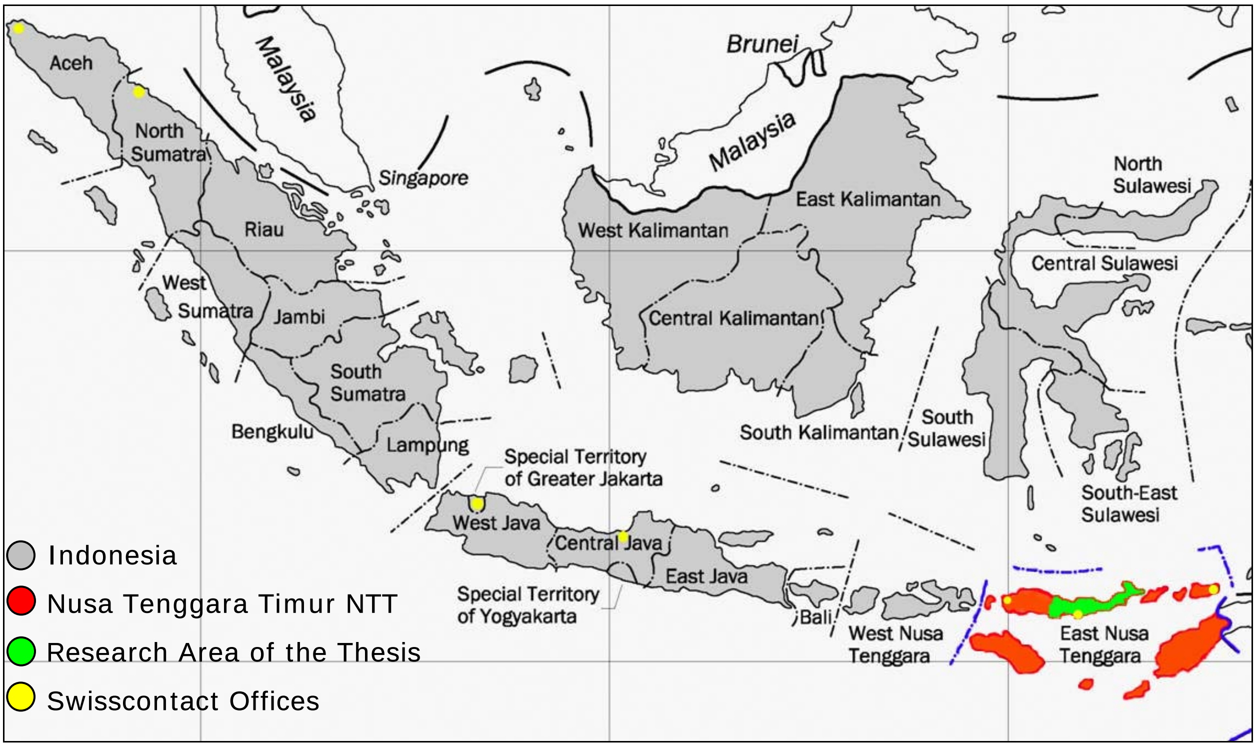



**Figure 10-1: Map of Indonesia and the region of intervention**

## 10.1 Indonesia

The Dutch began to colonize Indonesia in the early 17th century; the islands were occupied by Japan from 1942 to 1945. Indonesia declared its independence after Japan's surrender, but it required four years of intermittent negotiations, recurring hostilities, and UN mediation before the Netherlands agreed to relinquish its colony. Current issues include: alleviating widespread poverty, preventing terrorism, continuing the transition to popularly-elected governments after four decades of authoritarianism, implementing reforms of the banking sector, addressing charges of cronyism and corruption, and holding the military and police accountable for human rights violations. Indonesia has been dealing with armed separatist movements in Aceh and in Papua. Indonesia is the world's largest archipelagic state with a land area of about 1,826,440 sq km and a population of 241,973,879.[25]

## 10.2 Nusa Tenggara Timur

The province NTT is located between 8° to 12° South latitude and from 118° to 125° East longitude. NTT is the most South-Eastern part of Indonesia. The total land area of NTT is 47,350 sq km which are spread over 566 islands. Only 42 islands are inhabited and still 320 islands have yet no name. According to the results of 2004 census, the total population of

[25] Source: CIA; The World Fact Book (est. July 2005)

NTT was 4,188,744 people. The annual growth rate of the population between 1990 and 2000 was 1.64, with rising tendency.

Geologically, East Nusa Tenggara can be regarded as being divided into two zones: a volcanic inner curve formed by the islands of Rinca, Komodo, Flores, Alor, Pantar, Adonara, Lembata and Solor, which have fertile soils; and an outer curve of limestone and other rock formations, made up of Sumba, Sabu, Rote, Semau and Timor.

NTT has only two seasons, the dry season and the rainy season. Between June and September the wind flow comes from Australia and contains little moisture, hence, it causes the dry season. In contrast, between December and March the wind flow contains a great deal of moisture which comes from Asia and Pacific Ocean, causing the rainy season. This condition changes and turn for a half of a year, after passing the transitional period on April – Mai and October – November. Nevertheless, since NTT is not so far from Australia, NTT is a dry area which is relatively wet in four months (between December and March). (BPS, 2005: 3pp.)

Rich in natural resources and agriculture offerings, NTT is known as one of the most underdeveloped provinces in Indonesia. Although there is high potential for economic growth, investment and economic development are low. Employment outside the agriculture sector is almost nonexistent. In addition, the province is faced with high population growth which challenges both the local government and the private sector to create enough job opportunities.[26]

## 10.3 Flores Island

Flores has a land area of 14,231 sq km which represents a 30 percent share of the NTT area. Flores has several active and dormant volcanoes, including Egon (last eruption 2005), Ilimuda, Leroboleng, and Lewotobi. As a spectacular attraction, mount Kelimutu with its three crater lakes of different colours has become a favourite tourist destination.

Flores Island is divided in six regencies with an estimated population of 1,659,494 (BPS, 2005: 65pp.), which speak one of the island's five main languages alongside Bahasa Indonesia. Many older people, such as village heads, do not speak Bahasa Indonesia, let alone English.

The Human Development Index (HDI) is slightly more positive for Flores than for the rest of the province and a few indicators are even more positive for Flores than for both NTT and Indonesia. Although Flores has better access to safe water, some are still on an unacceptably high level: one quarter of the population is income-poor, almost half has no access to health facilities and more than one third of the children are malnourished.

[26] Source: Swisscontact brochure for the LED-NTT project

## 10.4 Area of Research

On Flores Island the intended research in the cacao sub sector focuses primarily on four regencies (*Kabupaten*[27]): Flores Timur, Sikka, Ende and Ngada. Those four regencies cover approximately 52% of the Islands land area. In the island's two remaining western regencies Manggarai und Manggarai Barat other cash crops are more important for the farmers. The regencies are again divided into several districts (*Kecamatan*).

Table 10-1 shows some statistic data of the selected regencies and their populations. With a total population of about one million people living in 739 villages, 60% of the island's population is taken into account. Around 75% of the population above the age of ten work in the primary sector, whereas agriculture, with a 50% share, is the main source of income for the working population in the selected area.

**Table 10-1: Area of research-population statistics (cf. BPS, 2005: 65pp.)**

| Regency | Area (sq km) | Districts | Villages | Population | Female rate |
|---|---|---|---|---|---|
| Flores Timur | 1,812.9 | 13 | 215 | 218,257 | 1.1040 |
| Sikka | 1,731.9 | 11 | 160 | 280, 841 | 1.1080 |
| Ende | 2,046.6 | 13 | 173 | 241,826 | 1.1327 |
| Ngada | 3,100.4 | 12 | 191 | 245,169 | 1.0506 |
| **Total** | **7,691.8** | **49** | **739** | **986,093** | **1.0985** |

The problem of illiteracy is widespread in Indonesia. With a rate of almost 91% adult literacy, the research area is not as bad as the whole NTT province with tight 87%. Despite huge efforts in the last few years, the illiteracy is still one of the main reasons to be income-poor. Women are always more affected by illiteracy than men, with a difference in the illiterate rate of up to 8.4% in Flores Timur regency (BPS, 2005: 215pp.). The problem of illiteracy exists because almost 8% of the population have never attended school, and 33% did not complete primary school. Despite rural poverty, 59% finished at least primary school.

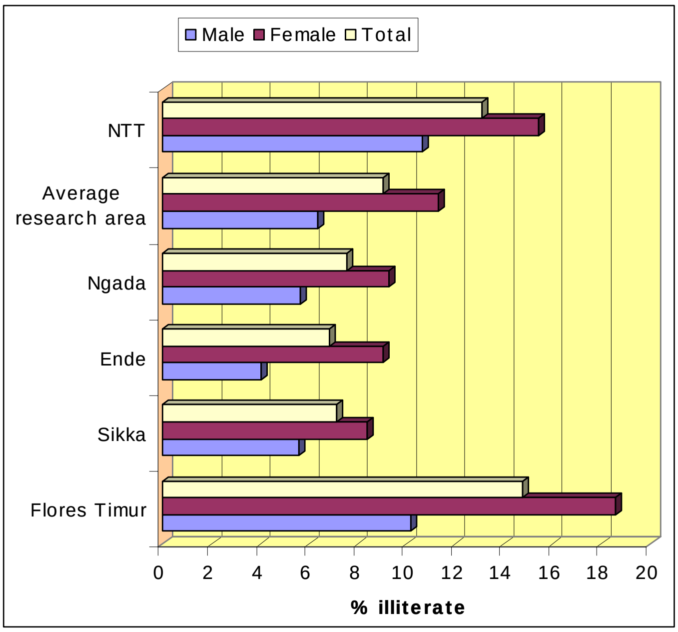



**Figure 10-2: Illiterate rate**

[27] In Indonesia, the administrative organization is as follows: *Negara* - Nation; *Propinsi* – Province; *Kabupaten* – Regency; *Kecamatan* – District; *Desa* - Village

The average monthly per capita expenditure per household in the research area in 2004 was 110,239 Rupiah[28] and of those 72% was for food. The non-food expenditures are shown in Figure 10-3. Households in rural areas have an income of slightly more or less than the average expenditures, therefore, savings (monetary or not) are not possible.

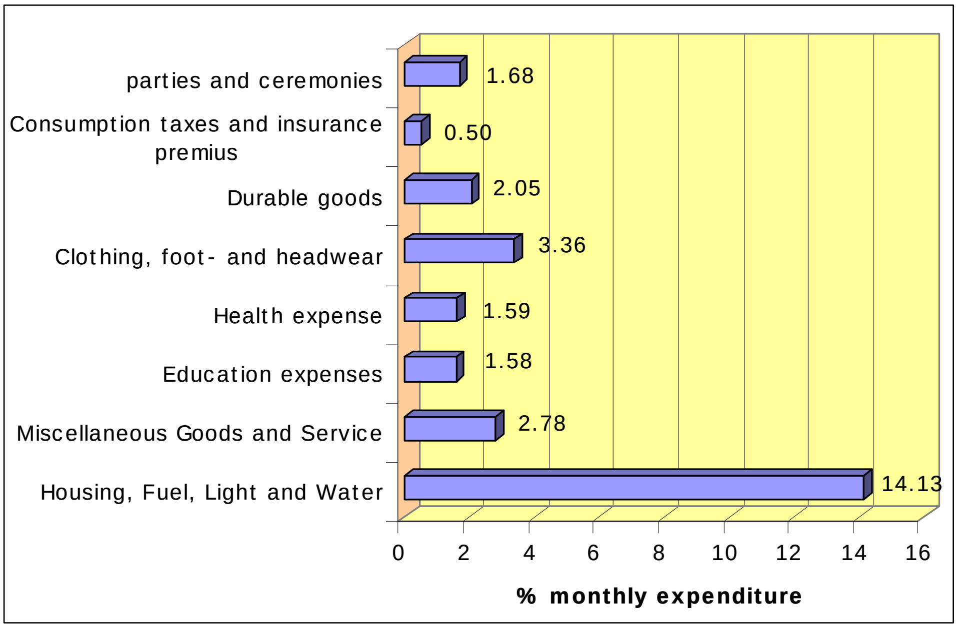



**Figure 10-3: Average monthly expenditure in rural areas 2004**

A great portion of the monthly expenditure is the amount used for housing, electricity and water. As a considerable number of the rural population live in their own or the parental house, only very few have to pay rent. Electricity is available for around 40% of the people living in rural areas; therefore, their costs are mostly for fuel for alternative lightning.

One of the most important infrastructures supporting economic activities is the availability of roads. In the research area only 41.8% of the roads are asphalted (BPS, 2005: 456pp.).

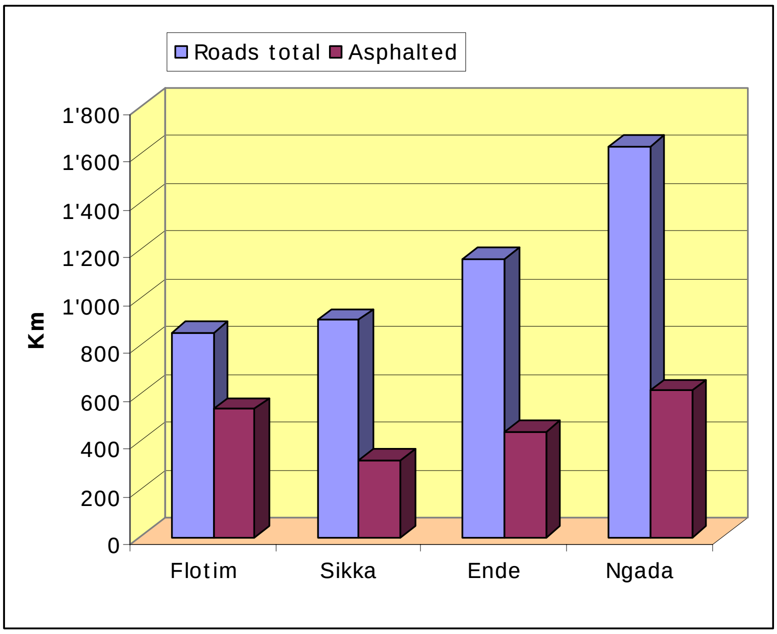



**Figure 10-4: Roads in the research area**

While all of the provincial roads are asphalted, the regency roads are mostly gravel or dirt roads. Problems arise in the rainy season, because 70% of the research area topography has slopes of 40% (BPS, Ende Dalam Angka, 2003). Not asphalted roads are mostly impassable during rain, furthermore, mud slides cover the main

[28] Rupiah is the official Indonesian currency; Value of 100,000 in October 2006: 13.60 CHF.

roads everywhere. Traffic is very limited during the rainy season and transportation must be well prepared and planned.

Like all of NTT and Indonesia, the research area has only two seasons. There exist great disparities between the regencies, therefore, the southern parts get more days of rain and also the amount of rain is higher there.

The temperature ranges from minimum 21°C during nights in July, up to a maximum of 33°C in December.

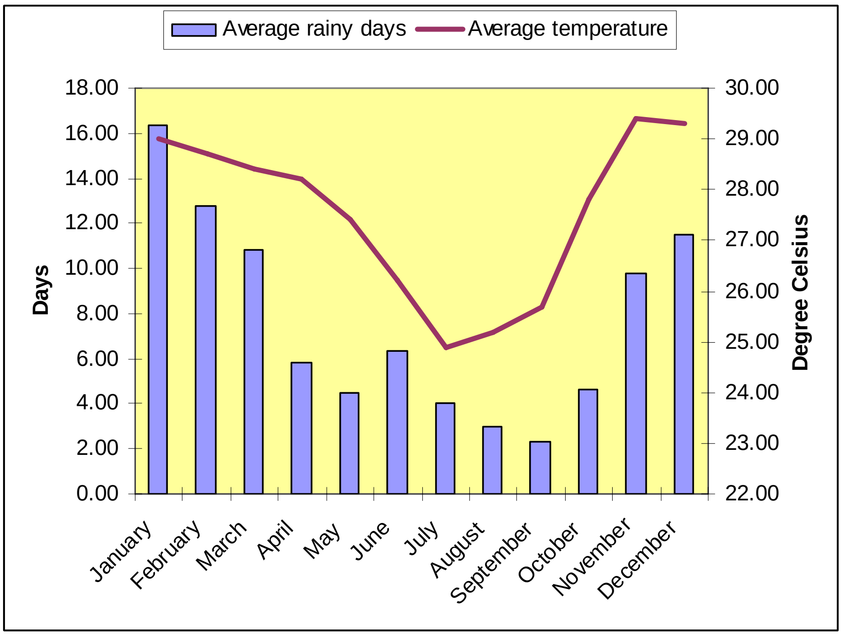



**Figure 10-5: Temperature and rainy days**

# 11 The Chocolate Tree

## 11.1 The Cash Crop

The cocoa tree (Latin *Theobroma Cacao*, meaning literally “food of the gods“) only grows in humid, tropical climates, with cultivation limited to regions between 20° north and 20° south of the equator.

Cocoa is a delicate and demanding tree requiring temperatures between approximately 24 - 26° Celsius, abundant and regular rains, and soil rich in potassium, nitrogen and trace elements. Young cocoa trees are particularly delicate, vulnerable to direct sun light and wind, having to develop initially in the protective shade of other trees, affectionately referred to as “mothers of cocoa“(including banana trees, cotton plants, rubber trees, etc.). It grows to about five meters within three years, and reaches eight meters at about ten years. A tree normally lives for 30 - 40 years. In most plantations, new cocoa trees replace older trees at 25 year intervals.

The cocoa tree produces millions of flowers throughout the year. In the wild, only midges of the *Forcipomyia*[29] genus carry out pollination. Only 5 - 10% of the flowers are fertilized, and five months are required for a fruit, in the form of a pod, to grow. A ripe pod can weigh, according to the variety, between 200g and 1kg, and contains 30 - 40 seeds in a cluster, surrounded by a white gel (“pulp” or “mucilage “), which is greatly prized by monkeys and parrots. Before ripening, the pod is green or red-violet. It becomes yellow or orange upon maturity and measures approximately 20cm in length, and 7 - 9cm in width.

The cocoa tree is very sensitive to insects and diseases. Among the diseases caused by fungus are witches broom (particularly in South America) and brown pod rot (particularly in Africa). Some insects can cause younger trees to wither. In South East Asia, the “cocoa pod borer” (CPB) insect causes considerable damage. All told, illnesses and parasites can destroy 20-30% of total production.

Pods are still harvested with a machete to this day. After extraction from the pod, the seeds are fermented and then sun-dried. A producing tree can deliver on average 0.5 - 2kg of dried seeds per year. In producer countries, plantations generally have a density of 1,000 - 1,200 cocoa trees per hectare. A cocoa plantation is expected to be profitable after approximately six years. A plantation's economic life is considered to last 15 - 40 years (Young, 1994; Wood, 1992).

[29] Latin: *Forcipomyja* – Biting midges

## 11.2 The Three Grand Varieties of Cocoa

Today, three distinct varieties of cocoa are recognized: *Criollo, Forastero* and *Trinitario* (Young, 1994: 42)

### 11.2.1Criollo (means 'Creole' in Spanish)

This variety is the original cocoa tree, the earliest plantations of which were recorded in the 17th century. Originally grown in Venezuela, Central America and Mexico, it is now also found in Ecuador, Nicaragua, Guatemala and Sri Lanka. Considered to be the "prince of cocoas", *Criollo* has a reputation for fineness and an intense aroma. This variety represents only 5% of global production, in part due to its vulnerability to insects and disease. It is reserved for use in only the very finest chocolates.

### 11.2.2Forastero (means 'foreigner' in Spanish)

This group is very diverse and, as a species, is more resistant to diseases and pests and therefore more productive than the *Criollo*. Originally grown in the high Amazon region, it is now the predominant variety cultivated in Africa and, consequently, accounts for nearly 80% of world production. It is considered to be of ordinary quality (a very slight aroma and a strong, short, bitter taste) and is widely used in mass produced chocolate products.

### 11.2.3Trinitario (from 'Trinidad')

This species of cocoa tree is a natural biological hybrid between the *Criollo* and the *Forastero*, which was exported from Trinidad where the Spanish colonists had established plantations. The quality of its cocoa varies between average and superior, with strong cocoa butter content. It represents 15% of world production.

### 11.2.4The Most Desired Cocoas

All of the great chocolate makers and famous chocolate houses use cocoas which are called fine or aromatic of *Criollo*, *Trinitario* (plus *Nacional* from Ecuador). These cocoas are distinguished by their individual flavours: fruity, woody and floral. They are also recognized by their colour and their structural and agronomic characteristics.

It is planned that the different origins and species of cocoa tree will soon be recognized with an *"Appellation d'Origine Controllé"* (French: Controlled Origin Name) label, in the same way that good wine is identified. This development coincides with an increasing demand for quality chocolate, recognized for distinct flavours. The production of fine and aromatic cocoas represents only 4% of the world market. Domination of the market by production of ordinary cocoas emerged in less than a century as a result of increasing demand for mass produced chocolate and the corresponding advances in the technology and means for producing larger and larger quantities, often at the expense of quality.

## 11.3 The World Cocoa Market

### 11.3.1 Production

After successive increases in production during the previous two cocoa seasons, world production of cocoa beans declined by seven per cent to 3.3 million tonnes in 2004/05 compared to the all-time high of 3.5 million tonnes produced in 2003/04. Most of the decline in global output resulted from lower production in the two leading cocoa producing countries – Côte d'Ivoire and Ghana which suffered from poor growing conditions generally experienced in West Africa during the development of the main crop in the summer of 2004.

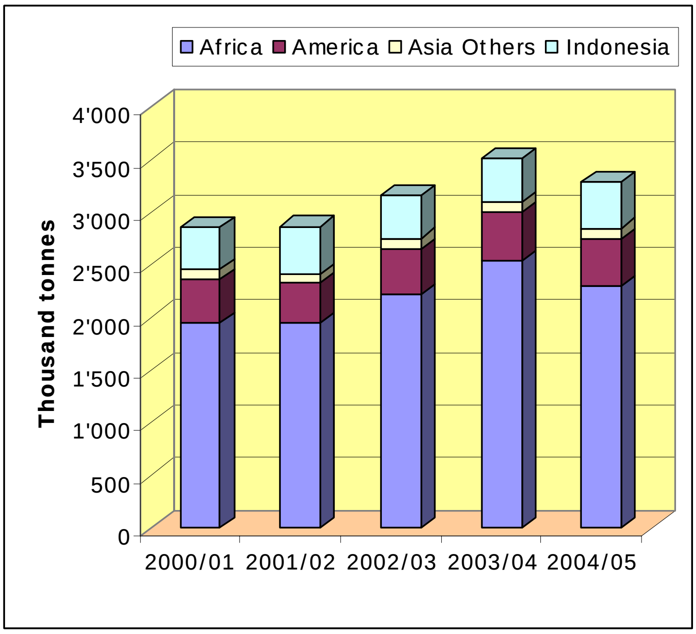



**Figure 11-1: World production of cocoa beans**

However, the final West African output was improved by the inclusion of beans from the 2005/06 main crop harvested during the tail end of the 2004/05 cocoa year. Production in Côte d'Ivoire fell from 1.41 million tonnes in 2003/04 to 1.27 million tonnes in 2004/05. In Ghana, cocoa bean output declined from 740,000 to 590,000 tonnes in 2004/05 despite a continued government-backed mass spraying programme to limit losses from pests and diseases. In addition to the weather induced setback in production, low farm gate prices in Côte d'Ivoire affected levels of husbandry and fertilizer inputs (ICCO, 2006).

### 11.3.2 Stocks

The production surplus in 2002/03 and the exceptionally large crop in 2003/04 had raised the worlds stocks from 1.20 million tonnes in 2002/03 to the highest accumulation of world stocks since 1992/93 at 1.49 million tonnes in 2003/04. The corresponding stocks-to-grindings ratio increased from 39.4% to 46.4%. Following a production deficit in 2004/05, world stocks of cocoa beans have declined to 1.44 million tonnes and reduced the stocks-to grindings ratio to 43.8% (ICCO, 2006).

### 11.3.3 Consumption

World consumption of cocoa beans, as measured by grindings, increased by three per cent to 3.3 million tonnes in the 2004/05 cocoa year, compared to an increase of five per cent in 2003/04 and six per cent in 2002/03. Strong demand for cocoa butter increased growth in processing during 2002/03 and 2003/04. However, the comparatively low demand for cocoa powder during this period compelled companies to adjust their rate of processing in 2004/05 to accommodate the resultant build-up of cocoa powder stocks, low powder prices and reduced processing margins. In regional terms, Europe remained the largest cocoa-processing region. The share of the Americas and Africa remained unchanged. By contrast, grindings in Asia and Oceania fell slightly. Grindings at origin are estimated at 1.18 million tonnes in 2004/05, representing a nominal growth of 22,000 tonnes from 2003/04. Côte d'Ivoire and Malaysia remained the top processing countries among the cocoa producing countries and accounted for more than 46% of origin grindings. Grindings in the cocoa importing countries were estimated at 2.12 million tonnes. The Netherlands and the United States were the principal processing countries, each processing over 400 thousand tonnes during the year (ICCO, 2006).

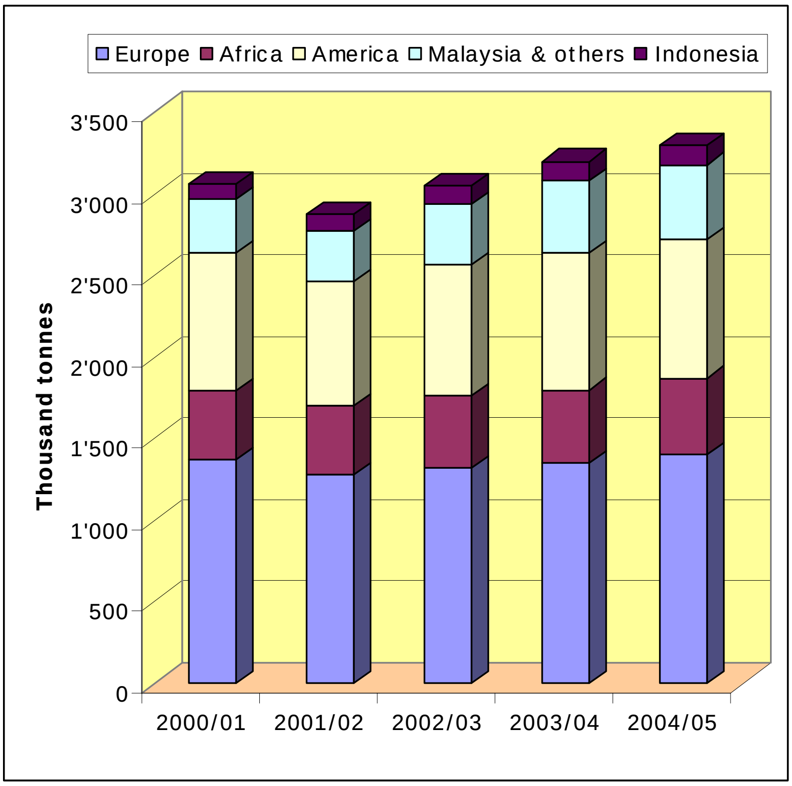



**Figure 11-2: World consumption 2000-2005**

### 11.3.4 Prices

The significance of the stocks-to-grindings ratio is its inverse relation to prices, so when it is high, prices are low and vice versa. Following the drastic decline in world production in 2004/05 and the consequent reduction in the stocks-to-grindings ratio, the average price of cocoa increased from US$1,534 in 2003/04 to US $1,571 per tonne in 2004/05. Price movement during 2004/05 was characterized by a large degree of volatility. Political and social events which threatened to disrupt cocoa supplies in Côte d'Ivoire early in the season pushed price to US$1,824 in November 2004. The disruption failed to materialize and prices dropped to US$1,507 in January 2005. However, an expected production deficit in the

2004/05 season combined with renewed tensions in Côte d'Ivoire inspired speculative buying which pushed prices to the highest level recorded since May 2003 at US$1,884 in March 2005. However, improvement in mid crops in West Africa and renewed hopes of a production surplus put a downward pressure on prices. Prices remained volatile for the rest of the cocoa year but by end of September, the price of cocoa had returned close to its level at the beginning of the year at US$1,488 per tonne (ICCO, 2006).

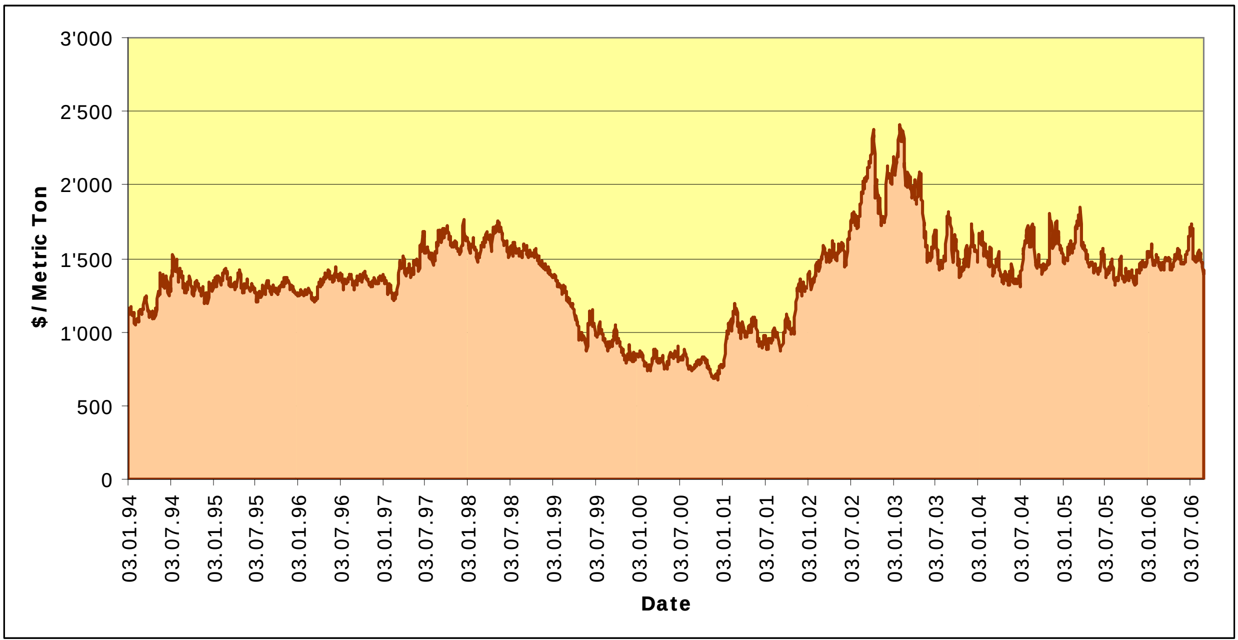



**Figure 11-3: Cocoa prices between 1994 and 2006 (cf. ICCO, 2006)**

## 11.4 Growing the Cocoa Bean[30]

### 11.4.1From Seedling to Tree

Farmers grow cacao trees on small farms in hot, rainy environments, mostly in areas near the equator. Cacao is a delicate and sensitive crop, and farmers must look after the trees, making sure the trees are protected from wind and sun. This care is particularly important for young trees, up to four years old.

Cacao seedlings are often sheltered by other trees, like banana, plantain, coconuts or hardwood trees. Seedlings take a few months to grow before they are ready to be transplanted. Once the trees are planted, the farmers must fertilize the soil and watch the trees closely for signs of distress. With cautious care, most cacao trees begin to bear fruit in the fifth year, although some cacao trees can yield pods in the third and forth years. A cocoa tree reaches peak production in approximately 10 years and will continue producing pods at a high level for an additional 12 - 13 years. It is not uncommon to find trees 30 - 40 years old, still producing pods.

[30] Source: http://www.worldcocoafoundation.org/

### 11.4.2 Bearing Fruit

Cocoa farms are awash in colour. Young cocoa leaves are large, red, and glossy, but darken to green when mature. Moss and colourful lichens often cling to the bark of cacao trees, and in some areas beautiful orchids grow on the branches.

Thousands of tiny, waxy pink or white five-pedalled blossoms cluster together on the trunk and older branches. But only three to ten percent of these blossoms will mature into full fruit.

The fruit grows as green or maroon pods on the trunk and main branches. Shaped like an elongated melon tapered at both ends, these pods ripen to a golden or sometimes scarlet hue with multicoloured flecks.

### 11.4.3 Harvesting the Cocoa Pods

To harvest cocoa beans, the ripe pods must be removed from the trees.

Cacao trees are fragile, and farmers cannot climb the trees to reach the fruit without snapping branches or entire uprooting trees. Instead, cocoa farmers and family members reach the cocoa pods with long handled, mitten-shaped steel tools. These tools reach the highest pods and snip them without wounding the soft bark of the tree. They can also use machetes to remove pods growing closer to the ground.

### 11.4.4 Experience Counts

The growing season in the tropics is continuous, due to rainfall that is evenly distributed through the year.

As a result, ripe pods may be found on cocoa trees at any time. It takes a lot of experience to recognize which fruit is ready to be cut.

In most cocoa areas, the main harvest lasts several months. Another harvest – the mid-crop -- lasts for several additional months. Changes in weather can dramatically affect harvest times, causing fluctuations from year to year, even on the same farm.

### 11.4.5 After Harvesting

Once ripe, the pods are removed from the trees and fall to the ground. Gathering the harvest pods can be a family affair. The farmer, family members and neighbouring farmers collect the pods in baskets and transport them to the edge of a field where the pod-breaking operation begins.

An experienced pod breaker takes one or two blows to split the shells with a hammer or other, similar instrument. A good breaker can open 500 pods an hour.

The husk and inner membrane of the pod is discarded, and a farmer can expect 20 to 50 cream-coloured beans from a typical pod. Dried beans from an average pod weigh less than two ounces, and approximately 400 beans are required to make one pound of chocolate.

### 11.4.6 Preparing the Crop for Shipment

Once the beans have been removed from the pods, the farmer packs the beans into boxes or heaps them into piles and covers them with mats. A layer of pulp that naturally surrounds the beans heats up and ferments the beans themselves.

Fermentation is an important step – lasting three to nine days – that removes the raw, bitter taste of cocoa. The sugars contained in the beans are converted to acid, primarily lactic and acetic, during fermentation.

The process generates temperatures as high as 52 degrees Celsius, activating existing enzymes in the beans to form compounds that produce the chocolate flavour when the beans are roasted. The result is a fully developed bean with a rich brown colour, a sign that the cocoa is now ready for drying.

### 11.4.7 Drying, a Natural Preservative

Like any moist fruit, the cocoa beans must be dried if they are to be kept from spoiling. In some months, the cocoa farmer can dry his beans simply by laying them on trays or matting and leaving them to bask in the sun. Sometimes farmers use solar dryers to help dry the crop.

With favourable weather, the drying process usually takes several days. The cocoa farmer turns the beans frequently and checks for foreign matter and flat, broken or germinated beans. During drying, beans lose nearly all their moisture and more than half their weight.

Finally, when beans are dried, they are packed in 130 to 200 pound sacks for shipping.

### 11.4.8 From Farmer to Exporter

After the farmer has packed all the dried cocoa beans, he delivers them to an exporting company. The exporting company inspects the cocoa and places it into burlap, sisal, or polymer bags.

The cocoa is trucked to the exporter's warehouse near a port. Sometimes additional drying is necessary at this point.

### 11.4.9 From Exporter to Shipper

The exporting company finalizes the time and place for shipment, an independent grading agency grades the bean and the beans are loaded onto ships.

Once the ship reaches its destination, the cocoa is removed from the hold and taken to a pier warehouse, where it is sampled and inspected by the importer and declared to customs.

### 11.4.10 From Shipper to Processor

U.S. importers often remove the cocoa from the bags at a warehouse. Trucks carry the cocoa in large tote bags or loose in the trailer to the manufacturer's facility on a "just-in-time" basis.

Larger processors in Europe frequently receive cocoa in "mega-bulk" shipments. The cocoa is placed loosely, into barges alongside the ships; into a "flat storage area," where it is held on the floor of the warehouse, or to silos, and shipped at prearranged intervals to the processing facility.

# 12 Cocoa in Indonesia

*Criollo* cocoa was introduced to Indonesia in 1560 but its production was small and limited to the island of Java. In 1888 *Forastero* cocoa was introduced to the *Criollo* stock resulting in a hardy *Trinitario* variety producing what is known as the "Java A Bean".

Cocoa plantings were cultivated by some estates in East Java and North Sumatra covering around 6,500 hectares before the Second World War, producing about 2,000 tonnes. Production remained small until Sulawesi, Kalimantan and Sumatra joined Java as production centres.

Indonesia expanded its cocoa production substantially from the early 1980s onwards. The Upper Amazon Interclonal Hybrid variety was chosen for a national expansion programme of smallholders' cocoa in 1975. Millions of seedlings were distributed and by 1980 cocoa areas were covering 37,000 hectares and by 1988 more than 135,000 hectares.

In 1981/82 Indonesia produced 16,000 tonnes of cocoa beans but by 2004/05 its production totalled 435,000 tonnes.

The expansion programme was encouraged by a free economy, cheap government grants to buy land, low production costs and planting technology and husbandry learnt in the plantations of Malaysia. Also, the Indonesian Cocoa Association provides extension services and technical assistance to farmers to improve efficiency and quality.

The tree stock in Indonesia, since 1983, has been mainly high yielding hybrid material. Before this, cocoa was grown only on a small scale and concentrated on the production of fine grade cocoa. The farms in Indonesia are a mixture of smallholders and larger plantations but, with the expansion programme, the total area planted by smallholders has increased to well over half the total area (ICCO, 2006).

## 12.1 Cocoa in Nusa Tenggara Timur

With over 13,000 tonnes of cocoa beans produced in 2004, NTT is the 9th largest producer of cocoa in Indonesia. In 2005 the total area of cocoa in NTT reached 34,379.86 ha.
On the island of Flores, smallholder farmers produce over 87% of cocoa export from NTT. The remaining NTT cocoa production takes place in West Sumba, Kupang, TTS, TTU Belu, Alor, and Lembata.

## 12.2 Cocoa in Flores

There is no large estate grow of cocoa in Flores, but there are approximately 15,000 small-holder cocoa farmers in Flores, who cultivate an average of less than 1.5 hectares each. Most labour on cocoa farms is provided by family members. In particular, the farmers who are cultivating more than two ha of cocoa hire labour from outside.

Average yield on these farms varies from 400 to 700 kg per hectare (2003/2004).

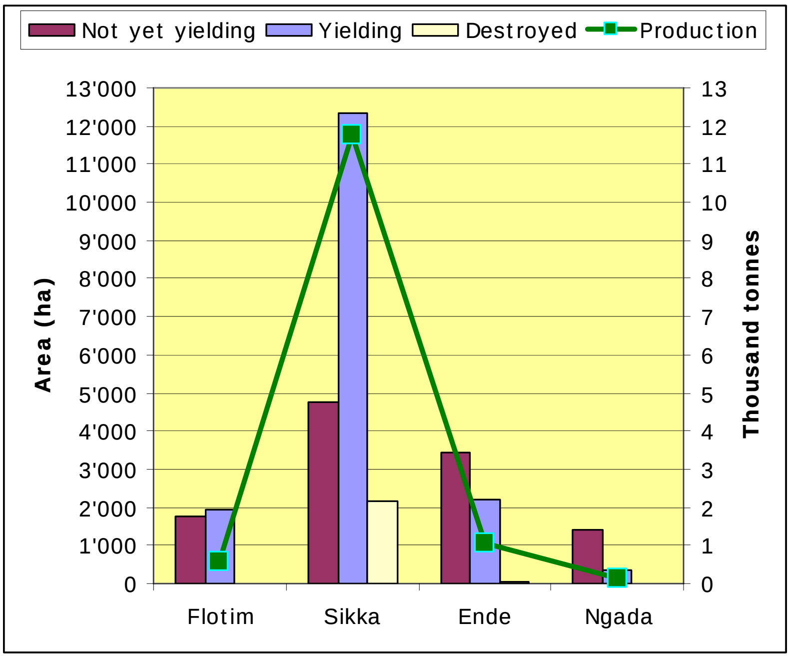



**Figure 12-1: Cocoa production and area in Flores**

In the research area, where most of the islands cacao is cultivated, Sikka is the main producing regency by nearly 86% (BPS, 2005: 332).

Cocoa is after cashew nuts, coconuts, and coffee the fourth largest (measured by foreign exchange earnings) cash crop cultivated in Flores. Cocoa is the primary cash crop for most farmers in the district of Sikka and secondary cash crop for other parts of Flores.

Plantation area of cocoa on Flores is diversified: 61% of the farmers also grow rice, maize and other food crops. These other crops -particular rice- have a greater social impact as the cocoa and farmers often spend more time on these crops and less on cocoa.

Flores cocoa is traded on the global market in unfermented quality. Cocoa farmers in some areas of Flores (e.g.: Hokeng) do ferment their beans, but their production is quite small and is mainly sold to agents for local processors in Surabaya rather than exported to Makassar. In Ngada and Ende there have been efforts to encourage smallholder farmers to expand production of fermented beans, but commercial incentives for such a widespread shift in production practices are inadequate.

Fermentation[31] of cocoa beans can help bring out their inherent flavour, but is not generally done in Flores. The global demand for these unfermented bulk beans has become relatively inelastic and not significantly affected by changes in price.

Cocoa production in Flores began to develop during the 1980s, fuelled by high global cocoa prices and a significant decline in output from West Africa. In addition, migrant Indonesians working on cocoa farms in Malaysia returned home to Sulawesi and then migrant from Sulawesi bringing back planting materials as well as technical skills and capital to invest in cocoa production in Maumere, Flores. Nowadays, dominantly cultivated by smallholder on Flores is the *Forastero* species.

Like in most Indonesian provinces the main harvest lasts from June to October and the interim harvest from December to April. The cacao farmers have only little storage capacity, therefore, they sell their cocoa beans while still wet for immediate cash, rather than wait until they are properly dried (or fermented some cases).

From 2004 until 2006, productivity was dropping from the highest production of about 700 kg/ha to the current levels of about 50 – 150 kg/ha. This due to high costs and limited availability of inputs, and a number of causes including: widespread infestation of pest and diseases (primarily the Cocoa Pod Borer and *Heliopeltis*), age and variety of existing tree stock, poor soil nutrition and drought. This results in highly declining income potential for smallholder farmers.

The major problems Flores' Cocoa industry is faced with are the low productivity and the infestation of CPB (Cocoa Pod Borer) and diseases, and low bean quality. With regard to overcome the problems of low productivity, CPB and other diseases, and low quality, the local government of Sikka, Ngada and Ende has conducted to develop superior clones.

## 12.3 Cocoa Pod Borer Infestation[32]

Cocoa pod borer (CPB, *Conopomorpha cramerella*) has become a major production-limiting factor in Malaysia, Indonesia and Philippines. CPB lays its eggs on the pods and the larvae then feed off the pod. Numerous outbreaks of CPB have occurred in Indonesia. In early 1997 CPB was officially confirmed in 42,864 hectares of approximately 450,000 hectares planted with cocoa. By March 1998 researcher estimated that up to 100,000 hectares or approximately 20% of all cocoa in Indonesia was infected with CPB. The estimated losses in dollars due to CPB approached $20m in 1998. The CPB has been the single most important

[31] Fermenting is a simple yeasting process in which the sugars contained in the beans are converted to acid. This is done after the pods are harvested, heaped, and covered. Fermenting lasts from three to nine days -removing the raw bitter taste of cocoa to develop a more characteristic chocolate flavour when the beans are roasted.

[32] This chapter is summarized by the analyst from various research materials from the international Cocoa Association website.

limiting factor in cocoa production in Indonesia. The beans from seriously infested pods are completely unusable and in heavy infestation over half the potential crop can be lost. With limited control, production losses in infested areas are significant (between 20-50%) for smallholders who rely on the year-round cash income provided by cocoa.

Chemical sprays (*Cypermethrin, Nurelle*, a formulation of *Cypermethrin* and *Chloropyriphos*) have become ineffective against CPB after continuous usage. Researchers highlighted the use of integrated pest management, which consists of cultural and biological control methods and planting of resistant clones for managing this pest. In Malaysia, cocoa black ant and egg parasitoid have been found to be potential bio-control agents in limiting cocoa pod borer infestation. Integration of weekly harvesting and spraying of *Beauveria bassiana* every two weeks was the most effective method to control CPB infestation in Indonesia. Pod sleeving with plastic bags have been able to control CPB in smallholders garden but not in larger plantations. Some of the clones have conferred resistance against the CPB in Malaysia but they may not have good agronomic traits, thus requiring further cross breeding with the agronomically good clones.

When pesticides are used on a frequent basis, there is a risk of build-up of pest resistance against pesticides. Serious outbreaks of pests, e.g. diamond back moth on cabbage and brown plant hopper on rice, have been documented in several SE Asian countries after intensive use of chemicals resulted in the reduction of natural enemies, and meanwhile building up of pest resistance to pesticides. Last but not least, farmers tend to increase the frequency and dosage of pesticide applications when crop health problems persist. As farmers get caught in the 'pesticide treadmill', costs of production escalate. Experiences must be shared about the reduction of effectiveness of insecticides due to build-up of pest resistance.

CPB is not only a direct problem to these farmers and the cocoa industry but, indirectly, it also poses a serious ecological and health hazard. When cash is available, some farmers use pesticides in an attempt to control the pest. But chemicals are generally ineffective against the larvae which burrow into cocoa pods. Controlling the adult moth is also potentially dangerous as it involves large

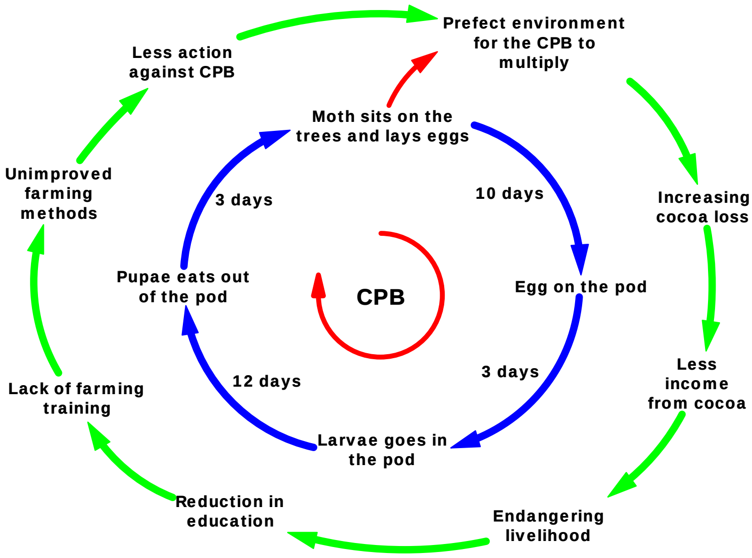



**Figure 12-2: CPB lifecycle and multiplication**

amounts of toxic insecticides being sprayed high into the canopy of trees. In addition, with decreasing yields from existing plantations, farmers often resort to cutting down surrounding forest to plant more cocoa trees.

Good management of the cocoa area and complete regular harvesting is having good results in containing the pest. Cultural techniques have proved successful in greatly reducing the damage within one crop cycle. Through demonstration plots, local farmers could be convinced that the additional labour required to keep the pest under control, will result in better farm management and increased incomes.

# 13 Value Chain Analysis of Flores Cacao

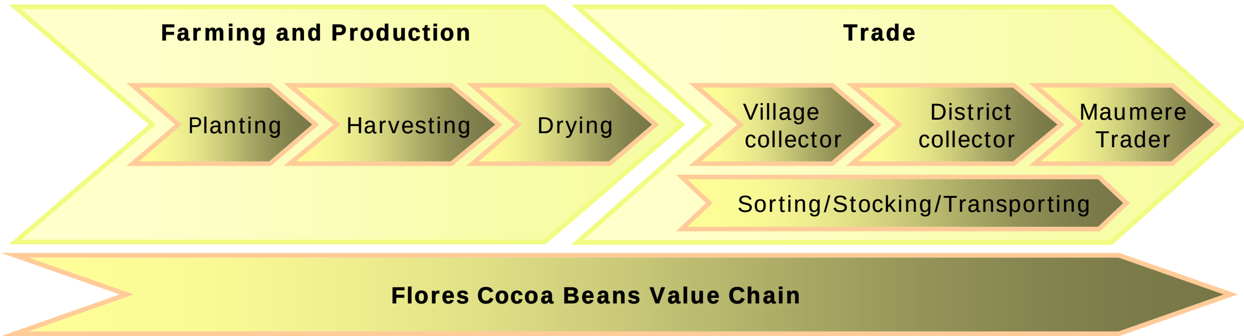



**Figure 13-1 Cocoa bean production value chain in Flores**

## 13.1 Research Area Cocoa Value Chain

### 13.1.1 Cocoa Bean Production

In 2003/2004, Flores cocoa exports were valued at approximately 11,313 thousand tonnes of unfermented coca beans, worth $ 15.2 million per year. This provides the main source of income and livelihood for over 15,000 smallholder farmers and their families in Flores.

Average yield on these farms ranges from 350 to 450 kilograms per hectare (2004/2005) dropping to 50 to 150 kilograms per hectare (2005/2006). Farmers sell to local collectors at farm gate or directly to local traders. There are few examples of cooperative-type horizontal linkages or group marketing among smallholder farmers in Flores; most smallholder farmers prefer to deal independently with private collectors and traders.

### 13.1.2 Collecting / Bulking

Local collectors are usually cocoa farmers themselves or rural entrepreneurs with a motorbike (or sometimes a truck) who purchase cocoa beans directly from farmers. The scale of these purchases is small and turnover is rapid. Local traders purchase cocoa beans from local collectors or, to a lesser extent, directly from farmers, and are usually engaged in a variety of other businesses (e.g., general merchants, vehicle hire, etc.). These traders sell most of their cocoa beans to local exporters although a smaller amount flows to local processors. Collectors and traders do not need licenses or permits to operate so competition is fierce with few barriers to entry.

### 13.1.3Local processing

Cocoa processing, or grinding, entails the transformation of dried cocoa beans into a variety of processed products including cocoa paste or liquor, cake, powder and butter. Processors have strict quality standards and expect their suppliers to meet these standards. Only ten percent of Indonesia's cocoa bean production is processed locally, the rest is exported as raw beans.

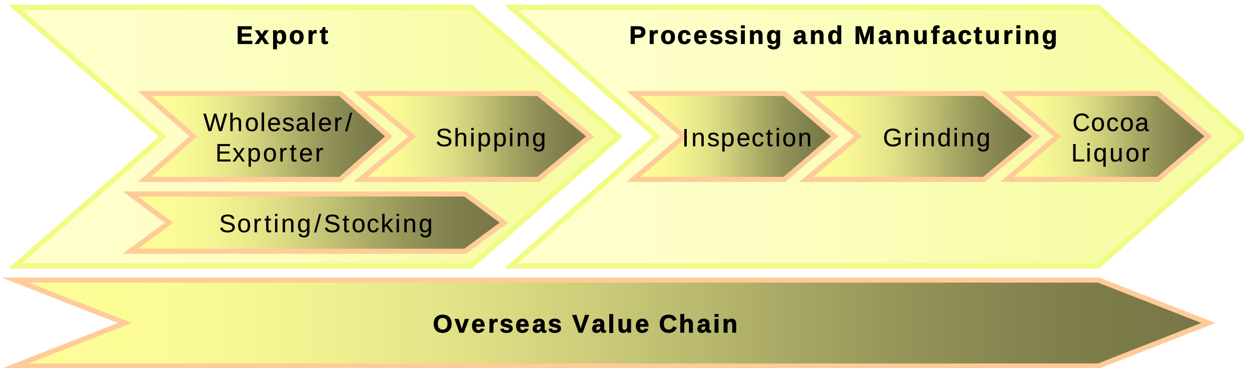



**Figure 13-2: Overseas value chain**

### 13.1.4Exporting

The biggest local trader in Flores, based in Geliting (Maumere), exports approximately 90% of the cocoa beans by ship direct to Makasar (Sulawesi). The remaining 10% are exported by truck to Bali and Java.

Local exporters buy from collectors and traders who deliver beans to their storage facilities. Many of these local exporters have found it increasingly difficult to compete with the large-scale international exporters and have begun to sell to them rather than continue to export independently. Approximately 80 percent of Indonesian cocoa beans are sold by the five main multinational affiliate exporters in Sulawesi: EDF & Man, Olam, Cargill, ADM and Continaf (these firms have offices worldwide engaged in international commodity trading). These large-scale exporters purchase bulk beans from traders who deliver to their warehouses, sort and grade for quality, and sell to buyers (primarily in the U.S., Malaysia, Singapore and Brazil) for processing.

### 13.1.5International Trading / Processing / Manufacturing

Once cocoa beans are exported from Indonesia they become part of the global trade in cocoa which includes multinational traders, processors and manufacturers. Multinational traders sell cocoa beans to processors and manufacturers around the world. Multinational processors are major producers of processed cocoa products (cocoa liquor, butter and cake). Multinational manufacturers are dedicated chocolate producers and are generally located close to their final consumer markets. There are also integrated multinational processors and manufacturers who are involved in multiple functions of processing and manufacturing of final products. One of the largest, Mars, has significant presence and representation in Indonesia.

## 13.2 Value Chain Characteristics

### 13.2.1 Volume and Cash-driven Transaction

Without incentives for exporters, intermediaries, or farmers to differentiate their cacao bean and invest in quality improvement they continue to be driven by volume-based transactions. For some intermediaries, mixing good quality beans with waste material or poor quality beans is a standard practice to maximize volume and income. The use of inappropriate weights and measures by a few collectors or traders has also heightened the level of mistrust of intermediaries among some farmers. But this practice of volume manipulation will be difficult to discourage or change without adequate commercial sanctions (or incentive) dictated by global processors and manufactures at the top of the value chain.

Transactions between cocoa farmers and market intermediaries, and between intermediaries and cocoa exporters or processors, are primarily conducted on a cash and carry basis.

Smallholder farmers have the option to sell to a large number of local collectors or buyers, but most will sell their cocoa soon after harvest (often without being adequately dried) for immediate cash. The collectors and the traders in Geliting-Maumere rely on advance from private bank (BNI and BRI) to finance these frequent cash purchases.

### 13.2.2 Margins and the distribution returns

Flores cocoa farmers receive on average a high percentage of the national price. The farm-gate price for Flores cocoa beans can range between 75% and 85% of the Sulawesi/New York Terminal exchanges price.

With farmers receiving up to 85% of the free on board price (FOB), depending on location based transaction; the small remaining balance is shared among the many other participants in the value chain. According to one source, the margin between the FOB price and the farm gate price in Flores can be broken down into marketing and logistical costs (10%), collectors/trading margin (3-4%), and exporter margin (2%). Given the slim margins, the large number of local collectors and traders in the value chain depend on quick turnover and high volume transactions.

While farmers are producing a better quality of cocoa beans and, consequently, should get a higher income for it, they complain that they are not getting any price differentials from collectors and traders for improved quality beans.

Some processor and exporter base in Makasar, Bali and Surabaya, have attempted to offer price differentials, up to 10%, for beans that can consistently meet higher quality specifications.

The prices that market intermediaries pay are based primarily on a “discounting” process. The daily global price for Sulawesi cocoa is widely known by all participants through the value chain, and serves as the basis for an initial price offer. Once an initial price is established, collectors and traders (as well as exporters) will then engage in a discounting process to reduce the initial price base on certain quality parameters.

Calculating net price for cocoa beans:
Initial price (base on NY Sulawesi FAQ) - Discount (base on quality specs) = Net price
Multiplied by volume = Income

The basic quality parameters include moisture content, bean count (i.e., number of beans per 100 grams), percentage of waste, mouldiness, and clumped or flat beans.

At the local farmer and collector level in Flores, moisture and general appearance are the most important factors consider in the discount process.

Since volume is a key driver in the cocoa value chain, as stated above, some market intermediaries will attempt to sell cocoa bean mixed with poorer quality beans or actual waste material (e.g. shells, foreign matter) to increase the volume.

There is a demand for fermented beans from local processors but their requirements are not currently large enough, nor is there sufficient differentiated pricing, to justify large-scale production of fermented Flores beans.

# 14 Swisscontact LED-NTT proposed interventions

## 14.1 The LED-NTT Project

In March 2004, Swisscontact launched the LED-NTT project in Flores. LED stands for Local Economic Development and defines the project goal, namely to facilitate economic development in specific areas in the Province of Nusa Tenggara Timur (NTT). The project focuses on income generation and job creation through an integrated approach on sector development such as cashew nuts, cacao and ginger. Likewise, the project aims to contribute to the reduction of poverty in selected areas of NTT.

Bearing in mind that 29% of the people in NTT are poor, the creation of decent employment is widely seen as a major route out of poverty. The LED-NTT project has already selected the cashew nuts sub sector as the first field of intervention.[33] Swisscontact identified the cacao sub sector with high potential for achieving high impact on farmer level for future interventions.

## 14.2 Major Problems

### 14.2.1Low Productivity

Aging trees (planted in 1980’s).

Insufficient improved varieties.

Limited disease and pest control.

Poor soil maintenance (fertilizer, water management).

Poor crop maintenance.

Average yield: 600 kg/ha/year.

Potential yield: 1,000 – 1,500 kg/ha/year.

### 14.2.2Low Quality

Cacao Pod Borer (CPB) problem (loses 30 – 40% of potential production)

Limitation of post harvest equipments (dryer, sorting, storage) on farm level

No price incentive at farmer level for good and fermented beans

### 14.2.3Poor distribution mechanism

Low bargaining power of farmers in cocoa bean transaction with village traders

High dependency of farmers on local traders (advance cash payment by local traders for consumptive purpose)

No rule / regulation on local traders (lots of cheating on moisture content and weight)

Volume based contract not quality based

[33] Source: Swisscontact brochure for the LED-NTT project

No quality differentiation treatment on exporter level

Limited farmers - industry partnership

Difficult to develop formal contract system to comply with quality

International market acceptability and demand for various quality of cocoa bean does not provide incentive for farmers to improve bean quality

### 14.2.4Regulation

*Standar Nasional Indonesia* (SNI) still voluntary based not mandatory

No law enforcement on SNI implementation which is mandatory for exporter

Cheating on SNI certification

Lack of custom control on mechanism for quality certification process

## 14.3 Constraints and Opportunities

Lack of knowledge of farmers about the benefits of using appropriate inputs (insecticide, pesticide, fungicide, hormones) leads to poor farm management. This result in lower productivity of cocoa.

Lack of knowledge of Farmers about the soil content leads to inappropriate use of fertilizer, which results in lower productivity.

Insufficient supply of appropriate inputs (fertilizer, insecticide, pesticide, fungicide, hormone) to the smallholder farmers leads to insufficient and / or inappropriate use of inputs that results in lower productivity of Cocoa.

Lack of knowledge about the potential benefit of drying leads farmers sell wet or poorly dried cocoa beans that results in lower price and profit.

Lack of knowledge of farmers about the profitability and benefits of supplying high quality beans leads to produce/supply poor quality cocoa that limits the opportunity to enter high-end market.

Farmers miss opportunity of getting higher price for selling unfermented cocoa beans.

Insufficient labour force for field management leads to poor farm management, which causes low productivity in farmer level.

Improved policy and business environment (land registration procedure, farmer group and cooperative formation, quality standards, coordinated research & extension service) can boost the cocoa sector growth in Flores.

Lack of knowledge of farmers / traders on maximization of financial resources from cocoa production

Insufficient amount of money hinders farmers to buy and use appropriate inputs or do further investment that results in un-optimized production.

## 14.4 Vision

The vision of the Flores Cocoa sub sector is:

> *"Small farmers continue to improve their productivity in the cocoa sub sector with an increased availability of and awareness in good quality inputs and improved farming knowledge on cultivation practices."*
>
> *"Increased production of quality beans creates opportunity to enter the higher segment of market with a higher profitability. Cocoa sub sector contributes significantly in the increasing of the farmers' income and generation of further employment."*

## 14.5 Strategies

**Strategy 1**

Better access and use of quality inputs

**Strategy 2**

Sustained productivity through improved knowledge of quality inputs and farming techniques

**Strategy 3**

Access to higher market segment by improving quality of Cocoa beans

**Strategy 4**

Availability of necessary financial resources and maximization of the available financial resources

**Strategy 5**

Improving conducive policy and business environment

## 14.6 Interventions

Besides many proposed interventions, Swisscontact LED-NTT selected the following one to start with:

Provision of and access to affordable and recommended inputs to the farmers to ensure better farm practice (appropriate application of technology and inputs).

# Appendix 2; Further Analytical Material and Research

# 15 System Description

## 15.1 The Systems relevant Variable Set

**Table 15-1: The variable set**

| No. | Element | Description |
|---|---|---|
| **E1** | Availability of suitable land | Cacao trees need specific soil, weather and environment circumstances.[34] Flores has suitable land to grow cacao trees, but this is either limited because of bounded general estate resources or used for other cash crops. This variable represents the amount of availability of suitable land to grow more or less cacao trees. |
| **E2** | Church, NPO or NGO intervention | This variable collects the availability and the impact of interventions from churches, non-profit and non-government organisations. This variable often represents a mediator role. |
| **E3** | Availability of information | This variable represents both the availability and the quality of information. The kind of information is not specified, but it is mostly media, like newspaper, radio and others provided by a system actor. |
| **E4** | Cacao trees stock/holdings | The sum of every planted cacao tree in Flores, from seedlings to peak trees up to old trees. |
| **E5** | Cocoa bean production | The cocoa bean production represents the production of all farmers and their trees. This variable can be quantified by the data of the exporters in Maumere. |
| **E6** | Collectors and middlemen | This variable represents all the actors in the value chain between farmer and the importers in Makasar. These actors are in strong competition because of the free marketing system for cocoa in Indonesia. |
| **E7** | Demand for cocoa beans | The demand for cocoa beans represents the specific demand for Indonesia cocoa either fermented or unfermented. |
| **E8** | Diseases and pests | This variable summarizes all the biological treatments for the cacao trees and the amount of action against them. The strongest impact within this variable has the current high CPB infestation. |

[34] For further information about the cacao tree see Appendix 1, chapter 11.

| | | |
|---|---|---|
| **E9** | Drought and bad weather | Drought and bad weather represents the impact of climate change and weather impact on the system. |
| **E10** | Farmers' crop know-how | This variable is influenced by the learning curve of the farmers and their experience in farming. Farmers' crop know-how is an average qualitative value of all the farmers on Flores. |
| **E11** | Farmers' expenses | The farmers' expenses summarize all the production cost for cocoa beans as well as their every day spending beside the farming costs. |
| **E12** | Farmers' capacity | Capacity is the qualitative value of the ability of the farmer to work, including motivation, fatigue, laziness and other working relevant capabilities except knowledge and experience. |
| **E13** | Farm gate price for cocoa | The farm gate price is the average price the farmers on Flores get for their cocoa beans. The prices vary up to 30%, depending on the distance to the exporters in Maumere. |
| **E14** | Agriculture agency intervention | This variable represents all the farming concerning government activities. |
| **E15** | Labour force (employees) | The amount of workforce which the farmers employ excluding their no paid family members. |
| **E16** | Livelihood of farmer | This variable has a priority issue in the international development work Farmers' livelihood is determined by the access to financial- , physical-, natural-, social, and human capital assets. |
| **E17** | Business environment | The variable business environment is an overall view on all restrictions and promoters on the political (government interventions) and the macroeconomics (exchange rates, inflation, trade connections) level. |
| **E18** | Farmers' health | The farmer's health is crucial to his ability to work and to have a liveable existence. This variable is closely connected to the farmers' capacity and his livelihood. |
| **E19** | Quality of cocoa beans | This variable is a qualitative value determined by the quality of the beans the farmers produce and deliver to the collectors. Qualitative aspects are specified in the SNI (Standard National Indonesia). |
| **E20** | Farmer group intervention | If there are farmer groups, this variable represents the intervention those groups can provide. |

| | | |
|---|---|---|
| **E21** | Input suppliers' action/support | Input suppliers are all actors in the value chain[35] ahead of the cacao farmer, which provide inputs, seedlings and tools for effective cocoa farming. |
| **E22** | Schooling in agriculture | The variable schooling in agriculture sums up all activities/institutions in which the farmers can gain knowledge about farming techniques. |
| **E23** | Financial institutions' intervention | Financial institutions are determined as the actors in the value chain which provide the necessary cash for every actor in the system itself. |
| **E24** | Soil and environment | This variable reflects the status of the soil in which the farmers plant the trees, as well the overall condition of the environment in which all the actors act and live. |
| **E25** | Transport infrastructure | The transport infrastructure includes the road infrastructure and its actual condition and also the transport facilities available. |
| **E26** | Farmers' income | This variable represents the monetary yield of the farmers' farming production (cacao and other cash crops and other income sources). |
| **E27** | Farmers' management know-how | This variable reflects the entrepreneurship and the farmers' business knowledge besides the crop know-how, and how to run a farm effectively. |

[35] For further information about the value chain in Flores cacao see Appendix 1, chapter 13.

## 15.2 The Systems Inherent Impact

The systems inherent impact matrix in Figure 15-1 is the result of extensive discussions about each possible connection of the variable set. Every possible interrelation has intensity between 0 and 3, as shown below:

0: No, or only a slight effect. No connection.

1: Strong intervention in the initial variable leads to a slight impact on the target variable.

2: Strong intervention in the initial variable leads to the same amount of impact on the target variable.

3: Little intervention in the initial variable leads to a strong impact on the target variable.

| | Systems variables: | E1 | E2 | E3 | E4 | E5 | E6 | E7 | E8 | E9 | E10 | E11 | E12 | E13 | E14 | E15 | E16 | E17 | E18 | E19 | E20 | E21 | E22 | E23 | E24 | E25 | E26 | E27 | AS | Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| E1 | Availability of suitable land | 0 | 0 | 0 | 2 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 10 | 0.53 |
| E2 | Church/NGO/NPO intervention | 0 | 0 | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 1 | 0 | 2 | 1 | 2 | 0 | 0 | 2 | 19 | 1.06 |
| E3 | Availability of information | 0 | 2 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 2 | 0 | 1 | 2 | 1 | 0 | 2 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 0 | 0 | 2 | 25 | 1.14 |
| E4 | Cacao tree stock/holdings | 3 | 2 | 0 | 0 | 3 | 0 | 0 | 3 | 1 | 1 | 2 | 3 | 1 | 2 | 2 | 1 | 0 | 0 | 1 | 2 | 1 | 1 | 1 | 2 | 0 | 3 | 0 | 35 | 1.09 |
| E5 | Cocoa bean production | 0 | 2 | 0 | 2 | 0 | 3 | 2 | 0 | 0 | 1 | 1 | 2 | 2 | 1 | 2 | 1 | 3 | 0 | 1 | 2 | 1 | 1 | 0 | 1 | 0 | 3 | 0 | 31 | 0.91 |
| E6 | Collectors and middlemen | 0 | 0 | 2 | 0 | 1 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 1 | 2 | 0 | 3 | 2 | 0 | 0 | 3 | 0 | 1 | 1 | 0 | 22 | 0.85 |
| E7 | Demand for cocoa beans | 0 | 1 | 1 | 0 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 1 | 2 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 24 | 1.71 |
| E8 | Diseases and pests | 1 | 2 | 0 | 3 | 3 | 2 | 1 | 0 | 0 | 1 | 2 | 1 | 0 | 3 | 1 | 0 | 0 | 2 | 3 | 2 | 3 | 0 | 0 | 2 | 0 | 0 | 0 | 32 | 1.45 |
| E9 | Drought and bad weather | 3 | 0 | 0 | 3 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 1 | 0 | 2 | 0 | 0 | 3 | 2 | 1 | 0 | 20 | 4.00 |
| E10 | Farmers' crop know how | 0 | 2 | 2 | 2 | 3 | 0 | 0 | 3 | 0 | 0 | 1 | 2 | 0 | 1 | 1 | 2 | 0 | 0 | 3 | 3 | 2 | 1 | 0 | 2 | 0 | 0 | 1 | 31 | 1.29 |
| E11 | Farmers' expenses | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 3 | 1 | 9 | 0.47 |
| E12 | Farmers' capacity | 0 | 1 | 0 | 2 | 3 | 0 | 0 | 3 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 2 | 3 | 2 | 0 | 2 | 0 | 1 | 0 | 1 | 1 | 26 | 1.13 |
| E13 | Farm gate price for cocoa | 0 | 0 | 0 | 1 | 2 | 3 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 19 | 0.95 |
| E14 | Agriculture agency intervention | 2 | 1 | 2 | 2 | 1 | 2 | 1 | 0 | 0 | 3 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 2 | 2 | 3 | 2 | 2 | 3 | 0 | 2 | 34 | 1.62 |
| E15 | Labour force (employees) | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 2 | 3 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 14 | 0.82 |
| E16 | Livelihood of farmer | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 2 | 0 | 1 | 1 | 0 | 0 | 2 | 0 | 2 | 0 | 2 | 0 | 1 | 0 | 0 | 1 | 19 | 0.68 |
| E17 | Business environment | 3 | 2 | 0 | 1 | 2 | 2 | 1 | 0 | 0 | 0 | 2 | 0 | 2 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 0 | 3 | 2 | 0 | 27 | 1.93 |
| E18 | Farmers' health | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0.45 |
| E19 | Quality of cocoa beans | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 0.44 |
| E20 | Farmer group intervention | 1 | 0 | 2 | 2 | 1 | 1 | 0 | 2 | 0 | 2 | 0 | 1 | 1 | 2 | 1 | 0 | 1 | 0 | 2 | 0 | 0 | 2 | 2 | 1 | 1 | 0 | 0 | 25 | 0.89 |
| E21 | Input suppliers' action/support | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 3 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 15 | 0.71 |
| E22 | Schooling in agriculture | 0 | 0 | 2 | 1 | 1 | 0 | 0 | 1 | 0 | 3 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 13 | 0.72 |
| E23 | Financial institutes intervention | 0 | 0 | 1 | 0 | 1 | 3 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 11 | 0.65 |
| E24 | Quality of soil and environment | 2 | 1 | 0 | 3 | 2 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 2 | 0 | 1 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 20 | 0.87 |
| E25 | Transport infrastructure | 2 | 1 | 1 | 0 | 0 | 2 | 1 | 1 | 0 | 0 | 0 | 1 | 3 | 1 | 0 | 2 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 20 | 1.43 |
| E26 | Farmers' income | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 1 | 0 | 0 | 17 | 0.89 |
| E27 | Farmers' management know how | 0 | 0 | 1 | 2 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 2 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 16 | 0.84 |
| | PS | 19 | 18 | 22 | 32 | 34 | 26 | 14 | 22 | 5 | 24 | 19 | 23 | 20 | 21 | 17 | 28 | 14 | 11 | 27 | 28 | 21 | 18 | 17 | 23 | 14 | 19 | 15 | | |
| | P | 190 | 342 | 550 | 1120 | 1054 | 572 | 336 | 704 | 100 | 744 | 171 | 598 | 380 | 714 | 238 | 532 | 378 | 55 | 324 | 700 | 315 | 234 | 187 | 460 | 280 | 323 | 240 | | |

**Figure 15-1: Impact matrix**

Active element: highest Q-number

Critic element: highest P-number

Passive element: lowest Q-number (in the graphic multiplied by hundred)

Absorbing element: lowest P-number

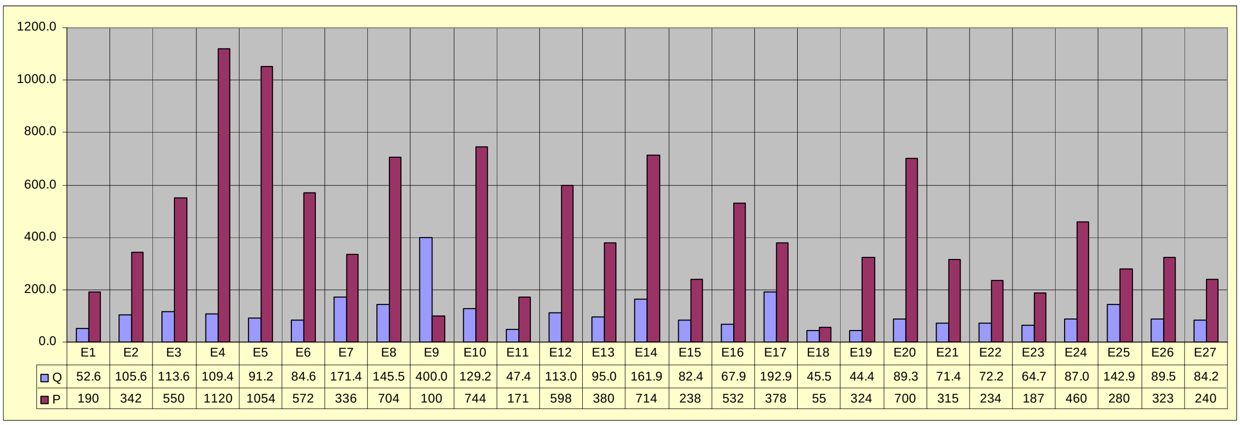



**Figure 15-2: Variables impact bar chart**

# 16 Causal Loop Diagrams Explanation

**Table 16-1: Loop interpretation of CLD part 1**

| Loop | Interpretation (telling the story) |
|---|---|
| **R1** “Achieve Livelihood” | If “Farmers' capacity” rises, then “Cocoa bean production” rises, thereby “Farmers' income” increases, which leads to a higher state of “Livelihood of farmer” which has positive effects on “Farmers' capacity”. |
| **R2** “Farmers’ growth” | When “Schooling in agriculture” is available and attended, then “Farmers' crop know-how” increases, therefore, a higher amount of “Cacao tree stock/holdings” is possible which leads to a higher “Cocoa bean production” and higher “Farmers' income” which again leads back to more “Schooling in agriculture”. |
| **R3** “Know-how against pest” | When the “Cocoa bean production” rises, the “Farmers' income” goes up too, therefore he can attend more “Schooling in agriculture” which leads to more “Farmers' crop know-how” and to more efficient ways to fight “Diseases and pests” to achieve a higher “Cocoa bean production”. |
| **R4** “I need help” | If “Cocoa bean production” raises, the “Farmers' income” increases, so they can afford more “Labour force” which leads to more “Cocoa bean production”. |
| **R5** “Cocoa expansion | If there is a beneficial “Business environment”, “Demand for cocoa beans” from Indonesia will rise, so the “Cocoa bean production” will go up as well, and more “Cocoa bean production” pushes again the “Business environment” to a higher level of influence. |
| **B1** “Overworking” | When the “Cocoa bean production” rises, the “Farmers' income” goes up too, therefore he can attend more “Schooling in agriculture” which leads to more efficient “Cacao tree stock/holdings”, but this reduces the “Farmers' capacity” to fulfil all the work, as a result the “Cocoa bean production” decreases. |
| **B2** “Tuition fees” | Attending “Schooling in agriculture” causes tuition fees, so the “Farmers' expenses” inclines and, as a consequence, “Farmers' income” drops, hence he cannot attend “Schooling in agriculture”. |
| **B3** “Help is not for fee” | When the “Labour force” increases, the “Farmers' expenses” increases too, therefore, the “Farmers' income” goes down, so he is not able to hire more “Labour force”. |
| **B4** “Quality control” | If the “Quality of cocoa beans” is higher, a higher “Farm gate price for cocoa” results, therefore, the “Demand for cocoa beans” in unfermented quality drops, which leads to a lower “Cocoa bean |

| | |
|---|---|
| | production" and a smaller "Farmers' income", hence, he cannot attend "Schooling in agriculture" and will not get "Farmers' crop know-how" to increase "Quality of cocoa beans". |
| **B5**<br>"Road construction and maintenance" | If there is a better "Transport infrastructure", the "Farm gate price for cocoa" goes up, therefore the "Demand for cocoa beans" will get lower and so will the "Cocoa bean production". As a result, the "Business environment" is not interested in better "Transport infrastructure". |

**Table 16-2: Loop interpretation of CLD part 2**

| Loop | Interpretation (telling the story) |
|---|---|
| **R6**<br>"Husbandry development" | The more "Agriculture agency intervention", the more "Availability of suitable land" because of better cultivation techniques, hence, more "Cacao tree stock/holdings" and a higher "Cocoa bean production". But a higher "Cocoa bean production" leads to less "Church/NGO/NPO intervention" so the "Farmers' crop know-how" will not increase, however, this leads again to more "Agriculture agency intervention". |
| **R7**<br>"Chemical against organic inputs" | An increase in the use of "Input suppliers' action/support" will lead to less "Diseases and pests"; hence, the "Cocoa bean production" rises. "Church/NGO/NPO intervention" diminishes when "Cocoa bean production" is higher, therefore, "Farmers' crop know-how" will not go up and "Input suppliers' action/support" will rise again. |
| **R8**<br>"Chemical action" | An increase in the use of "Input suppliers' action/support" will lead to less "Diseases and pests", hence, the "Cocoa bean production" rises and "Farmers' income" rises too, which makes further use of "Input suppliers' action/support" possible. |
| **B6**<br>"Limits to growth" | If the amount of "Cacao tree stock/holdings" is rising, the "Quality of soil and environment" suffers, leading to more "Drought and bad weather" which end up in lower "Availability of suitable land" for "Cacao tree stock/holdings". |
| **B7**<br>"Productivity goal" | More "Church/NGO/NPO intervention" levels up "Farmers' crop know-how" about "Cacao tree stock/holdings", hence the "Cocoa bean production" goes up too, but the "Church/NGO/NPO intervention" will decrease. |
| **B8**<br>"Organic action" | A higher "Diseases and pests" infestation decreases the "Cocoa bean production" and therefore, rises the "Church/NGO/NPO intervention" to increase "Farmers' crop know-how" and to |

| | |
|---|---|
| | decrease the “Diseases and pests” infestation. |
| **B9** “Knowledge based input reduction” | More “Input suppliers' action/support” results in bad “Farmers' health” which ends up in lower “Farmers' capacity” subsequently, the “Cocoa bean production” drops, while “Church/NGO/NPO intervention” starts to rise (to increase) “Farmers' crop know-how” to use less “Input suppliers' action/support”. |
| **B10** “Unhealthy inputs” | More “Input suppliers' action/support” results in bad “Farmers' health” which ends up in lower “Farmers' capacity” subsequently, the “Cocoa bean production” drop and “Farmers' income” declines. |
| **B11** “Cost of inputs” | If “Input suppliers' action/support” grows, “Farmers' expenses” will rise too, and therefore lowers “Farmers' income”. |

**Table 16-3: Loop interpretation of CLD part 3**

| Loop | Interpretation |
|---|---|
| **R9** “Management driven growth” | If “Farmers' management know-how” increases, “Cacao tree stock/holdings” increases, and so the “Cocoa bean production”, sequentially the “Business environment” is well disposed which leads to further “Agriculture agency intervention” to increase “Farmers' management know-how”. |
| **R10** “Open estates” | If there is more “Availability of suitable land”, then “Cacao tree stock/holdings” rises as well as the “Cocoa bean production”, and this is beneficial to the “Business environment” which triggers more “Availability of suitable land”. |
| **R11** “Market dynamics” | Bigger “Demand for cocoa beans” leads to an increase in “Cocoa bean production” which in turn levels up the “Business environment” which has a positive influence on “Collectors and middlemen”. |
| **R12** “Macroeconomic growth” | A better “Business environment” supports more “Financial institutes intervention”, consequently the “Collectors and middlemen” have more power to push the “Demand for cocoa beans” to a higher level and raise the “Cocoa bean production. |
| **R13** “Buy information” | If “Farmers' income” increases, the “Availability of Information” rise and causes higher “Farmers' crop know-how”, hence the “Cacao tree stock/holdings” increases as well as the “Cocoa bean production” increases. |
| **R14** “Providing information” | When the “Farmer group intervention” is rising, the “Availability of Information” is lifted, and so “Farmers' crop know-how is increasing too. |

# Appendix 3; Documentation of the Decision making Model

# 17 Model Documentation

This documentation is divided into three parts: An overview of the model and its structure, basic model settings, and the subsystems documentation.

## 17.1 Model Overview

The first page of the model provides an overview of the models parts. The yellowish buttons lead to further pages in the model.
The structure overview will be explained below. Simulation and gaming are two pages which allow real time simulations and gaming with this management flight simulator.

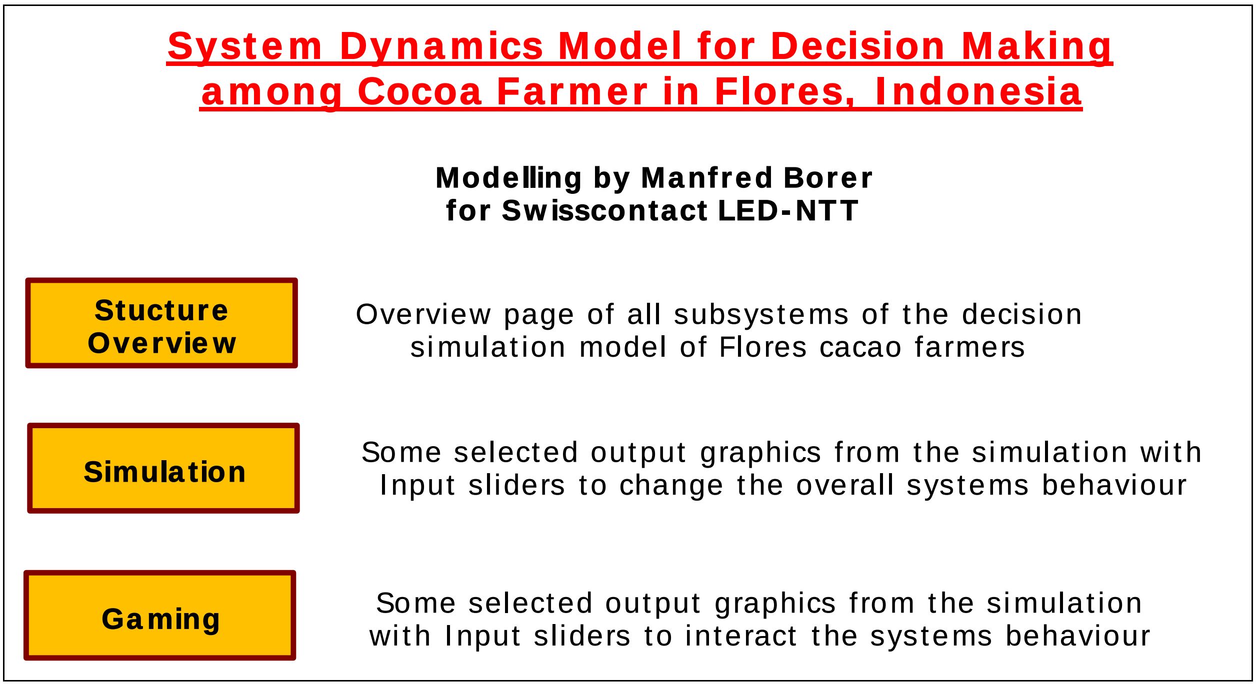



**Figure 17-1: Simulation start page**

## 17.2 Structure Overview

This page shows all the models subsystems. Every subsystem will be described by the stock and flow diagram as well every in the subsystem used variables and equations.
In every subsystem documentation are two chapters; the initial values and the equations. The initial values are set by the modeller and the equations outcomes are calculated by the model.

| Back to the Startpage | **Overview of all Subsystems of the Cocoa Farmer Decision Making Simulation** |
|---|---|
| **Production** | This section of the model shows the amount of cacao trees and their production on Flores Island |
| **Productivity** | This section of the model shows the cacao tree productivity and the desired and actual farmer know how |
| **Decision** | This section of the model summarices the decision making process and the work exploitation |
| **Livelihood** | This section of the model shows the changes in the farmers livelihood |
| **Environment** | This section of the model shows the state of soil and environment and as well the available land ressource for cacao |
| **Diseases** | This section of the model shows the amount of CPB infestation as the overall impact of dieseases and pests on cocoa production |
| **Quality and price** | This section of the model shows the quality of the cocoa beans and the farm gate price and the net incoome |

**Figure 17-2: Simulations' subsystem**

## 17.3 Model Settings

(234) TIME STEP = 0.125

The time step for the simulation.

Units: Year

(162) INITIAL TIME = 2005

The initial time for the simulation.

Units: Year

(125) FINAL TIME = 2035

The final time for the simulation.

Units: Year

(229) SAVEPER = 1

The frequency with which output is stored.

Units: Year

## 17.4 Subsystem: Production

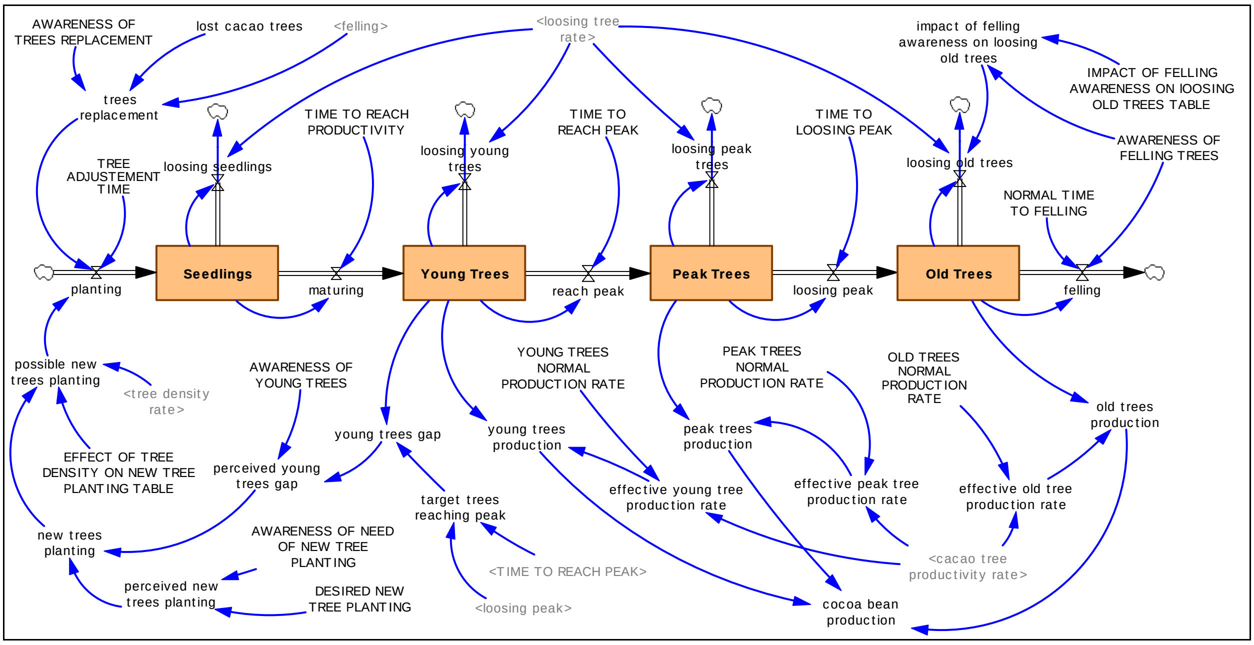



**Figure 17-3: Production stock and flow diagram**

### 17.4.1 Initial conditions

The initial conditions in the production subsystem for the amount of trees are calculated by the Excel sheet in Figure 17-4. The basic data about production area and yield are from Indonesian statistics (BPS, 2005). The allocations of the yielding trees (yellow fields in the figure) are based on assumptions of the modeller and the team.

| | Not yet yielding | Yielding | Destroyed | Total of Area | Production (MT) |
|---|---|---|---|---|---|
| Flotim | 1'782.38 | 1'953.74 | 0.00 | 3'736.12 | 0.586 |
| Sikka | 4'771.32 | 12'345.30 | 2'168.20 | 19'284.82 | 11.775 |
| Ende | 3'428.60 | 2'208.70 | 40.97 | 5'678.27 | 1.052 |
| Ngada | 1'425.00 | 347.00 | 20.00 | 1'792.00 | 0.145 |
| **Total** | **11'407.30** | **16'854.74** | **2'229.17** | **30'491.21** | **13.558** |

| | Trees < 5 year | Trees > 5 years | | |
|---|---|---|---|---|
| Production | 0 Kg | 13'557'670 Kg | | |
| | Seedlings | Young Trees | Peak Trees | Old Trees |
| Yield/Tree | 0.00 Kg/Year | 0.75 Kg/Year | 1.40 Kg/Year | 0.60 Kg/Year |
| Share Trees | 37% | 28% | 24% | 11% |
| Share Producing/Not | 37% | 63% | | |
| Share of Production | 0% | 44% | 38% | 18% |
| Cacao Bean Production | 0.0 Kg | 4'600'212.1 Kg | 7'416'099.4 Kg | 1'505'523.9 Kg |
| #Trees Producing | 0 | 6'133'616 | 5'297'214 | 2'509'207 |
| #Trees Producing/Not | 8'332'579 | 13'940'037 | | |
| #Trees Total | 22'272'615 | | | |

| | Seedlings | All Trees | | |
|---|---|---|---|---|
| Trees Distance | 3.70 m | 3.70 m | Total Production | 13'521'835.4 Kg |
| Trees per 100m | 27.02702703 | 27.02702703 | Average Trees per ha | 730.5 |
| Trees per ha | 730.4601899 | 730.4601899 | Average Kg per ha | 444.6 Kg |
| Area | 11'407.30 | 30'491.21 | Average Kg per Tree | 0.6 Kg |
| Trees per Area | 8'332'579 | 22'272'615 | Average Kg per Production Tree | 1.0 Kg |
| Years not yielding | 5 | | Trees planted/Year/Farmer | 111.1 Trees |
| Trees planted/Year | 1'666'516 | | Number of Farmers | 15'000 |

**Figure 17-4: Calculation of initial trees stock 2005**

(159) INITIAL OLD TREES= 2.50921e+006

Value of end 2004

Units: Trees

(160) INITIAL PEAK TREES= 5.29721e+006

Value of end 2004

Units: Trees

(161) INITIAL SEEDLINGS= 8.33258e+006

Value of end 2004

Units: Trees

(164) INITIAL YOUNG TREES= 6.13362e+006

Value of end 2004

Units: Trees

(138) G DESIRED NEW TREE PLANTING= 1.6e+006

SyntheSim variable

Units: Trees

(134) G AWARENESS OF NEED OF NEW TREE PLANTING= 1

SyntheSim variable

Units: fraction

(135) G AWARENESS OF TREES REPLACEMENT= 0
SyntheSim variable
Units: fraction

(145) G TIME TO MAKE DECISION TO ACT AGAINST CPB= 2
SyntheSim variable
Units: Year

(147) G TREE ADJUSTEMENT TIME= 1
SyntheSim variable
Units: Year

(203) NORMAL TIME TO FELLING = 10
Units: Year

(207) OLD TREES NORMAL PRODUCTION RATE= 0.0006
Units: Ton/(Year*Tree)

(213) PEAK TREES NORMAL PRODUCTION RATE= 0.0014
Units: Ton/(Year*Tree)

(253) YOUNG TREES NORMAL PRODUCTION RATE= 0.00075
Units: Ton/(Year*Tree)

(239) TIME TO LOOSING PEAK= 12
Units: Year

(241) TIME TO REACH PEAK= 5
Units: Year

(242) TIME TO REACH PRODUCTIVITY = 5
Units: Year

### 17.4.2Equations

(023) AWARENESS OF FELLING TREES= IF THEN ELSE( AWARENESS OF TREES REPLACEMENT=1 , 1, 0 )
Units: fraction

(025) AWARENESS OF NEED OF NEW TREE PLANTING= GAME (G AWARENESS OF NEED OF NEW TREE PLANTING)
Units: fraction

(026) AWARENESS OF TREES REPLACEMENT= GAME (G AWARENESS OF TREES REPLACEMENT)
Units: fraction

(027) AWARENESS OF YOUNG TREES= IF THEN ELSE(AWARENESS OF TREES REPLACEMENT=1, 1 , 0 )

Units: fraction

(028) Cacao tree production rate= (cocoa bean production*1000)/Cacao Trees

Units: Kg/(Year*Tree)

(030) Cacao Trees= Old Trees+Peak Trees+Young Trees+Seedlings

Units: Trees

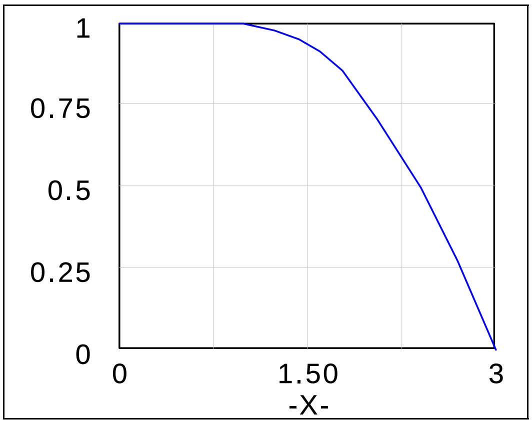
(035) cocoa bean production= young trees production+peak trees production+old trees production

Units: Ton/Year

(046) DESIRED NEW TREE PLANTING= GAME (G DESIRED NEW TREE PLANTING)

Units: Trees

(102) EFFECT OF TREE DENSITY ON NEW TREE PLANTING TABLE




Units: dmnl

(109) effective old tree production rate= OLD TREES NORMAL PRODUCTION RATE*cacao tree productivity rate

Units: Ton/(Year*Tree)

(110) effective peak tree production rate= PEAK TREES NORMAL PRODUCTION RATE*cacao tree productivity rate

Units: Ton/(Year*Tree)

(112) effective young tree production rate= cacao tree productivity rate*YOUNG TREES NORMAL PRODUCTION RATE

Units: Ton/(Year*Tree)

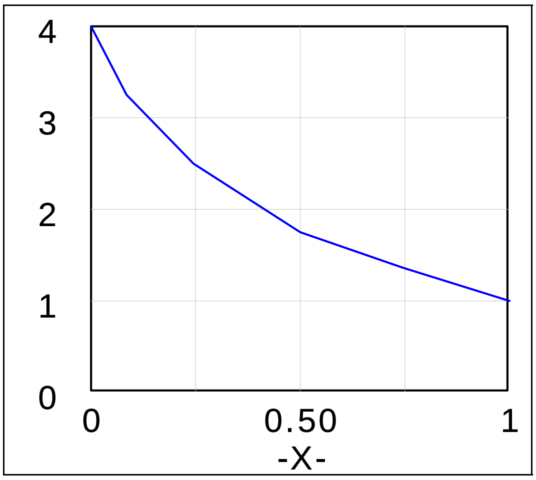
(123) felling= (Old Trees/NORMAL TIME TO FELLING)*AWARENESS OF FELLING TREES

Units: Trees/Year

(150) impact of felling awareness on loosing old trees= IMPACT OF FELLING AWARENESS ON lOOSING OLD TREES TABLE(AWARENESS OF FELLING TREES)

Units: fraction

(151) IMPACT OF FELLING AWARENESS ON LOOSING OLD TREES TABLE




Units: dmnl

(184) loosing old trees= loosing tree rate*impact of felling awareness on loosing old trees*Old Trees

Units: Trees/Year

(185) loosing peak = Peak Trees / TIME TO LOOSING PEAK

Units: Trees/Year

(186) loosing peak trees= loosing tree rate*Peak Trees

Units: Trees/Year

(187) loosing seedlings= loosing tree rate*Seedlings

Units: Trees/Year

(189) loosing young trees= loosing tree rate*Young Trees

Units: Trees/Year

(190) lost cacao trees= loosing old trees+loosing peak trees+loosing seedlings+loosing young trees

Units: Trees/Year

(191) maturing = Seedlings / TIME TO REACH PRODUCTIVITY

Units: Trees/Year

(196) new trees planting= perceived new trees planting+perceived young trees gap

Units: Trees

(205) Not Yet Yielding Cacao Trees= Seedlings

Units: Trees

(206) Old Trees= INTEG (+loosing peak-felling-loosing old trees, INITIAL OLD TREES)
Units: Trees

(208) old trees production= effective old tree production rate*Old Trees
Units: Ton/Year

(212) Peak Trees= INTEG (+reach peak-loosing peak-loosing peak trees, INITIAL PEAK TREES)
Units: Trees

(214) peak trees production= Peak Trees*effective peak tree production rate
Units: Ton/Year

(215) perceived new trees planting= AWARENESS OF NEED OF NEW TREE PLANTING*DESIRED NEW TREE PLANTING
Units: Trees

(216) perceived young trees gap= max(0, young trees gap*AWARENESS OF YOUNG TREES)
Units: Trees

(219) planting=(possible new trees planting+trees replacement)/TREE ADJUSTEMENT TIME
Units: Trees/Year

(221) possible new trees planting= new trees planting*EFFECT OF TREE DENSITY ON NEW TREE PLANTING TABLE(tree density rate)
Units: Trees

(226) reach peak= Young Trees/TIME TO REACH PEAK
Units: Trees/Year

(230) Seedlings= INTEG (+planting-loosing seedlings-maturing, INITIAL SEEDLINGS)
Units: Trees

(232) target trees reaching peak= loosing peak*TIME TO REACH PEAK
Units: Trees

(244) TREE ADJUSTEMENT TIME= GAME (G TREE ADJUSTEMENT TIME)
Units: Year

(246) trees replacement= AWARENESS OF TREES REPLACEMENT*(felling+lost cacao trees)
Units: Trees

(249) Yielding cacao tree production rate= (cocoa bean production/Yielding Cacao Trees)*1000
Units: Kg/(Year*Tree)

(251) Young Trees= INTEG (+maturing-loosing young trees-reach peak, INITIAL YOUNG TREES)

Units: Trees

(252) young trees gap= target trees reaching peak-Young Trees

Units: Trees

(254) young trees production= effective young tree production rate*Young Trees

Units: Ton/Year

(250) Yielding Cacao Trees= Old Trees+Peak Trees+Young Trees

Units: Trees

## 17.5 Subsystem: Productivity

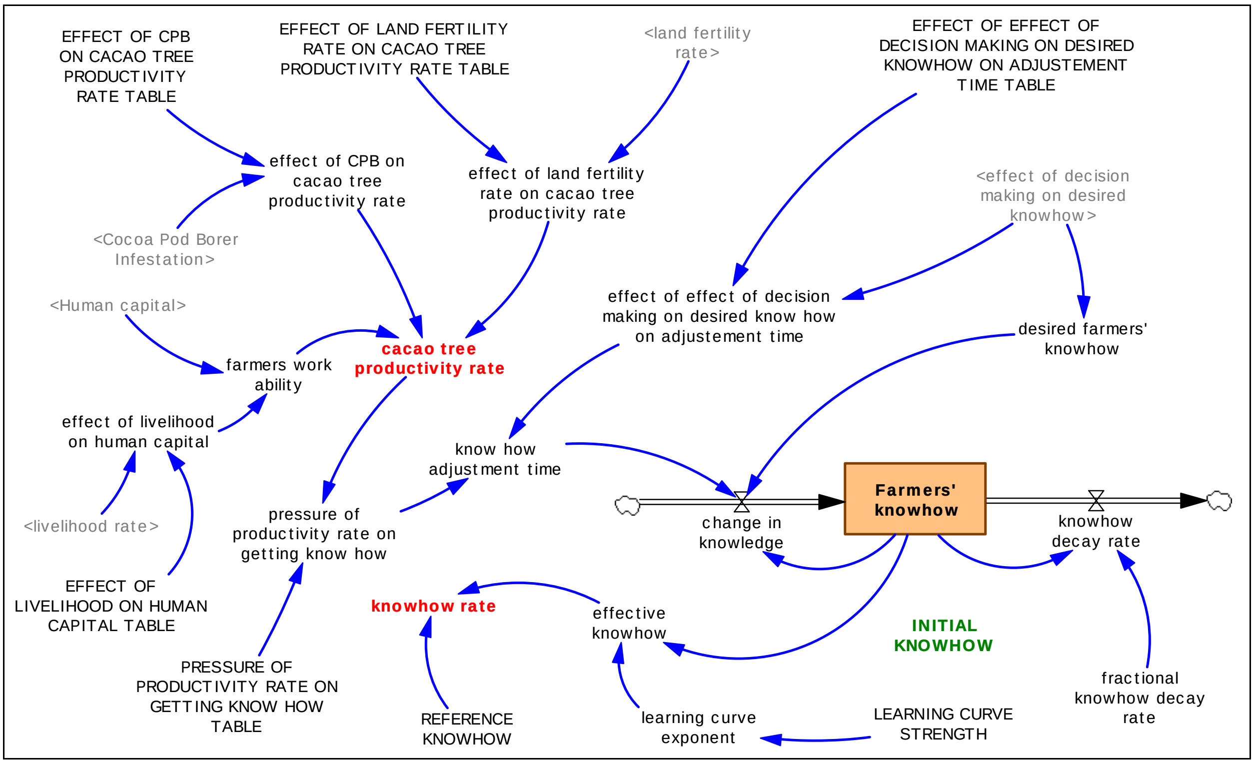



**Figure 17-5: Productivity stock and flow diagram**

### 17.5.1 Initial conditions

(128) fractional knowhow decay rate= 0.1

The fractional rate of experience decay from changes in the work environment that render existing knowledge obsolete, plus forgetting by workers.

Units: 1/Year

(156) INITIAL KNOWHOW= 100

Units: fraction

(181) LEARNING CURVE STRENGTH= 0.3

The fractional increase in productivity per doubling of experience.

Units: Dimensionless

(227) REFERENCE KNOWHOW= 6

The reference level of average knowhow that generates the productivity.

Units: dmnl

### 17.5.2Equations

(029) cacao tree productivity rate= effect of CPB on cacao tree productivity rate*effect of land fertility rate on cacao tree productivity rate*farmers work ability

Units: fraction

(033) change in knowledge= (Farmers' knowhow*(1-Farmers' knowhow/desired farmers' knowhow)/know-how adjustment time)

Units: fraction/Year

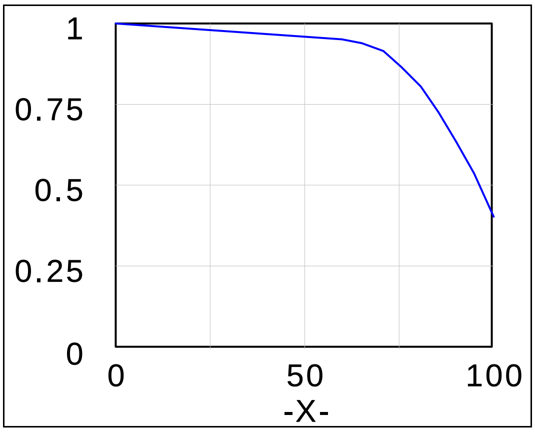
(043) desired farmers' knowhow= 100+(100*effect of decision making on desired knowhow)

Units: fraction

(056) effect of CPB on cacao tree productivity rate= EFFECT OF CPB ON CACAO TREE PRODUCTIVITY RATE TABLE(Cocoa Pod Borer Infestation)

Units: fraction

(057) EFFECT OF CPB ON CACAO TREE PRODUCTIVITY RATE TABLE

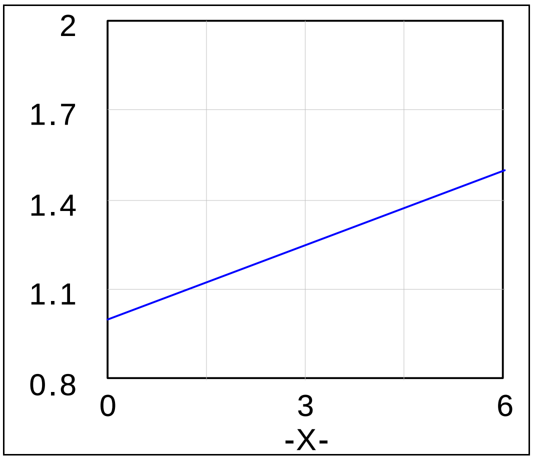



Units: dmnl

(065) effect of effect of decision making on desired know-how on adjustement time= EFFECT OF EFFECT OF DECISION MAKING ON DESIRED KNOWHOW ON ADJUSTEMENT TIME TABLE(effect of decision making on desired knowhow)

Units: fraction

(066) EFFECT OF EFFECT OF DECISION MAKING ON DESIRED KNOWHOW ON ADJUSTEMENT TIME TABLE

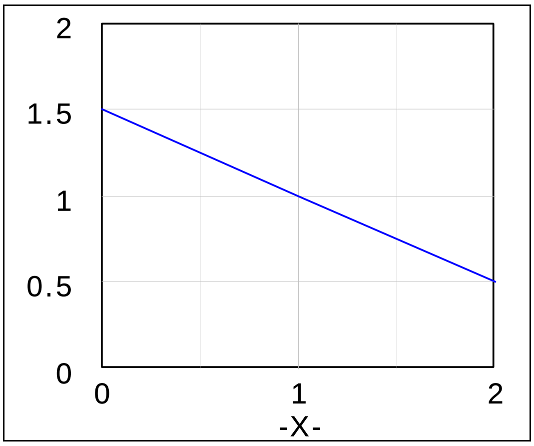



Units: dmnl

(087) effect of land fertility rate on cacao tree productivity rate= EFFECT OF LAND FERTILITY RATE ON CACAO TREE PRODUCTIVITY RATE TABLE(land fertility rate)

Units: fraction

(088) EFFECT OF LAND FERTILITY RATE ON CACAO TREE PRODUCTIVITY RATE TABLE




Units: dmnl

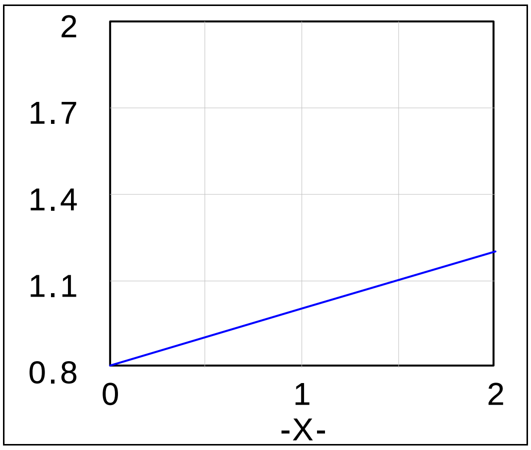
(089) effect of land fertility rate on loosing tree rate= EFFECT OF LAND FERTILITY RATE ON LOOSING TREE RATE TABLE(land fertility rate)

Units: fraction

(093) effect of livelihood on human capital= EFFECT OF LIVELIHOOD ON HUMAN CAPITAL TABLE(livelihood rate)

Units: fraction

(094) EFFECT OF LIVELIHOOD ON HUMAN CAPITAL TABLE




Units: dmnl

(119) farmers work ability= Human capital*effect of livelihood on human capital

Units: fraction

(121) Farmers' knowhow= INTEG (change in knowledge-knowhow decay rate, INITIAL KNOWHOW)

Units: fraction

(107) effective knowhow= Farmers' knowhow^learning curve exponent

Units: dmnl

(165) know-how adjustment time= 0.5*pressure of productivity rate on getting know-how*effect of effect of decision making on desired know-how on adjustement time.

Normal adjustement time for the desired knowhow is a half year. This changes by the influenced productivity pressure and the amount of desired know-how

Units: Year

(166) knowhow decay rate= (max(10, Farmers' knowhow))*fractional knowhow decay rate

Knowhow decays due to changes in required crop knowhow and forgetting.

Units: fraction/Year

(167) knowhow rate= effective knowhow/REFERENCE KNOWHOW

Units: fraction

(180) learning curve exponent= LN(1+LEARNING CURVE STRENGTH)/LN(2)

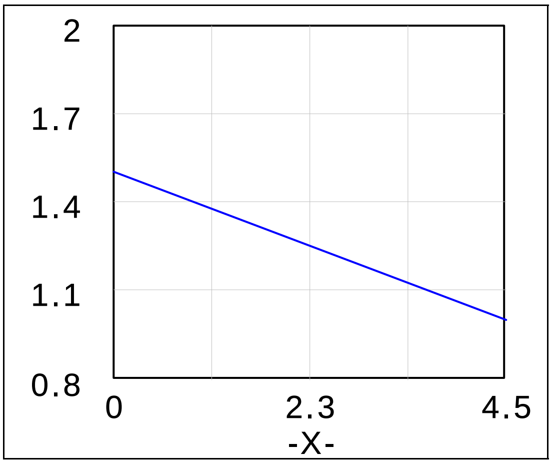
The exponent in the learning curve. Calculated from the strength of the learning curve expressed as the fractional improvement in productivity attained per doubling of know-how.

Units: Dimensionless

(223) pressure of productivity rate on getting know-how= PRESSURE OF PRODUCTIVITY RATE ON GETTING KNOW-HOW TABLE(cacao tree productivity rate)

Units: fraction

(224) PRESSURE OF PRODUCTIVITY RATE ON GETTING KNOW-HOW TABLE




Units: dmnl

## 17.6 Subsystem: Decision

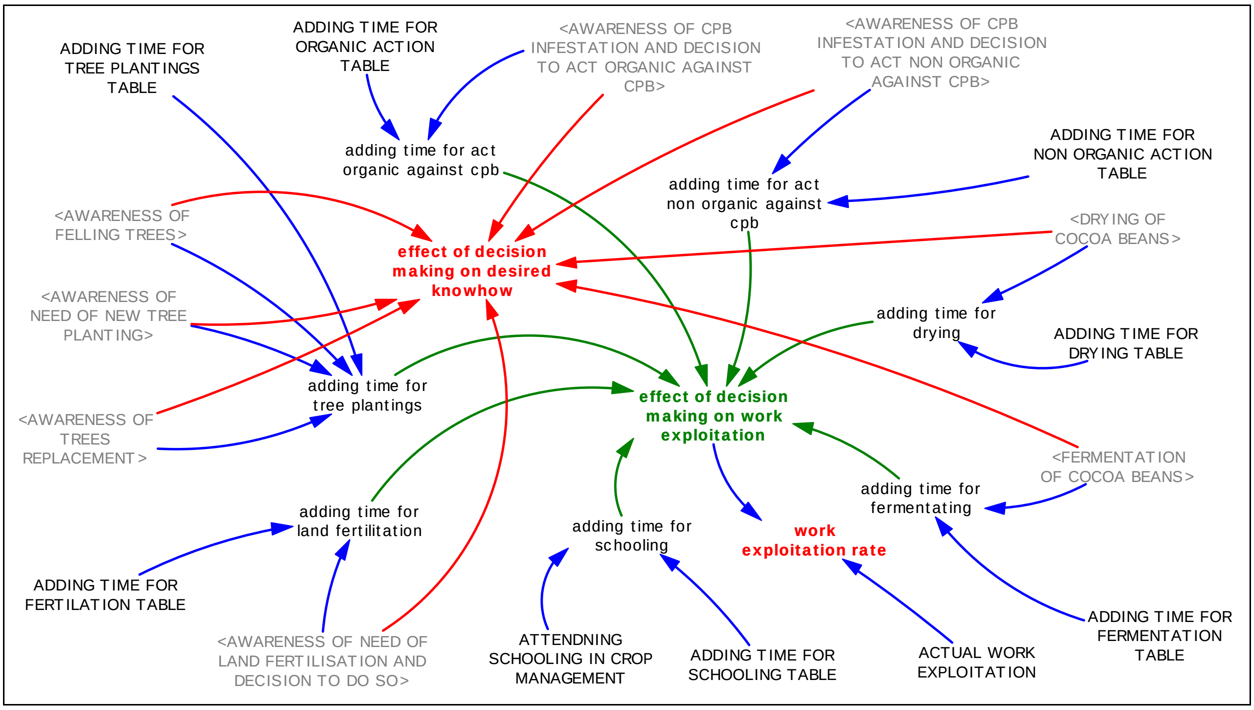



**Figure 17-6: Decision stock and flow diagram**

### 17.6.1 Initial conditions

(002) ACTUAL WORK EXPLOITATION= 0.15

Units: fraction

### 17.6.2 Equations

(003) adding time for act non organic against cpb= ADDING TIME FOR NON ORGANIC ACTION TABLE(AWARENESS OF CPB INFESTATION AND DECISION TO ACT NON ORGANIC AGAINST CPB)

Units: fraction

(004) adding time for act organic against cpb= ADDING TIME FOR ORGANIC ACTION TABLE(AWARENESS OF CPB INFESTATION AND DECISION TO ACT ORGANIC AGAINST CPB)

Units: fraction

(005) adding time for drying= ADDING TIME FOR DRYING TABLE(DRYING OF COCOA BEANS)

Units: dmnl

(006) ADDING TIME FOR DRYING TABLE([(0,0)-(1,1)],(0,0),(1,0.1))

Units: dmnl

(007) adding time for fermentating= ADDING TIME FOR FERMENTATION TABLE(FERMENTATION OF COCOA BEANS)

Units: fraction

(008) ADDING TIME FOR FERMENTATION TABLE([(0,0)-(1,1)],(0,0),(1,0.1))

Units: dmnl

(009) ADDING TIME FOR FERTILATION TABLE([(0,0)-(1,1)],(0,0),(1,0.15))

Units: dmnl

(010) adding time for land fertilitation= ADDING TIME FOR FERTILATION TABLE(AWARENESS OF NEED OF LAND FERTILISATION AND DECISION TO DO SO)

Units: fraction

(011) ADDING TIME FOR NON ORGANIC ACTION TABLE([(0,0)-(1,1)],(0,0),(1,0.1))

Units: dmnl

(012) ADDING TIME FOR ORGANIC ACTION TABLE([(0,0)-(1,1)],(0,0),(1,0.35))

Units: dmnl

(013) adding time for schooling= ADDING TIME FOR SCHOOLING TABLE(ATTENDNING SCHOOLING IN CROP MANAGEMENT)

Units: fraction

(014) ADDING TIME FOR SCHOOLING TABLE([(0,0)-(1,1)],(0,0),(1,0.1))

Units: dmnl

(015) adding time for tree plantings= ADDING TIME FOR TREE PLANTINGS TABLE(AWARENESS OF FELLING TREES+AWARENESS OF NEED OF NEW TREE PLANTING+AWARENESS OF TREES REPLACEMENT)

Units: fraction

(016) ADDING TIME FOR TREE PLANTINGS TABLE([(0,0)-(3,1)],(0,0),(3,0.05))

Units: dmnl

(018) ATTENDNING SCHOOLING IN CROP MANAGEMENT= IF THEN ELSE( effect of decision making on desired knowhow>=1, 1 , 0 )
Units: dmnl

(061) effect of decision making on desired knowhow= AWARENESS OF CPB INFESTATION AND DECISION TO ACT NON ORGANIC AGAINST CPB+AWARENESS OF CPB INFESTATION AND DECISION TO ACT ORGANIC AGAINST CPB+AWARENESS OF NEED OF LAND FERTILISATION AND DECISION TO DO SO+((AWARENESS OF FELLING TREES+AWARENESS OF NEED OF NEW TREE PLANTING+AWARENESS OF TREES REPLACEMENT)/3)+DRYING OF COCOA BEANS+FERMENTATION OF COCOA BEANS
Units: fraction

(062) effect of decision making on work exploitation= adding time for act non organic against cpb+adding time for act organic against cpb+adding time for drying+adding time for fermentating+adding time for land fertilitation+adding time for schooling+adding time for tree plantings
Units: fraction

(247) work exploitation rate= ACTUAL WORK EXPLOITATION+effect of decision making on work exploitation
Units: fraction

## 17.7 Subsystem: Livelihood

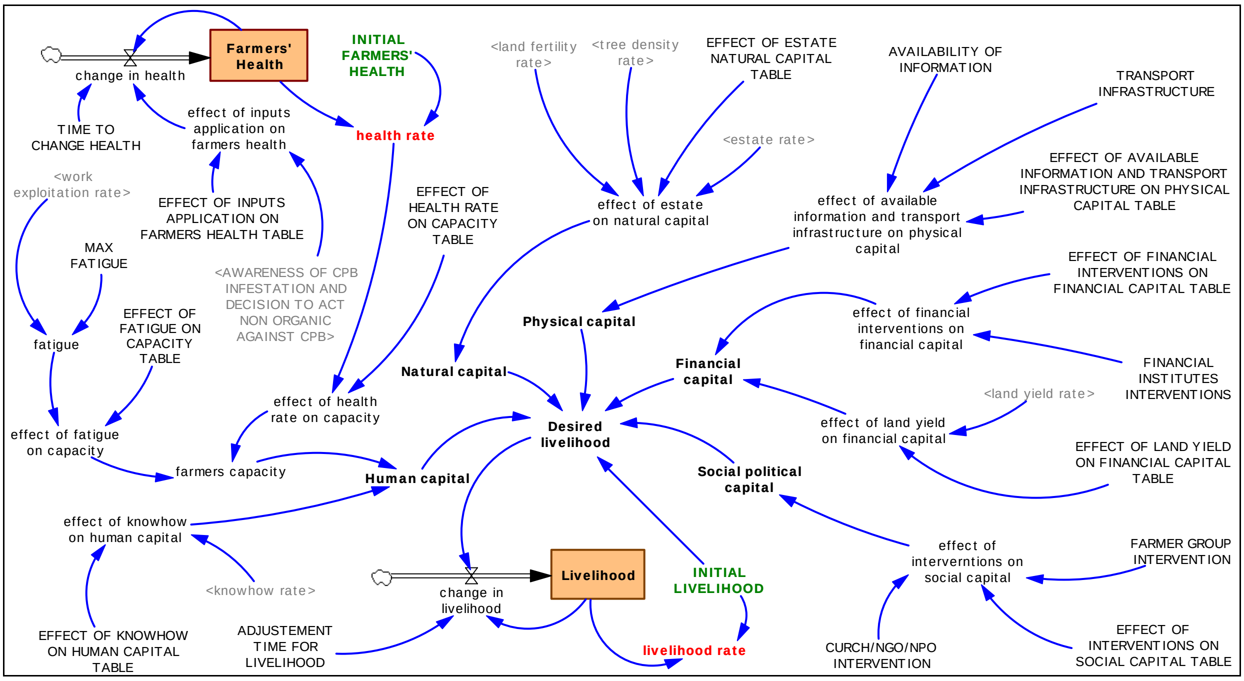



**Figure 17-7: Livelihood stock and flow diagram**

### 17.7.1 Initial conditions

(129) G ADJUSTEMENT TIME FOR LIVELIHOOD= 1
SyntheSim variable
Units: Year

(130) G AVAILABILITY OF INFORMATION= 0.5
SyntheSim variable
Units: fraction

(136) "G CURCH/NGO/NPO INTERVENTION"= 0.5
SyntheSim variable
Units: fraction

(140) G FARMER GROUP INTERVENTION= 0.5
SyntheSim variable
Units: fraction

(142) G FINANCIAL INSTITUTES INTERVENTIONS= 0
SyntheSim variable
Units: fraction

(146) G TRANSPORT INFRASTRUCTURE= 0.5
SyntheSim variable
Units: fraction

(155) INITIAL FARMERS' HEALTH= 100
Units: fraction

(158) INITIAL LIVELIHOOD= 50
Units: dmnl

(192) MAX FATIGUE=1
Units: fraction

(237) TIME TO CHANGE HEALTH= 2
Units: Year

### 17.7.2 Equations

(017) ADJUSTEMENT TIME FOR LIVELIHOOD= GAME (G ADJUSTEMENT TIME FOR LIVELIHOOD)
Units: Year

(019) AVAILABILITY OF INFORMATION= GAME (G AVAILABILITY OF INFORMATION)
Units: fraction

(031) change in health= Farmers' Health*effect of inputs application on farmers health/TIME TO CHANGE HEALTH
Units: fraction/Year

(034) change in livelihood= (Desired livelihood-Livelihood)/ADJUSTEMENT TIME FOR LIVELIHOOD
Units: 1/Year

(042) "CURCH/NGO/NPO INTERVENTION"= GAME ("G CURCH/NGO/NPO INTERVENTION")
Units: fraction

(044) Desired livelihood= INITIAL LIVELIHOOD*Financial capital*Human capital*Natural capital*Physical capital *Social political capital
Units: fraction

(053) effect of available information and transport infrastructure on physical capital= EFFECT OF AVAILABLE INFORMATION AND TRANSPORT INFRASTRUCTURE ON PHYSICAL CAPITAL TABLE(AVAILABILITY OF INFORMATION+TRANSPORT INFRASTRUCTURE)
Units: fraction

(054) EFFECT OF AVAILABLE INFORMATION AND TRANSPORT INFRASTRUCTURE ON PHYSICAL CAPITAL TABLE([(0,0.8)-(2,1.2)],(0,0.9),(1,1),(2,1.1))
Units: dmnl

(067) EFFECT OF ESTATE NATURAL CAPITAL TABLE([(0,0)-(8,1.2)],(0,0.9),(2,1.1),(6,1.2))
Units: dmnl

(068) effect of estate on natural capital= EFFECT OF ESTATE NATURAL CAPITAL TABLE(estate rate*land fertility rate*tree density rate)
Units: fraction

(073) effect of fatigue on capacity = EFFECT OF FATIGUE ON CAPACITY TABLE(fatigue)
Units: fraction

(074) EFFECT OF FATIGUE ON CAPACITY TABLE([(0,0.8)-(1.5,1.2)],(0,1.1),(1.1,0.9))
Units: dmnl

(075) effect of financial interventions on financial capital= EFFECT OF FINANCIAL INTERVENTIONS ON FINANCIAL CAPITAL TABLE(FINANCIAL INSTITUTES INTERVENTIONS)
Units: fraction

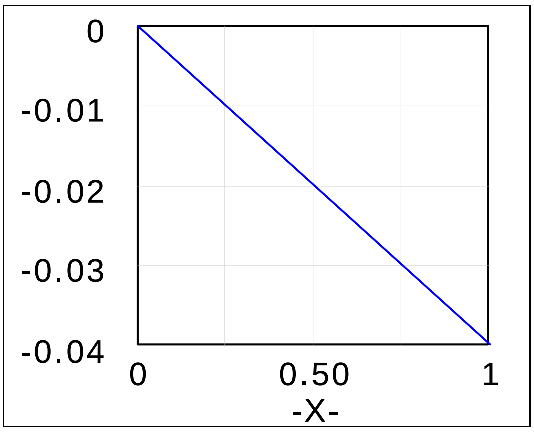
(076) EFFECT OF FINANCIAL INTERVENTIONS ON FINANCIAL CAPITAL TABLE([(0,0.8)-(1,1.2)],(0,0.9),(1,1.1))
Units: dmnl

(077) effect of health rate on capacity= EFFECT OF HEALTH RATE ON CAPACITY TABLE(health rate)
Units: fraction

(078) EFFECT OF HEALTH RATE ON CAPACITY TABLE([(0,0)-(1,1)],(0,0.8),(1,1))
Units: fraction

(079) effect of inputs application on farmers health= EFFECT OF INPUTS APPLICATION ON FARMERS HEALTH TABLE(AWARENESS OF CPB INFESTATION AND DECISION TO ACT NON ORGANIC AGAINST CPB)
Units: fraction

(080) EFFECT OF INPUTS APPLICATION ON FARMERS HEALTH TABLE




Units: dmnl

(083) EFFECT OF INTERVENTIONS ON SOCIAL CAPITAL TABLE([(0,0.9)-(2,1.1)],(0,0.9),(2,1.1))
Units: dmnl

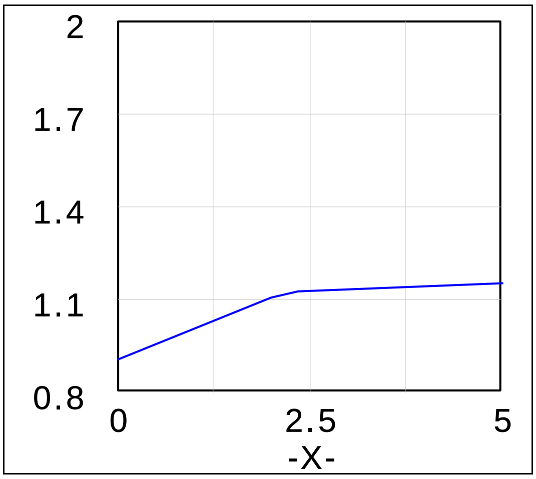
(084) effect of interverntions on social capital= EFFECT OF INTERVENTIONS ON SOCIAL CAPITAL TABLE("CURCH/NGO/NPO INTERVENTION"+FARMER GROUP INTERVENTION)
Units: fraction

(085) effect of knowhow on human capital= EFFECT OF KNOWHOW ON HUMAN CAPITAL TABLE(knowhow rate)
Units: dmnl

(086) EFFECT OF KNOWHOW ON HUMAN CAPITAL TABLE([(0,0.9)-(2.5,1.1)],(0,0.9),(2.5,1.1))
Units: dmnl

(091) effect of land yield on financial capital= EFFECT OF LAND YIELD ON FINANCIAL CAPITAL TABLE(land yield rate)
Units: dmnl

(092) EFFECT OF LAND YIELD ON FINANCIAL CAPITAL TABLE




Units: dmnl

(117) FARMER GROUP INTERVENTION= GAME (G FARMER GROUP INTERVENTION)

Units: fraction

(118) farmers capacity= effect of fatigue on capacity*effect of health rate on capacity

Units: fraction

(120) Farmers' Health= INTEG (change in health, INITIAL FARMERS' HEALTH)

Units: fraction

(122) fatigue= MAX FATIGUE*work exploitation rate

Units: fraction

(127) FINANCIAL INSTITUTES INTERVENTIONS= GAME (G FINANCIAL INSTITUTES INTERVENTIONS)

Units: fraction

(126) Financial capital= effect of financial interventions on financial capital*effect of land yield on financial capital

Units: fraction

(148) health rate= Farmers' Health/INITIAL FARMERS' HEALTH

Units: fraction

(149) Human capital= effect of knowhow on human capital*farmers capacity

Units: dmnl

(182) Livelihood= INTEG (change in livelihood, INITIAL LIVELIHOOD)

Units: dmnl

(183) livelihood rate= Livelihood/INITIAL LIVELIHOOD

Units: fraction

(193) Natural capital=effect of estate on natural capital

Units: dmnl

(218) Physical capital= effect of available information and transport infrastructure on physical capital

Units: dmnl

(231) Social political capital= effect of interverntions on social capital

Units: fraction

(243) TRANSPORT INFRASTRUCTURE= GAME (G TRANSPORT INFRASTRUCTURE)

Units: fraction

## 17.8 Subsystem: Environment

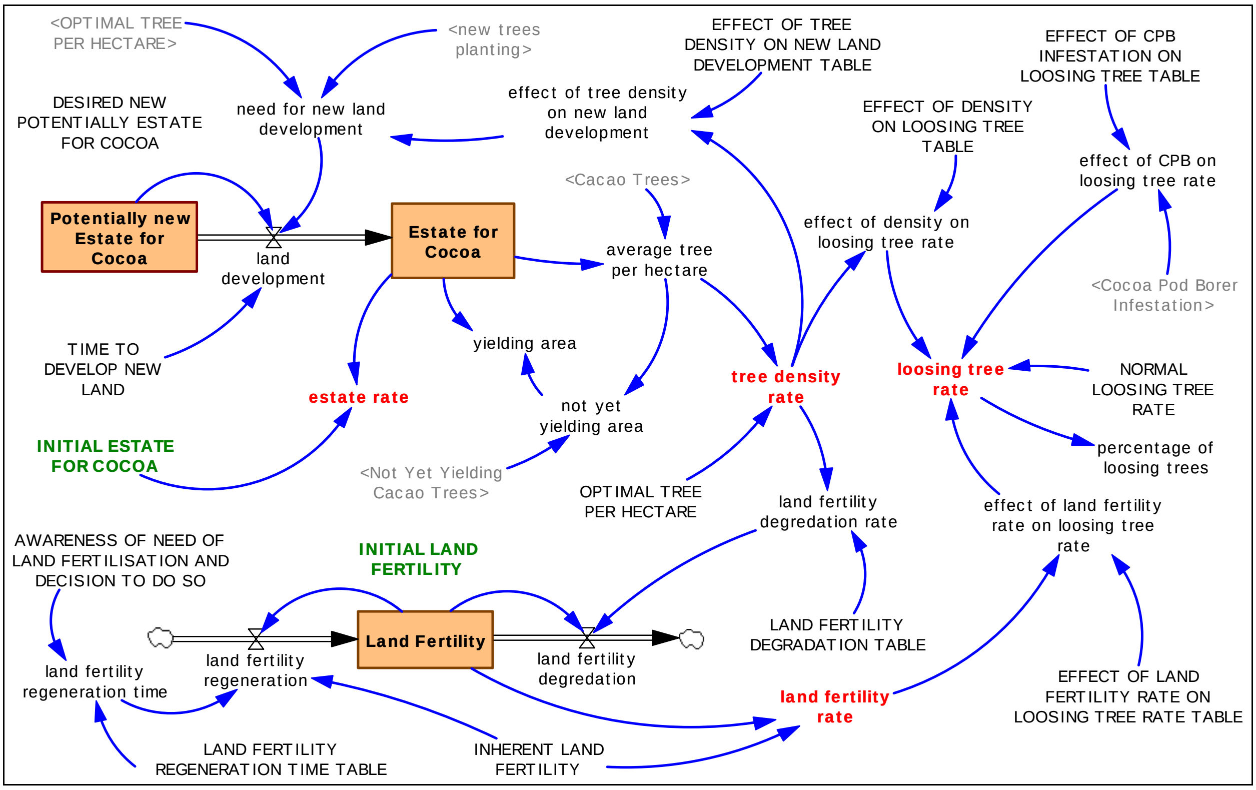



**Figure 17-8: Environment stock and flow diagram**

### 17.8.1 Initial conditions

(133) G AWARENESS OF NEED OF LAND FERTILISATION AND DECISION TO DO SO= 0

SyntheSim variable

Units: dmnl

(137) G DESIRED NEW POTENTIALLY ESTATE FOR COCOA= 30000

SyntheSim variable

Units: hectare

(144) G TIME TO DEVELOP NEW LAND= 1

SyntheSim variable

Units: Year

(152) INHERENT LAND FERTILITY = 600

Units: Veg equiv kg/(Year*hectare)

(154) INITIAL ESTATE FOR COCOA= 30491

Units: hectare

(157) INITIAL LAND FERTILITY = 600

Units: Veg equiv kg/(Year*hectare)

(201) NORMAL LOOSING TREE RATE= 0.03

Units: Percent

(210) OPTIMAL TREE PER HECTARE= 730

Units: Trees/hectare

### 17.8.2Equations

(020) average tree per hectare= Cacao Trees/Estate for Cocoa

Units: Trees/hectare

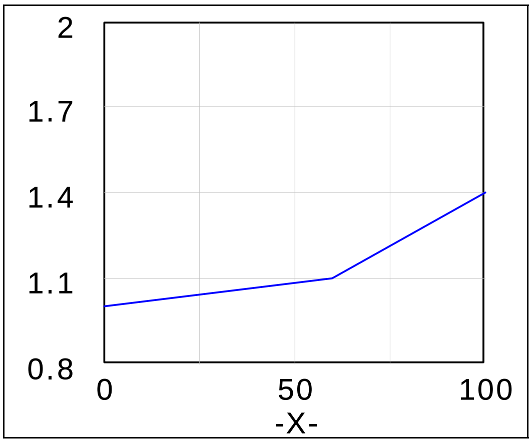
(024) AWARENESS OF NEED OF LAND FERTILISATION AND DECISION TO DO SO= GAME ( G AWARENESS OF NEED OF LAND FERTILISATION AND DECISION TO DO SO)

Units: dmnl

(045) DESIRED NEW POTENTIALLY ESTATE FOR COCOA= GAME (G DESIRED NEW POTENTIALLY ESTATE FOR COCOA)

Units: hectare

(055) EFFECT OF CPB INFESTATION ON LOOSING TREE TABLE




Units: dmnl

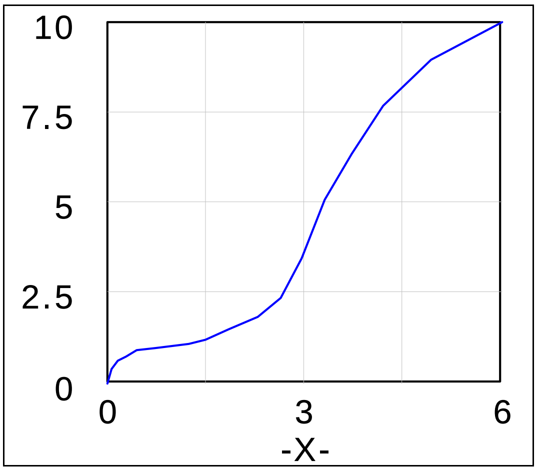
(058) effect of CPB on loosing tree rate= EFFECT OF CPB INFESTATION ON LOOSING TREE TABLE(Cocoa Pod Borer Infestation)

Units: fraction

(063) effect of density on loosing tree rate= EFFECT OF DENSITY ON LOOSING TREE TABLE(tree density rate)

Units: fraction

(064) EFFECT OF DENSITY ON LOOSING TREE TABLE




Units: dmnl

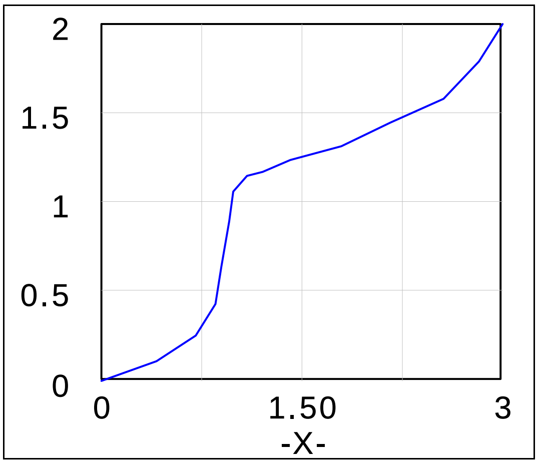
(090) EFFECT OF LAND FERTILITY RATE ON LOOSING TREE RATE TABLE([(0,0)-(2,2)],(0,1.5),(1,1),(2,0.5))

Units: dmnl

(100) effect of tree density on new land development= EFFECT OF TREE DENSITY ON NEW LAND DEVELOPMENT TABLE(tree density rate)

Units: fraction

(101) EFFECT OF TREE DENSITY ON NEW LAND DEVELOPMENT TABLE(




Units: dmnl

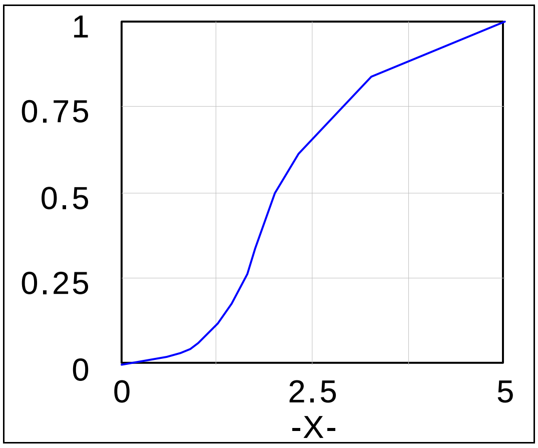
(113) Estate for Cocoa= INTEG (land development, INITIAL ESTATE FOR COCOA)
Units: hectare

(115) estate rate= Estate for Cocoa/INITIAL ESTATE FOR COCOA
Units: fraction

(168) land development= IF THEN ELSE(Potentially new Estate for Cocoa>0, need for new land development/TIME TO DEVELOP NEW LAND , 0 )
Units: hectare/Year

(169) Land Fertility =INTEG((land fertility regeneration - land fertility degredation ), INITIAL LAND FERTILITY )
Units: Veg equiv kg/(Year*hectare)

(170) LAND FERTILITY DEGRADATION TABLE




Units: 1/Year

(171) land fertility degredation= Land Fertility* land fertility degredation rate
Units: Veg equiv kg/(Year*Year*hectare)

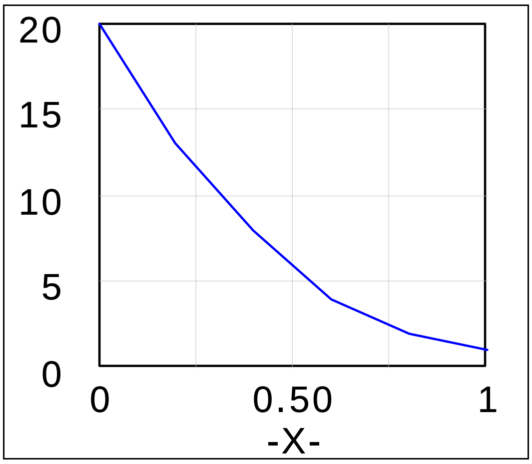
(172) land fertility degredation rate= LAND FERTILITY DEGRADATION TABLE (tree density rate)
Units: 1/Year

(173) land fertility rate= Land Fertility/INHERENT LAND FERTILITY
Units: fraction

(174) land fertility regeneration = (INHERENT LAND FERTILITY - Land Fertility)/land fertility regeneration time
Units: Veg equiv kg/(Year*Year*hectare)

(175) land fertility regeneration time= LAND FERTILITY REGENERATION TIME TABLE (AWARENESS OF NEED OF LAND FERTILISATION AND DECISION TO DO SO)
Units: Year

(176) LAND FERTILITY REGENERATION TIME TABLE




Units: Year

(188) loosing tree rate= NORMAL LOOSING TREE RATE*effect of density on loosing tree rate*effect of CPB on loosing tree rate*effect of land fertility rate on loosing tree rate

Units: Percent

(194) need for new land development= effect of tree density on new land development*(new trees planting/OPTIMAL TREE PER HECTARE)

Units: hectare

(204) not yet yielding area= Not Yet Yielding Cacao Trees/average tree per hectare

Units: hectare

(217) percentage of loosing trees= loosing tree rate*100

Units: Percent

(222) Potentially new Estate for Cocoa= INTEG (-land development, DESIRED NEW POTENTIALLY ESTATE FOR COCOA)

Units: hectare

(238) TIME TO DEVELOP NEW LAND= GAME (G TIME TO DEVELOP NEW LAND)

Units: Year

(245) tree density rate= average tree per hectare/OPTIMAL TREE PER HECTARE

Units: fraction

(248) yielding area= Estate for Cocoa-not yet yielding area

Units: hectare

## 17.9 Subsystem: Diseases

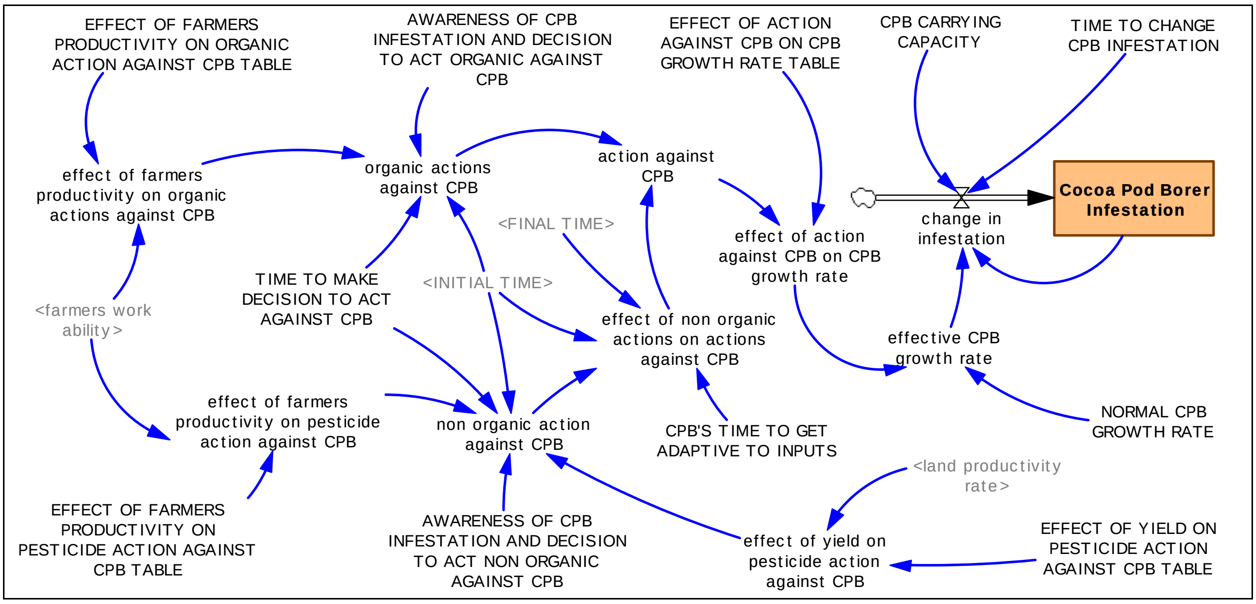



**Figure 17-9: Diseases stock and flow diagram**

### 17.9.1 Initial conditions

(039) CPB CARRYING CAPACITY= 100

Units: Percent

(041) CPB'S TIME TO GET ADAPTIVE TO INPUTS= 8

Units: Year

(131) G AWARENESS OF CPB INFESTATION AND DECISION TO ACT NON ORGANIC AGAINST CPB= 0

SyntheSim variable

Units: dmnl

(132) G AWARENESS OF CPB INFESTATION AND DECISION TO ACT ORGANIC AGAINST CPB= 0

SyntheSim variable

Units: dmnl

(163) INITIAL VALUE OF CPB INFESTATION= 50

Units: Percent

(199) NORMAL CPB GROWTH RATE= 0.03

Units: Percent

(236) TIME TO CHANGE CPB INFESTATION= 0.08333

Normal change time of infestation is below one month by effective treatment

Units: Year

(240) TIME TO MAKE DECISION TO ACT AGAINST CPB= GAME (G TIME TO MAKE DECISION TO ACT AGAINST CPB)
Units: Year

### 17.9.2 Equations

(001) action against CPB= effect of non organic actions on actions against CPB+organic actions against CPB
Units: fraction/Year

(021) AWARENESS OF CPB INFESTATION AND DECISION TO ACT NON ORGANIC AGAINST CPB = GAME (G AWARENESS OF CPB INFESTATION AND DECISION TO ACT NON ORGANIC AGAINST CPB)
Units: dmnl

(022) AWARENESS OF CPB INFESTATION AND DECISION TO ACT ORGANIC AGAINST CPB= GAME (G AWARENESS OF CPB INFESTATION AND DECISION TO ACT ORGANIC AGAINST CPB)
Units: dmnl

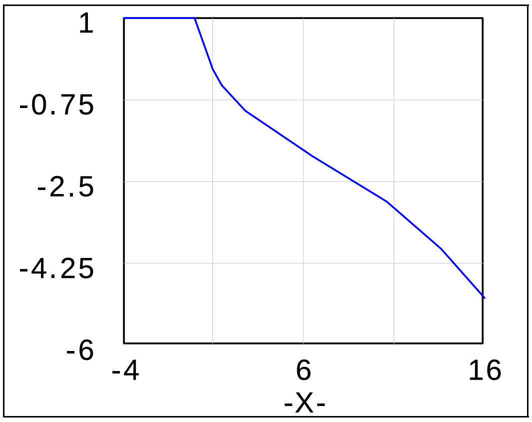
(032) change in infestation= (effective CPB growth rate*Cocoa Pod Borer Infestation*(1-Cocoa Pod Borer Infestation/CPB CARRYING CAPACITY))/TIME TO CHANGE CPB INFESTATION
Units: Percent*Percent/Year

(038) Cocoa Pod Borer Infestation= INTEG (change in infestation, INITIAL VALUE OF CPB INFESTATION)
Units: Percent

(040) CPB infestation rate= Cocoa Pod Borer Infestation/INITIAL VALUE OF CPB INFESTATION
Units: fraction

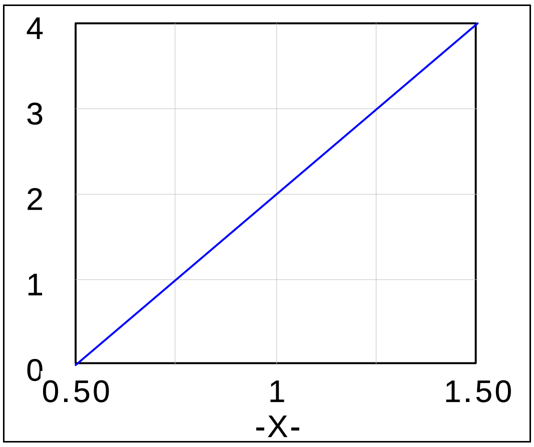
(051) effect of action against CPB on CPB growth rate= EFFECT OF ACTION AGAINST CPB ON CPB GROWTH RATE TABLE(action against CPB)
Units: fraction

(052) EFFECT OF ACTION AGAINST CPB ON CPB GROWTH RATE TABLE




Units: dmnl

(069) EFFECT OF FARMERS PRODUCTIVITY ON ORGANIC ACTION AGAINST CPB TABLE




Units: dmnl

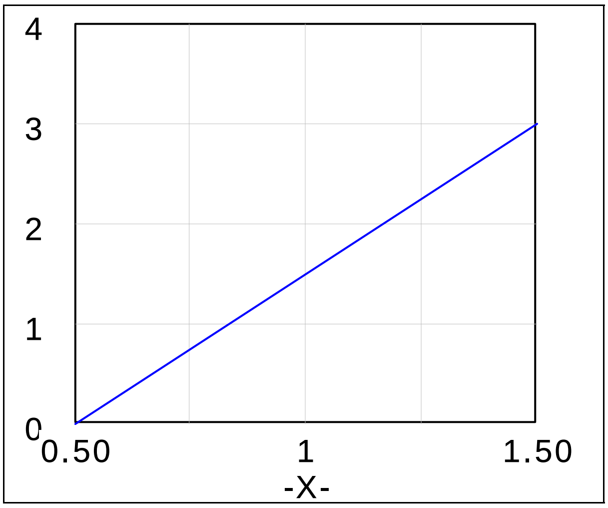
(070) effect of farmers productivity on organic actions against CPB= EFFECT OF FARMERS PRODUCTIVITY ON ORGANIC ACTION AGAINST CPB TABLE(farmers work ability)

Units: fraction

(071) effect of farmers productivity on pesticide action against CPB= EFFECT OF FARMERS PRODUCTIVITY ON PESTICIDE ACTION AGAINST CPB TABLE(farmers work ability)

Units: fraction

(072) EFFECT OF FARMERS PRODUCTIVITY ON PESTICIDE ACTION AGAINST CPB TABLE




Units: dmnl

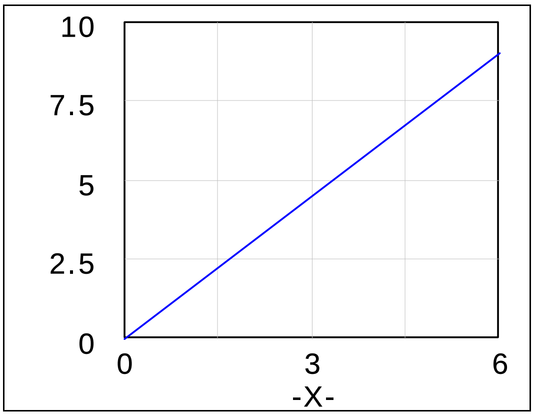
(095) effect of non organic actions on actions against CPB= non organic action against CPB+RAMP(non organic action against CPB*-0.2, INITIAL TIME+TIME TO MAKE DECISION TO ACT AGAINST CPB+CPB'S TIME TO GET ADAPTIVE TO INPUTS ,FINAL TIME)

Units: fraction/Year

(103) effect of yield on pesticide action against CPB= EFFECT OF YIELD ON PESTICIDE ACTION AGAINST CPB TABLE(land productivity rate)

Units: fraction

(104) EFFECT OF YIELD ON PESTICIDE ACTION AGAINST CPB TABLE




Units: dmnl

(105) effective CPB growth rate= NORMAL CPB GROWTH RATE*effect of action against CPB on CPB growth rate

Units: Percent

(197) non organic action against CPB= STEP( AWARENESS OF CPB INFESTATION AND DECISION TO ACT NON ORGANIC AGAINST CPB*effect of yield on pesticide action against CPB*effect of farmers productivity on pesticide action against CPB, INITIAL TIME+TIME TO MAKE DECISION TO ACT AGAINST CPB )

Units: dmnl

(211) organic actions against CPB= 0+STEP(AWARENESS OF CPB INFESTATION AND DECISION TO ACT ORGANIC AGAINST CPB*effect of farmers productivity on organic actions against CPB, INITIAL TIME +TIME TO MAKE DECISION TO ACT AGAINST CPB )

Units: fraction/Year

## 17.10 Subsystem: Quality and price

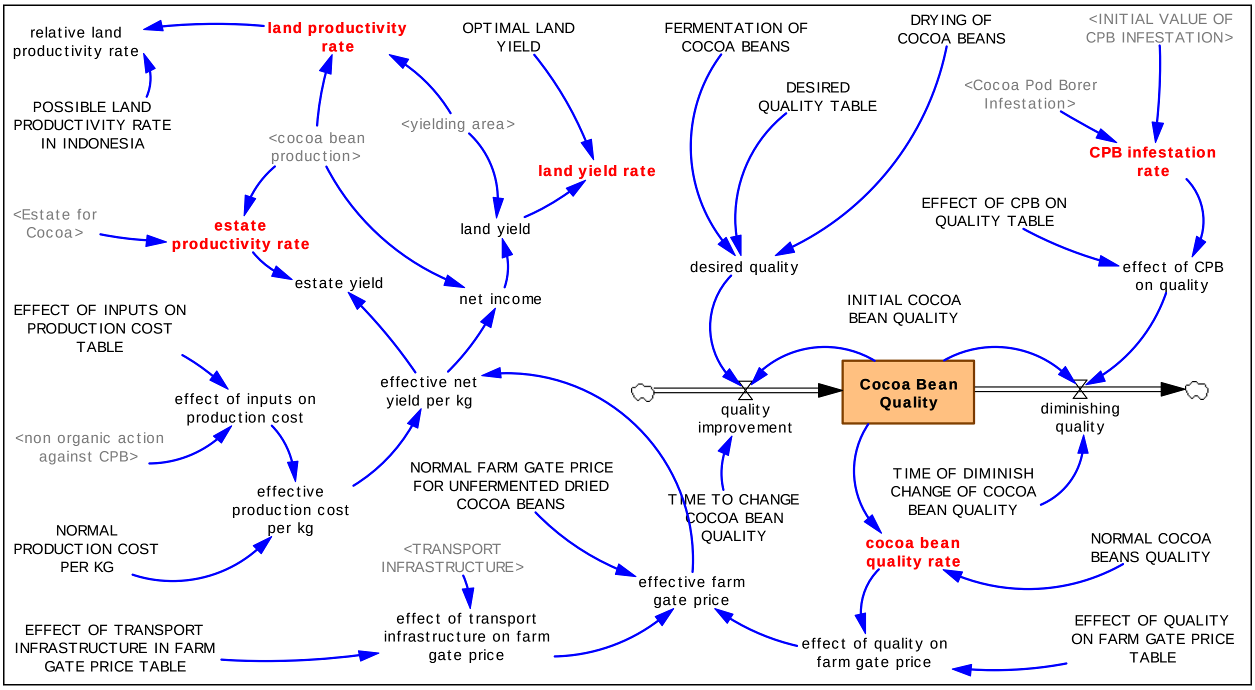



**Figure 17-10: Quality and price stock and flow diagram**

### 17.10.1 Initial conditions

US$ 180 x 9’100 Rupiah/US$ /1’000 Kg= 1’638 Rupiah/kg

Actual farm gate price for unfermented, good dried cocoa: 9’000 Rupiah

Possible farm gate price for fermented good dried cocoa: 10’600 Rupiah

(139) G DRYING OF COCOA BEANS 0.5

SyntheSim variable

Units: dmnl

(141) G FERMENTATION OF COCOA BEANS= 0

SyntheSim variable

Units: dmnl

(143) G TIME TO CHANGE COCOA BEAN QUALITY= 0.5
SyntheSim variable
Units: Year

(153) INITIAL COCOA BEAN QUALITY= 58.3333
Units: Percent

(198) NORMAL COCOA BEANS QUALITY= 66.665
The cocoa bean quality for fully dried, not fermented beans without CPB quality diminishing
Units: Percent

(200) NORMAL FARM GATE PRICE FOR UNFERMENTED DRIED COCOA BEANS= 9000
Units: Rupiah/Kg

(202) NORMAL PRODUCTION COST PER KG= 150
Units: Rupiah/Kg

(209) OPTIMAL LAND YIELD= 9e+006
Units: Rupiah/(Year*hectare)

(220) POSSIBLE LAND PRODUCTIVITY RATE IN INDONESIA= 1.3
Units: Ton/(Year*hectare)

(233) TIME OF DIMINISH CHANGE OF COCOA BEAN QUALITY= 0.5
Units: Year

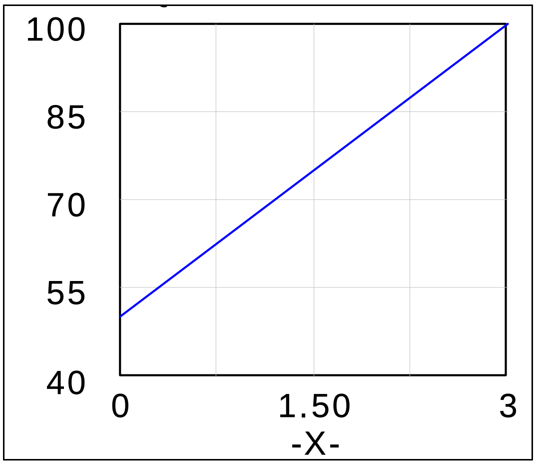
### 17.10.2 Equations

(036) Cocoa Bean Quality= INTEG (+quality improvement-diminishing quality, INITIAL COCOA BEAN QUALITY)
Units: Percent

(037) cocoa bean quality rate= Cocoa Bean Quality/NORMAL COCOA BEANS QUALITY
Units: fraction

(047) desired quality= DESIRED QUALITY TABLE(DRYING OF COCOA BEANS+2*FERMENTATION OF COCOA BEANS)
Units: Percent

(048) DESIRED QUALITY TABLE




Units: dmnl

(049) diminishing quality= (Cocoa Bean Quality*effect of CPB on quality)/TIME OF DIMINISH CHANGE OF COCOA BEAN QUALITY

Units: Percent/Year

(050) DRYING OF COCOA BEANS= GAME (G DRYING OF COCOA BEANS)

Units: dmnl

(059) effect of CPB on quality= EFFECT OF CPB ON QUALITY TABLE(CPB infestation rate)

Units: dmnl

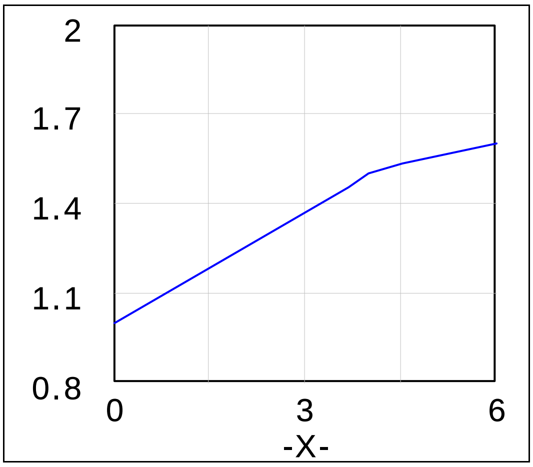
(060) EFFECT OF CPB ON QUALITY TABLE([(0,0)-(2,0.1)],(0,0),(2,0.05))

Units: dmnl

(081) effect of inputs on production cost= EFFECT OF INPUTS ON PRODUCTION COST TABLE(non organic action against CPB)

Units: fraction

(082) EFFECT OF INPUTS ON PRODUCTION COST TABLE




Units: dmnl

(096) effect of quality on farm gate price= EFFECT OF QUALITY ON FARM GATE PRICE TABLE(cocoa bean quality rate)
Units: fraction

(097) EFFECT OF QUALITY ON FARM GATE PRICE TABLE([(0,0)-(1.6,2)],(0,0.8),(1,1),(1.6,1.1))
Units: dmnl

(106) effective farm gate price= effect of quality on farm gate price*NORMAL FARM GATE PRICE FOR UNFERMENTED DRIED COCOA BEANS*effect of transport infrastructure on farm gate price
Units: Rupiah/Kg

(098) EFFECT OF TRANSPORT INFRASTRUCTURE ON FARM GATE PRICE TABLE([(0,0.9)-(1,1.1)],(0,0.9),(1,1.1))
Units: dmnl

(099) effect of transport infrastructure on farm gate price= EFFECT OF TRANSPORT INFRASTRUCTURE IN FARM GATE PRICE TABLE(TRANSPORT INFRASTRUCTURE)
Units: fraction

(108) effective net yield per kg= effective farm gate price-effective production cost per kg
Units: Rupiah/Kg

(111) effective production cost per kg= effect of inputs on production cost*NORMAL PRODUCTION COST PER KG
Units: Rupiah/Kg

(114) estate productivity rate= cocoa bean production/Estate for Cocoa
Units: Ton/(Year*hectare)

(116) estate yield= estate productivity rate*effective net yield per kg*1000
Units: Rupiah/(Year*hectare)

(124) FERMENTATION OF COCOA BEANS= GAME (G FERMENTATION OF COCOA BEANS)
Units: dmnl

(177) land productivity rate= cocoa bean production/yielding area
Units: Ton/(Year*hectare)

(178) land yield= net income/yielding area
Units: Rupiah/Year/hectare

(179) land yield rate= land yield/OPTIMAL LAND YIELD
Units: fraction

(195) net income= (cocoa bean production*1000)*effective net yield per kg

Units: Rupiah

(225) quality improvement= (desired quality-Cocoa Bean Quality)/TIME TO CHANGE COCOA BEAN QUALITY

Units: Percent/Year

(228) relative land productivity rate= land productivity rate/POSSIBLE LAND PRODUCTIVITY RATE IN INDONESIA

Units: fraction

(235) TIME TO CHANGE COCOA BEAN QUALITY= GAME (G TIME TO CHANGE COCOA BEAN QUALITY)

Units: Year

## 17.11 Market Dynamics' System

The International Cocoa Organization (ICCO) predicts not only a rise in world cocoa consumption over the coming years, but also a continuing drop in production, with demand exceeding production for the first time. Cocoa stockpiles provide only short-term relief, and an increase in demand for cocoa can only be met if pests and diseases are better managed, since they destroy almost half the potential production worldwide annually. Therefore, the demand side of the cocoa system is not depicted in the farmers' system.

## 17.12 Simulation and Gaming

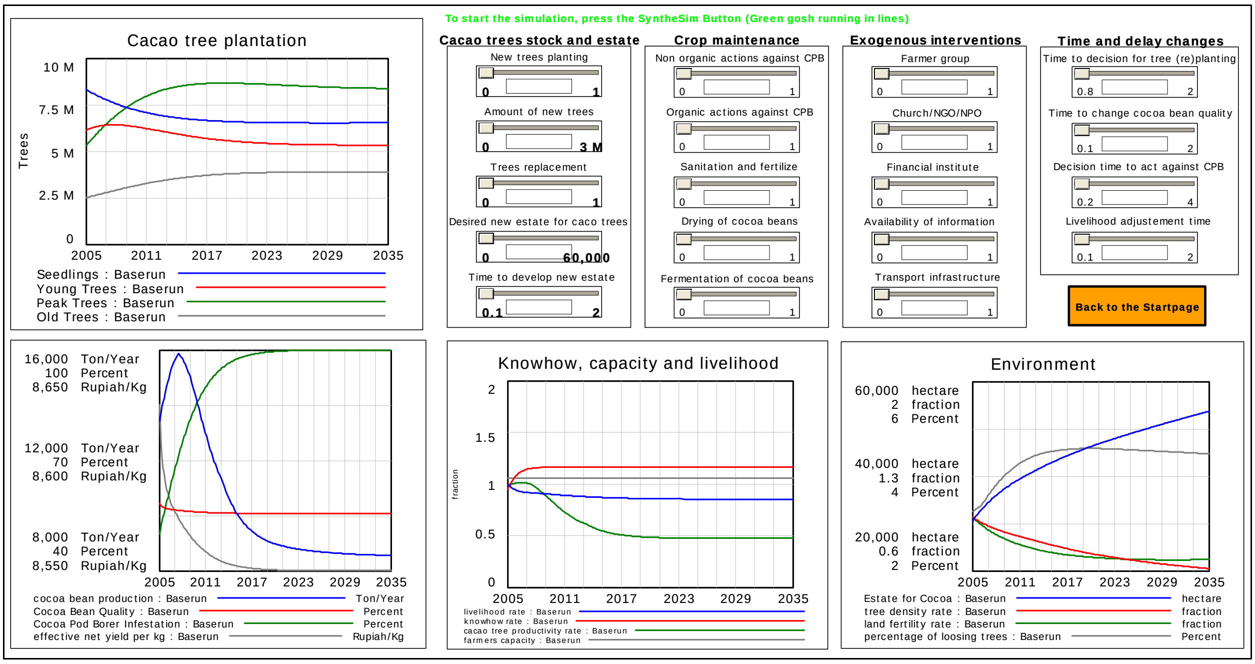



**Figure 17-11: Simulation model graphical user interface**

The graphical user interface of the cocoa farmers' decision model is both, a simulation screen and a gaming screen using the same levers for decision making.