Vrije Universiteit Amsterdam

Universiteit van Amsterdam

Master Thesis

Uncovering food security value networks in West-Africa using a value modeling approach.

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A thesis submitted in fulfillment of the requirements for the joint UvA-VU Master of Science degree in Information Sciences

July 29, 2021

Abstract

Despite worldwide efforts, many countries around the globe still face food insecurity and undernourishment. Many of these countries lay within the Sub-Saharan African region, of which Mali is an example. Within these countries, the value chains for cereal seeds form a major factor for food security. Problematically, the Malian seed value chains face many obstacles and challenges. To gain insights into these value chains and their difficulties, this research has opted for a business informatics perspective, resulting in applying a value modeling approach. The modeling language used for this is $e^3value(1)$. This is a visual business informatics model suitable for analyzing value networks. Creating two different e^3value models revealed major differences between the two main different seed value chains. The core of the traditional value chain lies in subsistence and bartering (using *un*improved seeds). In contrast, the other more commercial chain is based on profitability and economic activity (using improved seeds). Conclusively, the process of creating these models, along with gathering relevant information, has led to critical questions and observations. At the moment, the business infrastructure of Mali seems inadequate, whereas the traditional chain is not officially recognized and is even somewhat oppressed by privatization and commercial motives. It can, therefore, be challenged whether the (inter)national push for the commercial seed system comes too early or is even justifiable at all.

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The complexities and difficulties of feeding Sub-Saharan Africa

The second SDG on the list of seventeen carries a powerful statement: "Zero Hunger" (2). The goal is to achieve this by 2030, but even though steps are being taken, there is still a long way to go. In the year 2019, the data namely showed that within the continent of Africa alone, there are 256 million people that suffer from undernourishment (3). In the process of solving this, scientific research could (and maybe should) play a role. Therefore, in this research, the food value chains have been studied within a low resource environment, as they play a significant role in the overall food security of African countries.

Studying such a domain can be done from various scientific disciplines, such as economics, social sciences, or philosophy. This thesis, however, is written from a business informatics perspective, in specific ICT for development (ICT4D). It describes the study of the seed value chains of Mali using a value modeling approach.

1.1 Problem definition

1.1.1 The relation between cereal seeds, wealth and food (in)security

It is a well-known fact that sub-Saharan African countries are underdeveloped economically, organizationally and industrially compared to European countries. Since the economies of these countries are less industrialized, more than 60% of the population lives from smallholder farming (4). These are, in general, also the most vulnerable people with low incomes of less than 2 dollars a day, making food security an important topic for them. For Mali, the percentage is even higher, with 80 percent of the population being engaged in the agricultural sector (5). In total, this accounts for ca. 37 percent of the total GDP

(6). However, even though such a large part of the Malian population has inference with the sector responsible for growing food, 29 percent of the population is malnourished (5). Explaining this gap between the percentage of people who grow food and the percentage of people who actually have access to food is not easy. It is often attributed to a lack of governance and efficiency, whereas only 7 percent of the available soil is currently cultivated and only 14 percent of that land is irrigated (5, 7). However, as mentioned, this is a vast oversimplification, which does not do justice to the actual complexity.When discussing the food security of Sub-Saharan Africa, the value chains of cereal seeds are of significant importance (8). Mali is one of those countries for which this statement holds.

The value chains of cereal seeds in Mali can be roughly divided into two systems. It is namely traditional on the one hand, and commercial on the other hand (9). Both of them have their own very different characteristics. The traditional system makes use of seeds that are mostly not genetically improved. These seeds result from local production and selection of the best seeds within families/communities and are mainly acquired via local trading/transactions and gifts. The advantage of these seeds is that they can be replanted without limitations while also having better resistance to drought. Next to that, they do not require pesticides and fertilizers. The disadvantage is, however, that they offer a lower crop yield per hectare than improved seeds. Finally, it is crucial to understand that this more traditional type of trade is the basis of daily food consumption in Mali (7, 10).

The other type is the commercial cereal seeds. These seeds are genetically improved, which causes them to have a higher crop yield per hectare. There is also a growing demand for them on the commercial market. They do, however, require pesticides and fertilizer, and they can only be replanted for two or three seasons, depending on the type. Besides that, the higher yield does come with higher risk since these genetically improved seeds are less resistant to unfavorable environmental circumstances such as drought (10).

To conclude, these different seed systems indicate that farmers obtain and sell/use their seeds in various manners. The traditional seeds are driven primarily by a community-based system, while the improved seeds can either exist within a public or private-driven operation (7). Studying and analyzing the main differences between these systems is an important part of this research, attempting to create a better understanding of their dynamics.

1.1.2 The struggle of Mali with its seed value chains

This research is focused on the inefficiency of the seed value chains in Mali. On a high level, several problems/challenges are known. The high inefficiency is, for example, caused

by a lack of communication between the stakeholders (11). The main stakeholders being farmers, farmer organizations (Cooperatives & Unions), governmental organizations, NGOs, laboratories, and private companies. The farmers are responsible for planting and selling the seeds, which often happens in collaboration with a Cooperative and Union. A Cooperative is a cartel of multiple farmers accountable for setting a price and storing and certifying the seeds (at a laboratory). A Union is similar but on a higher level (multiple Cooperatives fall under one Union). Governmental organizations are responsible for improving food security and spreading and creating new seed varieties. NGOs primarily consist of philanthropic organizations that support the development and spreading of improved seeds. Lastly, private companies function as smaller or larger (international) agro-dealers buying and selling seeds with commercial motives (7, 12). The lack of communication between these stakeholders entails having insufficient insights into the supply and demand of seeds and limited possibilities of finding new sales channels (13). Eventually, this leads to under/overproduction of seeds, resulting in lower profits and vulnerability for food shortages. Other issues have to do with cultural resistance for using improved seeds since the traditional seeds are often an important part of villagers' cultural heritage (7, 9). However, these are all relatively macro-level facts, whereas detailed on-the-ground knowledge is necessary to understand the problem and design solutions.

An essential aspect is described in a recent article by Coulibaly, Claeys, and Berson (14). They have outlined the process of "Seed, Norms, and Peasants" (SNP). As a country, Mali is still indecisive when dealing with the two different seed systems described in the previous section. Farmers are supposed to certify improved seeds before selling them on the commercial market. However, the seed law of 2010 is proclaimed to ensure that selling (traditional) uncertified seeds is not strictly prohibited/illegal. Officially, though, Mali does not recognize the traditional or "informal seed sector", despite this being responsible for about 80% to 90% of the total seed production (8). This is partly due to legislation and (inter)national promotion of improved seeds, resulting in a disconnect between reality and politically steered ideals (14). For the improved seeds, Mali has pushed the privatization for the last decades, as will be discussed in the context chapter. However, this strategy hasn't yet paid off since adoption rates are slow. These low adoption rates have to do with limited access to seeds and high prices/startup costs, which are difficult to bear for most farmers (15). State actors mostly believe in the usefulness and coexistence of both systems, for which the traditional system functions as a fall-back option. Though, many traditional farmers feel threatened by the commercial system[1]. Next to this, when intellectual property

[1]Interview with Barke Ousmane, farmer representative from Mpto, Jan 2020

and seed enclosures (a way of making a particular seed variety property of a private party, forbidding others to store/use it) are implemented, it might become a human rights issue. This issue is because, for traditional farmers, seeds are not economic activity but a way of living/surviving and their primary access to food. The eventual goal of the SNP process is legal recognition of the traditional seed model, ideally in combination with a more progressive seed law. Though this is an ongoing process, that could be opposed by lobbying or other external pressures (14).

This research aims to contribute to a better understanding of the business dynamics of the value network for various stakeholders, notably the smallholder perspective. For this, the following research questions have been used:

RQ1: What can we learn from value network analysis of commercial versus traditional seed systems in Mali?
RQ2: In what ways can *e³value* contribute to gaining insights into a seed/food value chain in a low resource environment?

These research questions attempt to answer who the relevant stakeholders are within the value chain and what value they produce. And why is the value chain so inefficient, and what can be improved? This research proposes to answer these questions by analyzing the Malian seed value chains using the *e³value* methodology. The *e³value* modeling language is a visual IT-driven model that can map and quantify the value transfers between several relevant stakeholders.

1.2 Contributing knowledge about Mali and *e³value*

Firstly, a business model has not yet been applied to the seed value chain of Mali while using an information science perspective. The advantage of using a business model from an IS perspective (like *e³value*) is that it is more concrete/actionable than larger abstract models like the Business Model Canvas (16). In this way, the researcher is forced to implement a considerable amount of detail into the model, which helps discover what is unknown. Next to that, the *e³value* model aims at quantifying transactions, which leads to concrete numerical insights of feasibility and profitability.

Secondly, this research will offer validation for using the *e³value* method in a low resource environment. Despite this already been done a few times in Mali and other countries (17, 18, 19), it will still offer a valuable addition. For the previous cases, the *e³value* model was namely used for smaller businesses or micro-level business analysis. On the

contrary, this research will apply the *e*^{3}*value* model to the entire national seed value chain. Although this will be done by using data gathered in a specific area, it is still aimed at representing the nationwide system. Therefore, this research will be a valuable scientific addition because it uses the *e*^{3}*value* method to conduct a macro-level business analysis within a low resource environment. Lastly, this research will also use a newly suggested element of the *e*^{3}*value* language (group element), proposed by a master student some years ago (20). This element is not officially part of *e*^{3}*value*, so using it in one of the models in this research will offer insights into the usefulness of adding this specific element.

Thirdly, this research will be part of a international research program called "Web Alliance For Regreening Africa" (W4RA). This alliance forms a trans-disciplinary community of academics and non-academics that study the digital society, often in low resource environments (21). Within this alliance, many studies and workshops have been conducted in Mali, for which this research will be a valuable scientific contribution.

1.3 Adding value to society

As argued in the sections above, food insecurity and undernourishment are still major issues in large parts of (rural) Africa, such as Mali. Therefore, the overlapping societal relevance of this research lies in the (in)direct benefits for the people of Mali. Gaining more insights into the seed value chain, which is vital to food security, could improve nourishment and eventually stimulate local economies.

Looking at the aspects of this research from a more detailed view reveals that several factors play a role in determining this societal relevance. Firstly, this research will make use of a design science strategy. This indicates that the researcher will design and investigate an artifact within a local context (22). Since this requires a close connection/cooperation between researcher and stakeholders, it could be argued that this allows for more direct societal impact. Especialy when comparing it to studies that are focussed on a macro-level and have a higher level of abstraction.

Secondly, the created artifact will be in the shape of a business informatics model. Such models have a high level of detail and actionability. It could, for example, show relatively quickly which stakeholders are losing/gaining too much. Therefore, using such a model could argue for a relatively high level of societal relevance, especially in the short term, when comparing it to more abstract models.

Thirdly, this research will be conducted within the domain of ICT4D, which implies a likely possibility of studying an area where food security and good health are not evident.

Such needs are primary to a human being, and improving them could have an enormous impact on their quality of life. In comparison, a study related to secundairy or tertairy needs could also have societal impact, but it would be less drastic and of lesser importance to the studied population.

1.4 Thesis structure

The structure of this thesis will be as follows. The first chapter presented a brought introduction to the research topic combined with its societal and scientific relevance. It also shortly elaborates on the central research questions. The second chapter has the goal of explaining the context in which this research has taken place. This chapter will help the reader better understand Mali from several perspectives, such as demographic, political, economic, and seed perspectives. Next to that, it will also offer contextual insights into the research domain of ICT4D. The third chapter provides the used strategies and methods within this research. Next to this, it also contains a research timeline, elaborating more into detail on the process of conducting this study. The fourth chapter functions as a theoretical framework. This chapter explains the used theoretical frames: the ICT4D 3.0 framework and the e^3value methodology. After this, the fifth chapter offers the results of this research, which will consist of two main parts. One part is the outcome of the design science, in which the created models are presented and the first research question gets answered. The second part answers the second research question by explaining how e^3value has been helpful in this research. Lastly, the sixth chapter contains the conclusion and discussion.

1.5 Personal reflection

My motivation for choosing the topic of this research has different aspects. Firstly, I was drawn to the interdisciplinary character of this research. Since my educational background lies in public administration and organizational sciences, I am interested in economics and society, next to having an interest in ICT. These themes can be found in this research, considering the seed value chain of a developing country is very much related to economics and society, and the applied modeling technique I've used has ICT roots. Hence this research suited my interests very well.

Secondly, I've learned in the past that I am more motivated to study a topic when it has a high level of concreteness/actionability and contribution to society. I found these

Figure 1.1: Pictures taken during field studies in Mali, in 2019.

requirements in the subject of this research since the outcome could help to increase the understanding of a vital element in feeding millions of people in Mali and Sub-Saharan Africa.

Thirdly, the complexity and newness appealed to me. I am enthused by relatively unknown and complex topics, which require a deep dive into various forms of information to develop an increased understanding. Before this research, I had little to no knowledge of Mali or seed/food value chains of African countries or the ICT4D field in general. This means that conducting this research didn't only offer a great experience of writing my master thesis but also meant discovering and learning about fascinating topics previously unknown to me.

2

Context chapter

Since this research will be focused on the seed value chain of Mali (within the domain of ICT4D), the reader of this study ought to have a basic understanding of the right context to place the results within a proper perspective. Therefore, this context chapter will offer the contextual knowledge necessary, split up into three main sections. The first section provides general insights into the field of ICT4D. The second section centers on giving a clear, holistic picture of Mali as a country. Lastly, the third section is likewise focussed on Mali, but specifically on (the history of) the seed value chain.

2.1 ICT4D

Since this research is conducted from an ICT4D perspective, it is valuable to shed some light on this domain. Studying ICT in developing areas emerged around the 1980s (23). Back then, the focus lay on the diffusion of computers and how governments incorporated them in policy (24, 25, 26). At the time, governments of developing countries believed that ICT's could endanger their competitive advantage, which consisted of cheap labor. This belief was, however, not supported by researchers. They agreed on ICT having great potential to solve several societal issues like inadequate government administration and healthcare provision (23). Later, in the 1990s, the slow diffusion of ICT (infrastructure) in developing countries became a concern for worldwide NGOs and development organizations. This significant lack of ICT infrastructure and lack of access to information was also dubbed the term digital divide. The importance of this digital divide was backed by several publications, suggesting a causal effect between ICT and development (27, 28, 29, 30).

Other research has focussed on a more detailed and micro-level approach by examining the use of computers in organizations and communities in developing countries. Despite

positive anecdotal stories being available within this domain, it turned out to be more complicated than it might have seemed. For example, some online sellers of products in developing countries were very reliant on expert aid from more developed countries (23). Others didn't manage to sell to international markets (31). These complexities often resulted in disappearance over time, revealing a lack of sustainability (32).

Such a common lack of sustainability for ICT solutions in developing countries doesn't imply an absence of a causal relationship between ICT and development. It does, however, show that this causality can be very complex and reliant on many different factors. In a later stage, when ICT4D became a more extensive and prevailing research field, other subdomains arose. Examples of these are Human-Computer Interaction for Development and AI for development (33, 34).

The effectiveness of ICT4D research is, in general, a topic that is broadly discussed. A study that specifically analyzed the extent to which ICT4D academic research conforms to the requirements for achieving economic and societal impact found a lack of transferring research results into actual policy and effects (35). A possible given explanation is researchers being more prone to achieving "impact" via publications and citation counts. It is also stated that transferring research into policy requires a very different skill set than conducting the actual study. However, these points are not limited to the field of ICT4D (36, 37, 38, 39). The latter point is also a large part of why the ICT4D framework was developed, used within this research, and discussed in depth in the theoretical framework chapter (36).

It is crucial, though, for (ICT4D) Researchers to strive for tangible impact on society and policy to realize the maximum potential and remain to receive funding, especially since there is a trend of philanthropists desiring to see actual results of their investments (35).

2.2 Context of Mali

To get a clear picture of Mali as a country, this section will offer an oversight of the country's properties from different perspectives.

2.2.1 General context

Historically seen, Mali has a very intriguing past, with great kingdoms and enormously wealthy rulers. Eventually, though, these kingdoms fractured and got colonized by the French in the late 19th century. In 1960 Mali found independence and can be found on the West side of Africa and is one of the poorest countries located in the world, being at place

179 out of 187 countries (40). It currently has about 20 million inhabitants (12), which is expected to grow rapidly to approximately 50 million in 2050. This means that women in Mali have an average expected amount of 6,2 children, bringing the yearly population growth at 3% (41). These high birth rates cause the population to be very young, with half the population below the age of 15. Despite the pressure this brings to (the future of) food security, the government is very reluctant to promote family planning since it is politically sensitive (42). The country is landlocked between large countries like Mauritania and Algeria on the North- and westside while having smaller countries on the East and South. Being landlocked, Mali relies significantly on the river Niger and some other smaller rivers coming from Senegal. The topographical borders of Mali include three climatic zones: The desert-Saharan zone in the North with less than 200mm rainfall, the Sahelian zone in central Mali with 200mm to 600mm rainfall, and the Sudanese zone in the south with 600mm to 1400mm of rain falling from late May to October (43). Because of this, by far the most people live in either the Southern or central zone.

It is challenging to feed everyone in Mali, given the (changing) arid climate, rain-fed agriculture, and unreliable rainfall (12). In combination with more and more land being sold, these factors decrease the available land for agriculture. This is problematic since three-quarters of the inhabitants rely on agriculture for their food and income. Despite the potential for agriculture growth being present, about 30% of the population is malnourished (5). The reasons for not achieving this potential are low productivity, under-developed markets, post-harvest crop losses, vulnerability to climate change effects, and insecurity of Central and Northern Mali (42).

Culturally and ethnically seen, Mali is a very diverse country. About half the population is comprised of three main African ethical groups, which are the groups of Bambara, Malinke, and Soninke. Besides these groups, there are smaller communities which are the Fulani (17%), Voltaic (12%), Songhay (6%), Tuareg (3%), and other groups, including Arabs and Moorish (5%). Although all these ethnic groups have different languages, cultures, and traditions, the main dividing line has been between the Tuareg/Arab northern population and the black majority groups living south of the River Niger. Historically, the Tuareg were powerful folk seeing themselves as "masters of the desert" P. 5 (42). However, this was disrupted by French (post) colonialism, resulting in the Tuareg being a minority ruled by the black Southern community. One can imagine this brings cultural/political tension, considering that the Tuaregs once raided this black community for slavery and are now subject to their ruling.

This ruling is, however, not very concrete. Since the Tuareg/Arab people live in the remote North, and most, if not all, political activity happens from the south, it is said that the Northern regions are practically a different country (42).

2.2.2 Political context

In terms of politics, Mali knows an eventful past. In 1960, Mali gained independence from its French colonizers. Between 1960 and 1990, this led to the country having several presidents and army coups, which were politically seen as somewhat similar to Soviet-style socialism. State enterprises and corporations were formed, which turned out to be very inefficient and money-wasting. Also, development aid ended up in the wrong hands due to corruption and impunity of the elite community (44, 45). After an economic recession in 1980 leading to an economical liberalization process and democratic protests in 1990, the current government got overthrown, resulting in multi-party democracy. However, this new system did not lead to a strong nation and government, with institutional weakness, mismanagement, and cultural clashes still being prevalent. These issues are also problematic for development aid since the Malian government doesn't set any priorities, which leads to NGO's just cherry-picking whatever suits their agenda best (42).

Fast-forwarding to 2012, Mali faced a double crisis since the army committed a coup on the state while simultaneously rebellions (among ISIS and Al Quida) were attacking and possessing the Northern regions. The French and Dutch made international military efforts in cooperation with the Malian army to suppress these rebellion efforts (between 2013 - 2019). Although they did succeed to a certain extent to expel the rebellions, there are still Jihadi threats to this day (2021), and Mali is recently facing new issues. The military again committed a coup in 2020, promising to bring power to the people after years of violence and instability. Although this gave hope for a proper democratic solution, it went all wrong again in May 2021. The military, namely, imprisoned some current interim government officials, as commissioned by the vice-president. This interim government was working towards new elections, but whether that will still happen in the short term is unclear and maybe even unlikely (46).

To conclude this small political analysis, it is not surprising that many Malians lost their faith in Mali as a modern state (47). Democratization and decentralization namely haven't improved their lives but only lead to complications, corruption, and mismanagement (42).

2.2.3 Economic context

As described in the earlier sections, Mali is a poor country. Not only from a global perspective but also when comparing Mali to the rest of sub-Saharan Africa. Its gross national income per capita is only 790 USD a year, making the country very dependent on foreign aid. Expressing this in numbers means that foreign aid accounted for 11% of the gross national income and 80% government expenditure (41). Officially, the Malian economy mainly runs on a couple of large markets: Agriculture (Cotton), livestock, and mining/gold (42). Because of this, the economy is quite vulnerable to price fluctuations of gold and cotton (43). There are, however, also substantial market segments consisting of unofficial/illegal practices. Examples are the smuggling of cocaine, heroin, cigarettes, and even people (42). These markets are related to some elite communities of Mali but are also partially connected to Islamist insurgents.

In recent years, the Malian government has promoted foreign direct investment (FDI) (48), leading to an FDI of 494 million USD in 2019, mainly originating from the UK, Australia, Canada, South Africa, and Ivory Coast (49). This FDI amount might sound like much, but it is quite weak and unstable. To compare, The Netherlands, being one of the highest receivers of FDI, had an FDI amount of 84 billion USD in 2019 (50). This is, of course, an unfair comparison, but it does show the significance of the gap between modern western and developing countries. Besides that, Mali is still among the African countries with the lowest FDI amount in general (51).

Despite the possibilities of globalization and foreign investment for developing countries, it also brings new challenges. In Mali and many African countries, globalization leads to the exploitation of natural and human resources, combined with the risk of growing inequality (48). These risks could be mitigated by proper financial and economic governance, but as read before, that is precisely what is missing in countries like Mali.

2.3 Seeds in Mali

This last section of the context chapter will offer a contextual overview of the seed value chains in Mali. The results chapter will expand on this, based on the created artifacts and conducted interviews within this research.

Within Mali, around 75% of the population relies on agriculture (8). Seeds are closely related to this since it is used to grow grains for food production (12). However, as described earlier, the Malian seed value chains face many issues, such as a lack of communication

channels between involved parties. This absence of proper communication leads to a mismatch in supply and demand and increases the risk of food insecurity and malnourishment (13).

At a high level, the seed value chain of Mali can be divided into two primary categories: A system that uses traditional unimproved seeds and a commercial system that uses genetically improved seeds.

2.3.1 Traditional unimproved seeds

The traditional unimproved seeds form the backbone of Malian food supply and agriculture. They are used by (small) farmer communities and traded locally among each other. Although it is difficult to put an exact number on it, this type of seed makes up about 65% to 85% percent of the used seeds in 2010, depending on the type (7). Other sources declare comparable numbers, claiming that only 10-15% of the cultivated land is used for improved seeds (52), and nearly 90% of seed exchanges happen between traditional farmers (53). The two most-produced cereal crops are Pearl millet and Sorghum, of which numerous local varieties exist (8).

Small traditional farmers receive their unimproved seeds in a couple of different ways. They exchange seeds, receive donations, and incidentally purchase them on the commercial market. For the latter case, the seeds they acquire are actually improved and certified. However, because of the high price of these seeds and a general lack of information, they are often reseeded too many times and therefore lose their yield/productivity and can no longer be seen as improved (7). Besides that, only 7-10% of the seeds obtained by small producers come from the market (54).

The unimproved seeds used within traditional local farms are part of the village heritage. They have been selected/cultivated to adapt to local conditions. Such seeds are seen as a community good, making it normal to exchange and donate them among farmers within a community. In some communities, it is even seen as a violation to sell them externally (7).

2.3.2 Improved seeds

In the past decades, Mali has known several phases that determined how improved "professional" seeds could be bought and distributed.

In 1960-1980, the seed sector in Mali was under state monopoly. This took the form of the Institute of Rural Economy (IER), being created in 1960. The IER, and some suborganizations formed later on, were responsible for the varietal improvement, control, and

dissemination of genetically improved seeds. However, at some stage in the late 1970s, the capacity of these institutions ran short. As a solution, the production cells called for help from peasants (7).

This help of local peasant farmers ushered in a new period of opening the seed sector to non-state actors. This period, which took place between 1980 and 2010, existed of new legal restrictions and networks being created between state- and non-state actors. After 2010, the seed sector was liberalized entirely. For the most part, the IER lost its monopoly on improved varieties, opening up the market for external (foreign) investors and actors (7).

Today (2021), this process of the past decades entails that improved seeds can be obtained either via the public circuit or via private institutions. Receiving seeds via the public process might also mean that seeds are received for free via an NGO. Whether this will cause unfair competition will be discussed in the result section (7).

2.3.3 Unimproved vs. Improved seeds

A workshop conducted with the AOPP, an umbrella organization aimed at representing and regulating the seed value chain (12), revealed several advantages of unimproved seeds:

- No cost for fertilizers and pesticides.
- Better for biodiversity since pesticides can kill essential insects.
- Better for the soil quality, since they do not exhaust the soil as much as improved seeds.
- Traditional seeds are more adaptive to changing rain patterns and temperature.
- Certification is not needed.

In addition to these points, a mattering difference has to be noted. Traditional seeds only go through one life cycle. In other words, if they are planted, they immediately turn into eatable food when harvested. For improved seeds, this is different. Farmers receive/buy basic seeds (Semences de base), either from private or public institutions. After planting these basic seeds, they can be harvested as R1 seeds. These R1 seeds can be sold and replanted, which can then be harvested as R2 seeds. Finally, when R2 seeds are planted, they are harvested as regular seeds, which can then be planted for food consumption (12). This processual difference also indicates the different nature of these seeds. Traditional seeds are planted mainly for their own consumption, while improved seeds are commercial

goods. In other words, planting traditional seeds is a matter of necessity and survival, while planting improved seeds entails running a business. Since many (pour) farming communities rely on their food production, they do not have the financial means to invest in pesticides or fertilizers, let alone bear the risk of a failed harvest.

3

Research strategies & Methodology

3.1 Research strategies

This research is conducted as part of a larger ongoing (action) research of the VU Amsterdam into food security in low resource environments, such as rural Africa. It has an interdisciplinary character since it is based on business informatics, applied in a particular social context in Mali. Next to this research, four other students have studied a related (Malian) topic from another perspective, such as an ethical- or software architecture perspective. In order to answer the research questions for this research, two types of research strategies have been applied:

RS1: The first strategy is to apply design science to Mali's cereal seed value chain to develop a business model.

RS2: The second strategy is to apply a qualitative study through interviews & document analysis.

The overlapping paradigm within which this research is written is the inductive paradigm. In opposition to the deductive paradigm, this research aims to build a theory instead of testing one (55). The goal is to do extensive explorative research concerning various methods of data analysis, which have been gathered and analyzed throughout the entire process, which is in line with the grounded theory (56).

3.2 Methods

3.2.1 Document analysis

The first method that has been used within this research is document analysis. For this method, the documents are interpreted as those not explicitly created for social research but were already existent (56). Examples could be reports, websites, or other materials that the umbrella organization has produced for farmers (AOPP). This method has been used since it requires very little to no effort from the studied population but can help understand local context and circumstances. Therefore, it has been used at the beginning of the research for contextual purposes and in further stages to complement other sources like interviews.

3.2.2 Literature Review

Another technique being used in this research is a literature review. A literature review can chase after different goals to contribute to the outcome of a study. It can, for example, be used to see what is already known or find out what methods have already been applied (56). Within this research, existing literature has had two primary goals: The first goal was to gain a more extensive understanding of the studied context. The main result is the context chapter, which uses previous literature (and reports) as a base for contextual knowledge. The second goal was to find base knowledge for developing the e^3value model based on the seed value chain. Thus, existing literature formed a good starting point, for which our newly conducted interviews filled in the knowledge gaps.

Conducting a literature review can be done systematically or unsystematically. For this research, a middle way has been chosen. Doing systematic literature research entails predefining its goal and following several prefined steps, which is not done in this research. Though, systematical techniques have been used, such as coding within Atlas.TI to analyze and categorize different pieces of literature. Next to this, the use of existing literature took the shape of a narrative review. With a narrative literature review, which is common in interpretative studies, the researchers uses literature to gain initial impressions and understanding of the studied context (56). The internal result of this was a better understanding of Mali as a country and producer of seeds. The external product is the context chapter, offering contextual knowledge for the reader of this research.

3.2.3 Interviews

The third method that has been used is conducting semi-structured interviews. This interviewing style differs from a structured interview, which is typically used within quantitative research. The main difference is the amount of flexibility offered to the researcher. Within structured interviews, the researcher will not deviate from the questions to maintain its external validity and measurability (56). However, this blocks the possibility of digging deeper into one question by asking follow-up questions, which is just desirable within interpretative research since the data is considered complex and very rich (55). The seed value chain in Mali is a complex theme, making semi-structured interviews the most suitable method to understand the given phenomenon. Next to that, this research is also open-ended with an explorative character, which makes it necessary that the option exists to deviate a bit from existing questions or come up with new ones on the spot.

A second argument for conducting interviews is the low Malian adult literacy rate of 35% (57). Therefore, conducting surveys would be unsuitable since the majority (especially the poor) would not be able to read the questions. Lastly, the Coronavirus brought some limitations to the execution of this research, of which the main one is the inability to travel to Mali physically. The fact that conducting interviews can be done relatively well via online meeting tools is, therefore, the third and last argument for using semi-structured interviews as an important method. Though, it should be mentioned that holding all the meetings online via Zoom did have its implications. For example, the sessions are more chaotic, audio is sometimes challenging to hear, and there is less structure in general.

Also several interviews with the relevant study population have already been conducted before this research. These interviews have been used in executing this research and therefore offered one of the basics for the derivation of information. They also functioned as a roadmap to show what information was still missing. This missing information could then be retrieved by conducting new interviews based on the ones that are already existent. Since the interviews were done in French, a language which I do not speak, they were carried out by my supervisor Anna Bon. She summarized the result related to my thesis and handed them over to me.

3.2.4 *e³value*

The fourth used method is related to the design science strategy, namely applying the *e³value* modeling technique. The *e³value* method is based on the assumption that there exists a value network or a value constellation (58), in which several actors exchange objects

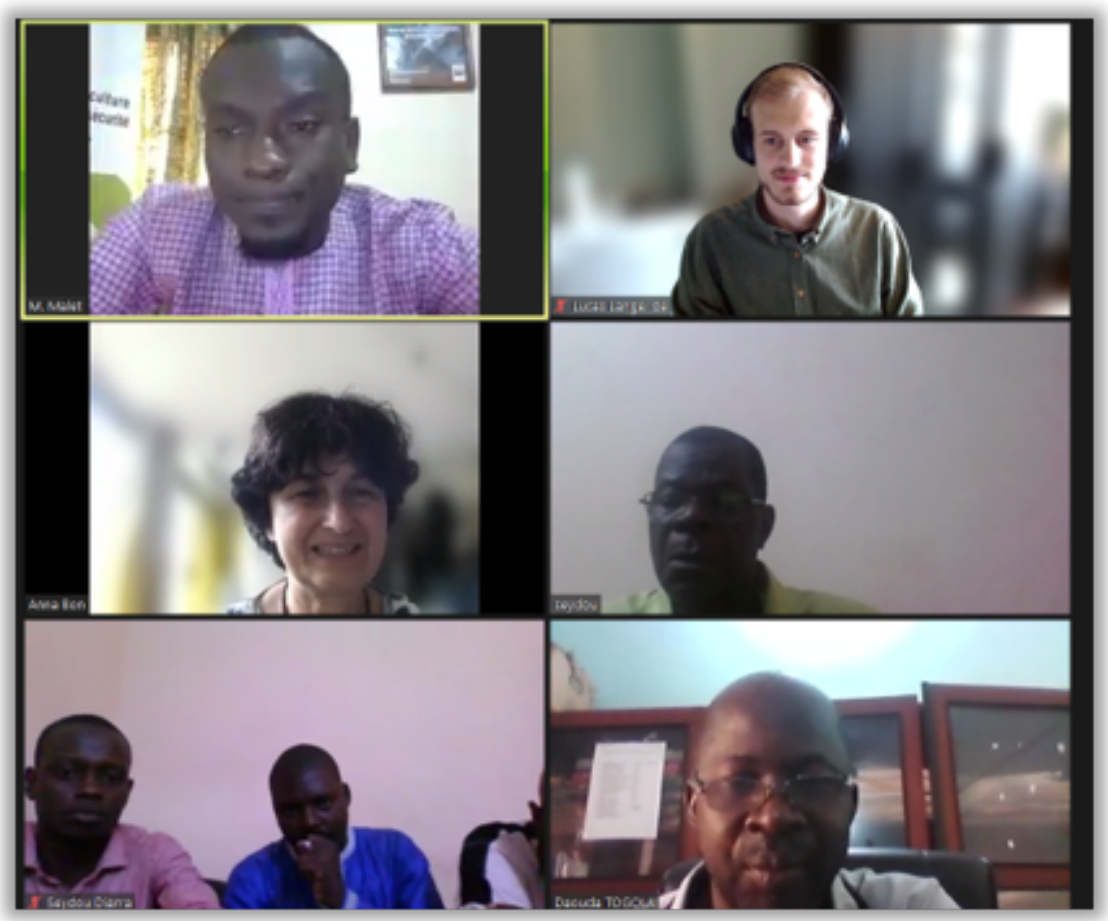


Figure 3.1: A screenshot of a Zoom meeting with members of the AOPP and partners from within the seed value chain.

that reflect value (59). In the case of this research, this will primarily be consisting of different types of seeds. The *e³value* method offers a visual model in which the exchange of value objects can be shown and quantified to eventually achieve insights into the feasibility and profitability of an entire economic network. The argumentation behind why this model is chosen can be found in the scientific and practical contribution section in the introduction chapter.

3.2.5 Qualitative data analysis using coding & Atlas.ti

When conducting qualitative research, many different rich forms of data will be used, as is described above. Since (especially the interviews) have offered quite large textual documents, it can be challenging to keep oversight. Therefore, a coding method has been used in this research, combined with corresponding software (Atlas.TI). Coding means that a researcher assigns tags or labels to pieces of data representing units of meaning (60). This will categorize all the essential concepts within the research, which allows for more oversight and a more accessible general analysis of all the used materials.

3.2.6 Low-resource aware framework for the development of ICT4D services (ICT4D 3.0)

Within ongoing research in the ICT4D domain, researchers at the VU Amsterdam have created a framework (36). This framework is also called the ICT4D 3.0 framework, which is developed to study ICT interventions in low-resource environments. The main scope of the framework is that IT solutions in such environments should not be considered a linear process but should be studied in their complex context. Therefore, this research has used this framework to effectively learn how to conduct an IT-related study in such a low-resource environment.

The ICT4D 3.0 model consists of 5 different elements, which will be discussed in the theoretical framework. However, since this research is not large enough to cover all of them, the focus has been put on the sustainability assessment. To assess this, the created *e³value* models show whether all involved stakeholders in the seed value chain hold an economically feasible position. If this is the case, the business environment can be sustainable in the long run. On the other hand, if this is not the case, some parties might lose their financial incentive and decide to discontinue their activities, which could significantly impact the entire value network.

Typically, though, the *e³value* methodology is used to assess (partly) digital systems. This research has, however, taken *e³value* one step further by applying it to a non-digital system. This means that an ICT model has been used to assess a (not yet) ICT-driven system, whereas it still proved helpful to study the underlying processes.

3.3 Research timeline

3.3.1 November

In November, I've got in contact with my supervisor about a thesis subject. After some brainstorming on themes and topics I liked, we ended up on the seed value chain of Mali. The interdisciplinary character of the case, entailing economic, societal, and IT aspects, made me interested and willing to choose this topic.

3.3.2 January

In January, we got the chance to write a research proposal for our thesis. It gave me the opportunity to get to know more about the topic and brainstorm on the content of the thesis. The first raw version of the research question(s), methods, and intended scientific contribution originated from this process.

3.3.3 February

In February, after finishing the thesis proposal, it was time to start doing the research. My first steps were to create a draft of the *e³value* model for the improved seeds value chain. Other activities consisted of watching online webinars about Atlas.ti, and reading the user guidebook of the *e³value* method. After learning to work with Atlas.ti, I started reading existing literature to explore my research topic and get to know more about it. While I was reading, I coded the most informative segments of the literature to structure my knowledge and to use for later reference in the context chapter.

3.3.4 March

In March, I had an increased understanding of the topic. I had made a clear list of relevant actors/stakeholders, for which the next step was to analyze which would be pertinent to place in the *e³value* model. In this decision process, new meetings and newly received workshops/interview reports from my supervisor were very helpful. I learned about Cooperatives, Unions (which will become more evident in the result section).

3.3.5 April

In April, the *e³value* model started to get its shape. A meeting with Jaap Gordijn, co-founder of the *e³value* language, helped increase the model's syntactic correctness. In this phase, the missing information and questions started to arise. Examples are costs of certification, types of seeds, and others. These will be described more in-depth in the results section.

Earlier literature recognized three main distribution models for seeds in Mali (7); Producer centered model, State service model, and Private centric model. The first mainly focuses on traditional unimproved seeds, while the other two focus on improved seeds. I decided to transfer this into two *e³value* models for this research, one for the improved seeds and another for the traditional unimproved seeds, as seen in the results section.

3.3.6 May

In May, a meeting was done by my supervisor Anna Bon, which delivered valuable insights to further concretize and quantify the *e³value* model. I also spend much time writing the context chapter. I attached great value to having a relatively extensive context chapter. It helped me create a better understanding of the local circumstances, as it will also help the reader achieve that same goal.

3.3.7 June

In June, I finished the context chapter and finalized the methods section and introduction chapter. Then, together with my supervisor, we created a simplified version of the *e³value* model to show to our contacts in Mali. The goal of this model was to check whether our findings were already correct or still needed some adjustments. Lastly, I created the *e³value* model for the traditional unimproved seeds. Within this model, I used a small addition to the *e³value* language proposed in a recent master thesis. This addition introduced a visual element meant for describing groups/communities (20).

3.3.8 July

In July, I finalized the last steps of my research. I wrote the results and conclusion sections, next to creating my presentation.

4

Theoretical framework

4.1 ICT4D 3.0 Framework

Various studies have shown that implementing ICT solutions (to improve information access) in developing areas can enhance general well-being (61, 62, 63). However, there is a significant difference between the IT-related circumstances of Western/Northern countries compared to low resource areas such as rural Africa. In Mali, this entails underdeveloped infrastructure for internet and electricity connections, low literacy rates, and relatively weak economies (36). Interestingly though, last years, the adoption rates of mobile telephony have risen substantially, offering more possibilities for voice-based solutions (64).

Despite the hard work, investments, and scientific potential that is posed for using ICT solutions in development areas, the failure rates of such projects are high (65). The cause of this high failure rate is based on the lack of consideration for local context within the implementation of ICT solutions. This absence of local context creates a mismatch between the created artifact and the intended users. Bon, Akkermans & Gordijn pose a typical example (36). A three-year project in Tanzania was based on the use of SMS to indicate the local state of drinking water. However, it turned out that local phone coverage was inadequate and that retrieving water was a job for women & children who didn't own a mobile phone (only man did). Recognizing these local conditions could have prevented the enormously low adoption rates and, therefore, failure of the SMS-based system.

As explained and elaborated within the context chapter, this research will be conducted in the context of ICT4D. The used e^3value model is namely an ICT-driven artifact. Also, the outcomes of this artifact could eventually contribute to creating ICT solutions within the local (development) context.

The high failure rate of ICT4D solutions has resulted in the expression of concern from various scientific fields. A typical posed remedy for these high failure rates is to perform severe monitoring and evaluation. This method, however, focuses mainly on problem-solving after the implementation of the artifact, while it is desirable to consider sustainability and success-rate ex-ante (36).

The above-described concerns and problems of ICT4D led to the creation of an ICT4D framework (4.1) based on extensive sociotechnical field action research in Ghana, Burkina Faso, and Mali (2009 - 2016). How this framework is used within this research is discussed more in-depth in the methodology chapter. The framework is based on five main steps that allow for flexibility, reflectivity, and an in-depth understanding of the local context (36).

4.1.1 Context analysis

Since the local (African) context is so different from the modern western context, it is crucial to observe and understand the type of environment in which the ICT solution should eventually function. In addition to this, some local stakeholders should be aware of what the ICT solution can(not) offer.

4.1.2 Needs assessment

Determining the actual needs of the user of the ICT solution is essential but challenging. Sometimes both parties (users and developers) don't know what they don't know. In other words, it takes time to create a complete comprehension of all the necessities or possibilities. Therefore, using focus groups, demos, and workshops is very important to grasp what is needed for the users to improve their situation.

4.1.3 Use case & Requirement analysis

After the needs assessment, it is vital to transfer the users' needs into the requirements of the intended ICT solution. The researchers can show these requirements to users in sketches/demos to confirm/discuss whether these requirements cover their needs and desires.

4.1.4 Sustainability assessment

It is crucial to understand that ICT4D solutions often work within a network of (small) actors. This could, for example, be a radio, a telecom provider, and a farmer. Suppose

one of these parties is interested in a particular ICT solution but needs some cooperation from the others to function. In that case, it is only sensible to create such a solution if it is feasible for all of them. If, namely, any of the parties/stakeholders makes a financial loss or the obtained added value from the artifact does not outweigh the expenses, the artifact/system is not sustainable. This network, and the value transfers within, can be analyzed with the e^3value method, showing whether the total sum of value transfers ends in a positive net cash flow for all the stakeholders.

4.1.5 Develop, Test & Deploy - Co-Creating the System in Cycles

Lastly, the development of the created ICT solution is done as much as possible during the workshops on sights. This allows users to provide their feedback during the creating process. After this process, the coding and creation are done from a distance, and then it becomes an agile process. This means that the artifact is improved/build on further step by step, taking into account new feedback, testing, and deployment results.

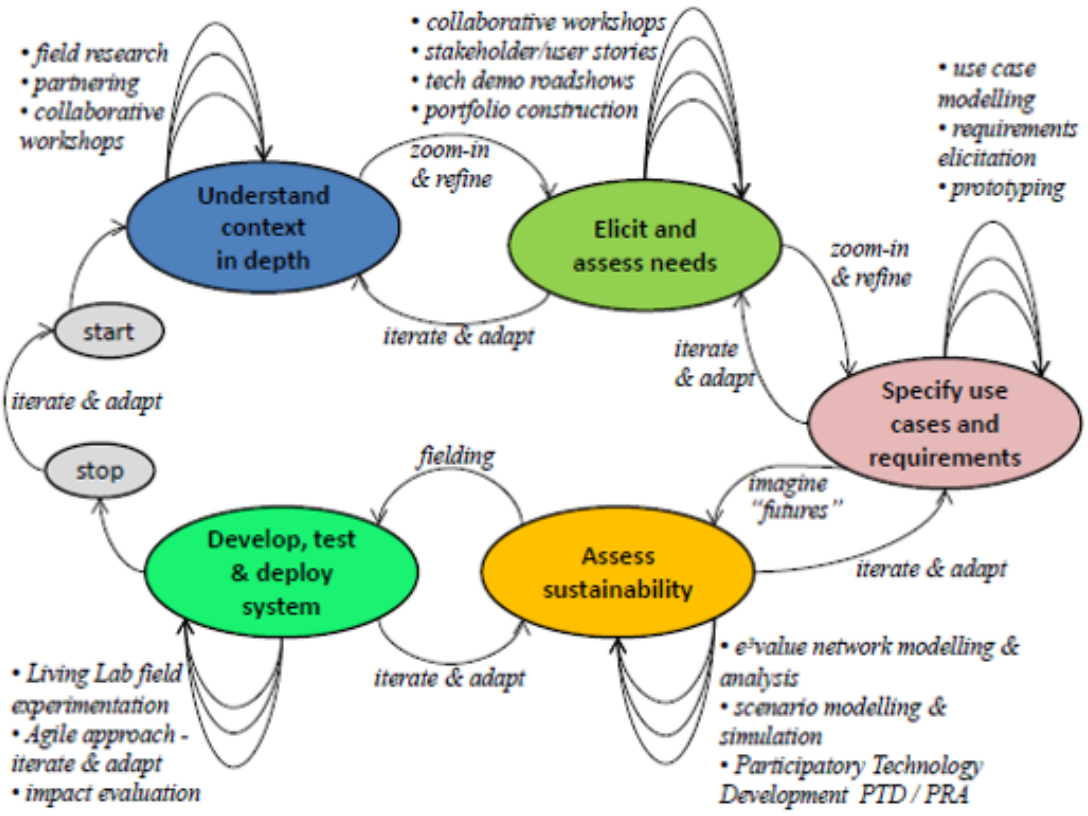


Figure 4.1: The collaborative-adaptive-iterative process model for our ICT4D Service Development framework, expressed in the form of an intention-strategy map.

4.2 *e³value*

4.2.1 The elements of the *e³value* language

Since the *e³value* modeling technique is used for the creation of the core artifacts within this research, it will be introduced and explained within the theoretical framework.

The *e³value* modeling technique is based on the concept of companies existing within their own value network/constellation (58). Within such a network, independent actors offer goods/services that represent value to others. For example, a company like Apple can't function without its value network of designers, producers, marketers, and others involved in establishing their products (1). These actors can exist of commercial organizations, non-profit or governmental organizations, and individual consumers. The decision process of which actors should (not) be shown within the model is up to the creator and is mainly based on whether it is interesting enough to assess their financial sustainability (core actors). Another reason for modeling an actor could be the provision/consuming of value objects from/to the core actors. Such actors are called contextual actors (17).

The *e³value* language is used to create a visual representation of transactions between actors in a value network. It can either be applied to develop and analyze models for existing value networks or realize new business ideas(1). The *e³value* language consists of a specific set of visual syntactical elements representing a particular component of the model. An educational model (4.2) will be introduced to summarize its core functionality and explain the *e³value* language in the most accessible manner. For more in-depth information about *e³value* other sources can be consulted (1, 66).

Two value objects are exchanged within the educational model: money and book(s). These are represented by the textual phrases/words between the square brackets, which are linked to the black lines, representing the value transfer between actors. A value transfer symbolized the change of ownership or right of experiencing from one actor/segment to another. For simplicity reasons, the value objects in this model are tangible items, but they could also embody more abstract notions like services or experiences.

These value objects are exchanged between three different actors: The reader, bookstore, and publisher. Visually, this is represented by the rectangle with a small title inside. However, these actors could also exist in a plural form, such as having multiple book stores, called a market segment. A market segment can be visualized as three stacked actors, such as shown in the legend (not shown in figure 4.2). Lastly, within an actor or segment, value activities can be displayed as rectangles with rounded corners. Such value activities allow for a more detailed description of the actors' tasks/operations. Note that,

although this is not shown in the figure (4.2), one actor or market segment could have multiple value activities.

The objects of value are being exchanged via value ports, demonstrated by the small black triangles. These value ports present a willingness to provide or request value objects (1). The oval-shaped circles in which the value ports are located are called value interfaces. Note that such an interface should always contain at least one in- and outgoing value port. Value interfaces, namely, model the notion of economic reciprocity. Economic reciprocity implies that for an outgoing value object from one actor, an incoming compensation is expected from another actor, which is of at least the same perceived economic value (1). Within the educational model (4.2), this is demonstrated by exchanging a book in return for money. The usage of money in the education model is no coincidence since some form of money is often involved in such models, but it isn't a requirement. When, for example, thinking about a barter deal, it is well imaginable that actors exchange physical non-money value objects amongst each other.

A customer need initiates the entire network of value ports, value interfaces, and value transfers. In the figure (4.2), this is shown by a customer who has the desire to read a book. Fulfilling this customer need requires the customer to exchange value objects (money & book) with other actors, such as a book store. In other words, the customers' ability to fulfill their need (reading a book) is dependent on these exchanges, which is modeled by the dependency path (dotted line) in between the customer need and value interface. However, a dependency path can also be connected to two value interfaces, such as shown for the bookstore. The bookstore is namely dependent on buying the book from a publisher before selling it. Lastly, the boundary element is used to indicate "the end" of the model, which means no further transfers are considered. The publisher, for example, has other transfers like payments to writers or printing houses, but these are outside the scope of this model.

4.2.2 General properties of the e^3value language

Firstly, it should be noted that an e^3value model does not consist of any sequence or chronology. The dependency paths are, therefore, not shown within a particular order. The dependency paths only state that all the transfers on the paths must happen to fulfill the customer need (17). Because of this, the e^3value language/model is different from, for example, BPMN (67). It is namely focussed on assessing the sustainability rather than the actual processes.

Secondly, the model is created within a specific contract period. The length of such a period is variable, such as a week, month, or year. Therefore, when quantifying the model,

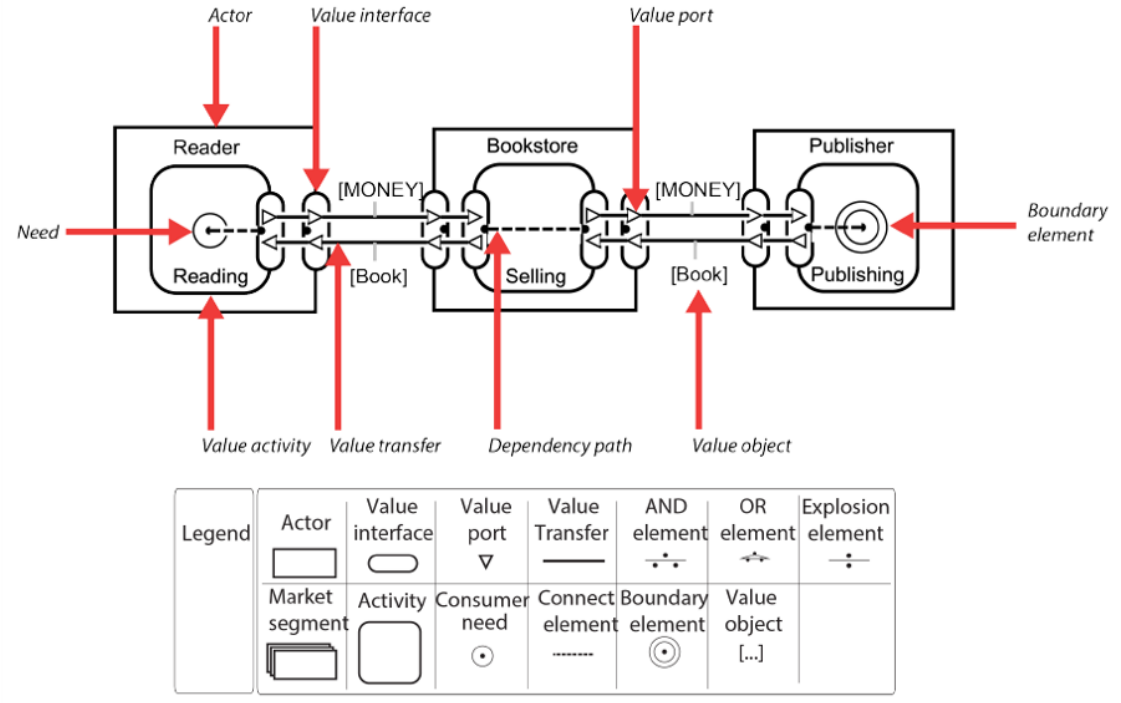


Figure 4.2: An educational *e³value* model. From *Understanding financial sustainability of ICT services for social and economic development using e³value* (p. 7), by Jaap Gordijn, Cheah WaiShiang, Anna Bon, Hans Akkermans, 2019.

the creator can specify the frequency of the transfers within this contract period. This quantification allows for the calculation of net cash flow for all the stakeholders within the specified timeframe (1).

Thirdly, the value interfaces within the model are subject to atomicity, which is closely related to the contract period. Atomicity implies that when one value transfer of a value interface happens, all the value transfers of that value interface should occur within the contract period. The atomicity, therefore, ensures that actors are always economically compensated within the given contract period (1).

5

Results

This chapter will present the results of the research that has been performed. The chapter will be split into two main sections, both containing their part of the results. The first part will mainly be on the outcome of the design science strategy to answer the first research question. It will namely present the creation of the *e³value* models and offer an in-depth explanation of the different seed value chains in Mali. The second part aims to answer the second research question, namely, how the *e³value* language has proven helpful in its application in a low resource environment.

5.1 The *e³value* models of Mali's seed value chain

The first part of this result section will consist of demonstrating and explaining the *e³value* models. These models are the outcome of the design science strategy, in which an artifact has been created to study the seed value chain of Mali. First, the *e³value* model for the improved seeds will be covered, after which the model for the unimproved seeds will be shown. Afterward, a third section will answer the first research question by analyzing the main differences between the two *e³value* models. Before examining the two separate models, some remarks have to be made.

First, it is important to emphasize that there is no chronological order recognized in *e³value* models, but only ongoing economic transactions that happen at least once within the contract period. The contract period is the period in which the quantification of the models takes place. However, the model will not yet be fully quantified within this research since not all the necessary information could be gathered. Therefore, this research will focus on the transactions among the actors and market segments without (full) quantification.

Second, the interviews and workshops used to base these models on are mainly conducted with Cooperatives and Unions in Beleco, a specific area in Mali. Therefore, these models should be seen as a case study. Although they represent the situation for other regions of Mali to some extend, differences could still exist. If it is known that such differences could exist, they will be noted in the explanation of the model.

Stakeholder	**Description**
Farmer	Farmers produce different types of seeds to make a profit or use them for their own consumption.
Cooperative	Farmer Cooperatives unite farmers, meaning multiple farmers can be a member of one Cooperative. They buy the seeds from farmers so that they can store, certify and sell the seeds. Lastly, they form a price cartel, setting a fixed price for the market.
Union	A Union is similar to a Cooperative, but then on a higher level. This means multiple Cooperatives fall under one Union. Their goal is to promote the production, processing, and marketing of cereal seeds. Next to this, they train and equip their Cooperatives/farmers to provide customers with quality products.
ICRISAT	ICRISAT is an international non-profit organization that performs scientific research into development areas. Their goal is to make farming profitable by helping farmers move from subsistence to commercial operators.
IER	The IER is a Malian governmental organization responsible for introducing, creating, and improving seed varieties. Other related organizations are the DNA (National Agriculture Division), DRA (Regional Agriculture Office), and SSN (National Seed Service).
AOPP	The AOPP is an umbrella organization for all Malian farmers. Its goal is to recognize/examine the problems of farmers and communicate with government authorities. The AOPP also functions as a disseminator of seeds among its network of farmer organizations.
LABOSEM	The LaboSem functions as a seed laboratory. It carries out field controls and certifies/rejects seeds.

Table 5.1: Main stakeholders in the Malian seed value chains.

5.1.1 e^3value model on improved seeds

Figure (5.1) shows the e^3value model for the value chain of the improved seeds within Mali. This model is easiest to understand by reading it from the left bottom corner. It starts at ICRISAT[1]. ICRISAT is a research institution that delivers the basic seeds to the coöperatives for free[2]. Often, though, organizations such as ICRISAT do not finance these seeds by themselves since development projects support them. ICRISAT is, for example, (partly) financed by the Bill & Melinda gates foundation. Because of this, the incoming value transfer is modeled as "Mission compliance". Thus, the element of "value" they receive is coming closer to their mission of achieving good food security levels. However, there also exist Cooperatives that do have to pay for basic seeds or buy R1 seeds to immediately produce R2 seeds[3]. Farmers mentioned the price they pay to be around 300 to 400 CFA (West African Franc) per kilo. It means some farmers receive seeds for free, while others have to pay for them. Whether this causes unfair competition between different Cooperatives has not been studied within this research but would be valuable to investigate further. According to existing literature, though, it seems very plausible that this is driving unfair competition. Claims have namely been made that seed aid tends to threaten local seed production (68). The Cooperatives spread out the basic seeds for free to the farmers that fall under them. After the farmers have planted these seeds and turned them into R1 (or R2, depending on the seeds they started with), the seeds are sold in different ways. For a small amount, farmers themselves sell the seeds to other small farmers or customers. The majority of the seeds are, however, sold back to their Cooperative for a fixed price. This price was mentioned to be 500 CFA per Kilo[3]. At the level of the Cooperative, seeds are being certified. In Mali, certifying the seeds is obligated, but as described in the introduction chapter, it officially should not be illegal to sell without certification. The costs of this certification process are 7000-8000 CFA, based on 1 kilo per monster[2]. This certification process is a significant issue since it is a prolonged and untransparent process[4].

From the current information, it seems as if some of the seeds are locally sold "illegally" by farmers since the certification happens at the Cooperative level. Therefore, it hasn't happened yet when the farmers directly sell some of it to small customers. Unfortunately,

[1] https://www.icrisat.org/

[2] Online (Zoom) test session with coordinators from different Unions and the AOPP, May 2021

[3] Trip report with the AOPP, April 2019

[4] W4RA Trip Mali AOPP, January 2020 Bamako

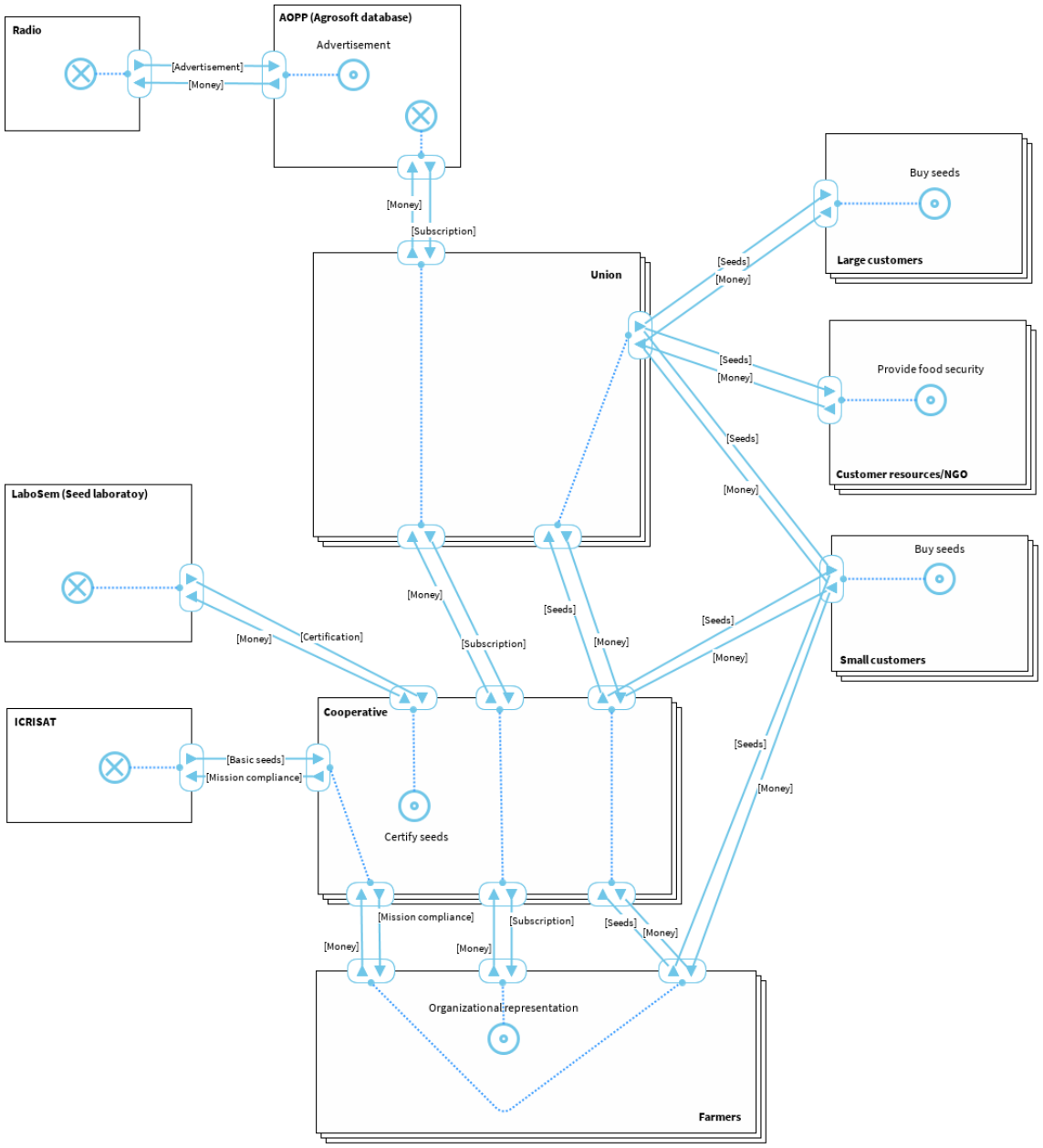


Figure 5.1: *e*^{3}*value* model for the improved seed system.

though, this is not confirmed in interviews or reports. After certification, the Cooperatives sell a small number of seeds to small customers, whereas the rest is sold to their Union.

At the Union level, the seeds are sold to three different groups, namely small customers (15%), medium customers (30%), and large customers (55%)[1]. Small customers are mainly other farmers looking to produce food or plant and resell the seeds. Medium customers are mostly NGOs or governmental organizations like the red cross. They buy and spread the seeds among the poorest for cheap or for free. Lastly, the large customers consist of big agro-dealers. Such parties place orders for large quantities and mostly resell the seeds abroad, for example, to Senegal and Guinea. What is remarkable is the price difference between the three customer types. The small customers pay 300 CFA, the medium customers pay 350 CFA, and the large customers pay 400 CFA[1]. In the second section of this result chapter, this will be discussed more in-depth. Besides these differences being remarkable in how they relate to stack discounts, they also seem striking when comparing them with an earlier number. Halfway through this section, it was mentioned that farmers get a fixed price of 500 CFA per kilo when selling to their Cooperative. Eventually, though, seen from the current information, the Union will sell most of these seeds for a maximum of 400 CFA per kg. This raises the question of how the Cooperatives could ever turn a profit if these numbers are correct? Do the Unions pay more to Cooperatives than what they will ever earn from the seeds? Do the Cooperatives make a lot of money on subscriptions? Or are the current prices mentioned in this research incorrect/inconsistent (since it is unknown whether they originate from one or multiple different Cooperatives).

Now that all the seed-related transfers have been discussed, there are a few value transfers left. One is the customer need that starts in the market segment of farmers and ends at the AOPP, which is organizational representation. For a farmer to be a member of a Cooperative, they pay a certain fee. The same goes for the membership of a Cooperative to a specific Union. Lastly, the AOPP forms the umbrella organization for all Unions in Mali, for which also a membership has to be paid. Being part of this chain has the advantages of access to improved seeds and having a fixed sales channel to sell the seeds. One part of that fixed sales channel is the Agrosoft database, which the AOPP manages (69). Unions can report seeds that are for sale and place them on that database. After that, clients can see those seeds on the database and contact the specific Union. The last value transfer shown in the model is related to this, namely radio broadcasting. This broadcasting is used to publish commercial information, to make people aware of the seeds for sale in the database(12). However, a remark should be made for this database since it

[1]SEVOSEM meeting report, October 2020

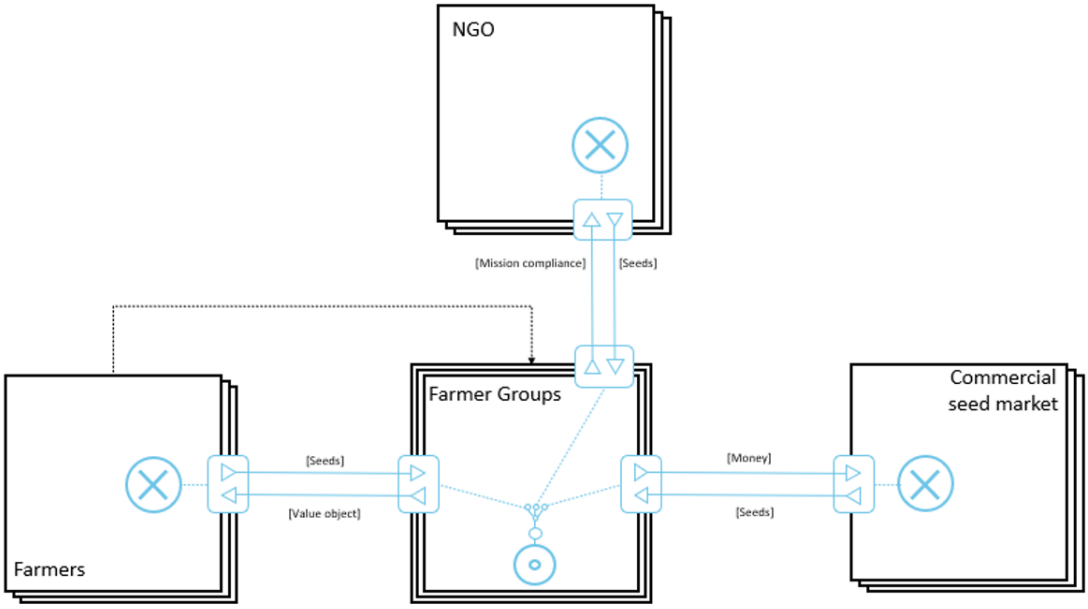


Figure 5.2: *e³value* model for the unimproved traditional seed system.

later turned out that its usage is barely or none at all. This will be discussed further in the conclusion/discussion chapter.

5.1.2 *e³value* model on traditional unimproved seeds

As can be seen in figure (5.2), the *e³value* model for the unimproved seeds is much more straightforward and elementary. However, it does contain an element that is not yet shown within the model for the improved seeds and is not discussed in the theoretical framework section. This element is the group/community element (in this model farmer group), demonstrated by the three centered stacked squares. This element is not officially part of the *e³value* language (it might be in the future) but was proposed within a previous master thesis at the VU University, guided by one of the founders of *e³value* (Jaap Gordijn) (20). This element was proposed as an addition since communities play an increasingly important role in business models. Considering the importance of communities in the value chain for unimproved seeds, using this new element was a valuable addition. Lastly, several set operators indicate the relationships between the group element and the market segment, as shown in figure (5.3). In this model, the Farmer group(s) are a subset of the total farmer population since not all farmers work with unimproved seeds.

Now that the additional element is clear, the model itself can be explained. Within the

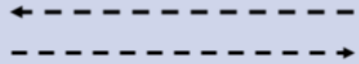
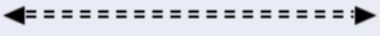
Set Operator	Symbol
Is a Sub-set of Is a Superset of	
Equal set of	
Union of	
Intersection of	

Figure 5.3: Symbols corresponding to the set relationship.

(traditional) unimproved seeds model, things work pretty differently from the improved seeds value chain. First, it is essential to understand that many smaller farmer communities exist in Mali (from now on, farmer groups). The added community element isn't yet suitable for indicating singularity or plurality, as is the case with actors vs. market segments, but for this *e³value* model, there are multiple farmer groups. For these groups, there are three ways of obtaining seeds. The first and far most crucial method is trading and gifts within or between communities. For this type of value transfer, money is never used, which means it comes down to exchanging value objects or pure goodwill. These value objects can be different seeds, livestock, or other necessities to survive. According to previous research, this method of gaining seeds accounts for about 90-95% (7). The second method to receive seeds is by donations from NGOs or other organizations. What percentage this accounts for is still unclear, but it probably takes the shape of very incremental emergency help from organizations such as the Red Cross. The third and last method is buying improved certified seeds from the commercial market, accounting for about 7-10% (7, 54). Despite these seeds being improved, they quickly lose this characteristic. A lack of knowledge makes farmers reuse and reseed these seeds, which reduces their productivity and varietal purity (7). The interesting about this is, though, that this does form the gate of the unimproved traditional model towards the improved model since this is where they cross. In conclusion, the value chain for the unimproved seeds is very different from the improved seeds, which will be covered more in-depth in the next section.

5.1.3 Analyzing the differences between the two *e³value* models

When discussing the two different *e³value* models, the first and most overlapping difference is the level of formality and structure. The model for the improved seeds is relatively clear, showing the relationship and value transfers between the different stakeholders. The

traditional unimproved model, though, leaves a lot of open questions. From the current observations, the traditional model seems to be a very arbitrary system in which seeds are shared and gifted relatively randomly between and within communities. This observation might, though, be biased and incorrect. It is namely stated that the traditional seed system is often wrongly referred to as "informal seed sector", since, in reality, it is a well-established peasant seed system (8, 14). A second difference between the two models could have a potential relationship with how the seeds are supposed to be planted. The improved seeds seem to switch ownership more often within their life cycle, moving from basic to R1 to R2 and eventually R3 (R3 seeds turn into eatable food when planted). By contrast, the traditional unimproved seeds do not adhere to this process, where seeds are always immediately planted for consumption. This difference might significantly impact transportability since seeds are easier to transport and preserve than food and could potentially play a role in the number of times the products are sold. The third difference has already been mentioned indirectly during this research but is still relevant to emphasize: The dominant value object in the improved seeds model is money, due to this being an economic and business-minded model. Such a model entails having investments, taking risks, and dependence on other parties for procurement and sales. These investments form a high barrier for (poor) farmers to start using improved seeds (14). The traditional model is entirely different at its core. The dominant value object is not a fixed item such as money since bartering is still the prevailing way of doing business. Therefore, the traditional model is focused on a way of living and surviving using barter deals. In contrast, the other model shows the value chain of economic activity using money as its main value object.

5.2 Using value modeling for a food value network

As described at the beginning of this chapter, this second part will illustrate how e^3value can provide insights into a food value network in a low resource environment. This will be done in three separate sections, each consisting of a different element.

5.2.1 Get to know the unknown

Analyzing a seed, food, or any value network in a very different country from western nations can be complicated. It can be challenging to find a starting point or figure out which elements deserve follow-up questions or are already clear enough, especially since data gathering can be an incremental and slow process because of psychical and language

barriers. Of course, a researcher could try to fathom a value network by using textual methods or self-developed shapes and figures. Working like that, however, lacks a structure in building the knowledge. Hence, for such challenges, the *e³value* language can be very suitable. The concreteness and level of detail used within the model force a researcher to dig into certain value transfers. For example, specific information and knowledge on the Malian seed value chain were already available at the beginning of this research. When I started to formulate that knowledge in *e³value*, many questions were immediately revealed. It, therefore, uncovered the unknown, which was very useful in the formulation of new interview questions. A concrete example has to do with the first phase of the model. When connecting the value transfers, we were unsure which parties sell the seeds, but we assumed it would always be the Union. However, when we checked this, it turned out that also Cooperatives and sometimes even farmers sell their seeds independently. Other examples of arising questions were about basic seeds, R1 and R2. These questions arose when concretizing the actual value transfers between seed suppliers, farmers, Cooperatives, and Unions.

To conclude, the *e³value* methodology can help discover what is yet unknown, which is crucial in posing the right interview questions to understand a value network thoroughly.

5.2.2 *e³value* as a conversation starter

When trying to gain insights into a value chain, the goal of a researcher is to understand the model thoroughly. An important element of achieving that understanding is verifying the perceived information and data with the research population. Though, conceptually, especially within a low-resource environment, this can be challenging. This claim seems paradoxical since the research population provides the information that a researcher has used to develop the *e³value* model. However, it can be difficult for research subjects in a low-resource environment (for example farmers) to comprehend a value chain on a high level, especially without visual oversight. This difficulty is caused by them having a lower or no level of education and not being used to work on abstract and conceptual cases. For such a situation, the *e³value* language is a valuable method. The visuality of the language makes it much easier to comprehend a complex value chain, especially when accompanied by a proper explanation. Though, a remark should be made concerning a limitation to this statement. Within this research, a simplified form of the *e³value* model was made to verify the outcome with our research population. My supervisor Anna Bon felt that was necessary since the regular *e³value* model is still too complex. I agreed with this since explaining the syntax to the research population takes time and places another

barrier in gathering data. As a researcher, it is tricky to be sure that the population fully comprehends the visual syntax, which poses a challenge of its own. Therefore, to conclude, *e³value* is an excellent method to have as a conversation starter in workshops/meetings with the research population. A researcher could use it to gather data, but especially also to verify whether the model adequately represents the value network. Though, in its current form, it can be expected that it is still slightly too complicated to present within a low-resource environment, which means it requires a free-form simplification.

5.2.3 Values with a story

One property of the *e³value* language is the quantification of the value transfers between actors/market segments. The eventual goal of this quantification is to calculate the net cash flow for each actor/market segment to see whether their situation is economically feasible. Although this research did not succeed in finding all the values necessary to do so, it uncovered valuable information concerning the quantities and pricing within the value chain. However, besides it is helpful to gain more information on those elements, this research also showed something else. It showed that gathering values from within a value chain can tell a story on its own. On the 28th of October 2020, there was a meeting between the AOPP, a Cooperative (Bèlèco), and researchers Anna Bon (my supervisor) and André Baart from the VU[1]. One of the topics discussed was the price paid by the three different types of customers. It turned out that large customers pay 400 CFA, medium customers pay 350 CFA, and small customers pay 300 CFA. These numbers told a lot about the way of doing business in their local context. Such pricing schemes seem unthinkable in Western countries since large customers often pay less because of their stack discounts. It appeared, however, that in the Malian context, more factors played an important role, such as which party has the most desperate needs for these seeds for their survival. It, therefore, seemed as if a form of altruism was taken into account when formulating the prices. Of course, these are just assumptions that should be further investigated before drawing any conclusions. However, it shows that numerical values do not only show quantities but can also uncover ways of interacting and doing business amongst each other.

[1] SEVOSEM meeting report, October 2020

6

Conclusion & Discussion

6.1 Is Mali ready for a commercial seed system?

This research has tried to analyze the Malian seed value chains by applying a value modeling technique called *e³value*. The information used for these models was derived from previous interviews and workshop reports, literature, and newly conducted interviews. As is demonstrated in the results chapter, the differences between the commercial and traditional seed systems are substantial. They are not only different in their processes but also in their core goals. The traditional system is namely about subsistence, while, in contrast, the commercial system is aimed at running a profitable business. Besides, the commercial system is more formalized and documented, resulting in a more complete and detailed *e³value* model, while the traditional model is still partly a black box.

However, as touched upon in the introduction chapter, these systems sadly do not coexist without friction, leaving many questions open for debate. This friction between the two systems is not caused by the farmers themselves. Instead, it is driven by (inter)national policy, actions, and interests. Remarkably, these three things all seem prompted by a form of bias to promote the usage of improved seeds. For example, ICRISAT mentions their goal as: "helping move farmers from subsistence to commercial operators"[1]. Without calling the sincere intentions of ICRISAT into question, it can still be challenged whether this is the right tactic. The question is, what drives this impulse towards improved seeds? Is it strictly the benefits (such as higher crop yield) of the improved seeds, or are more factors involved? An organization such as ICRISAT is financed by many philanthropic organizations. These organizations probably require some form of reporting of the achieved outcome, especially since there is a trend among philanthropists desiring to see results (35). This desire could

[1] https://www.icrisat.org/overview/

lead to something called evaluability bias. Such bias indicates a preferential attitude in charity regarding having low overhead costs and high evaluability of results, potentially at the expense of cost-effectiveness (70). Although based on assumption, it seems plausible that this bias for low overhead costs and evaluability could hold for implementing improved seeds in Mali. For example, monitoring how many KG of improved seeds are sold or how many farmers have started growing improved seeds is easier than investing in more abstract projects to improve seed-related business processes. Also, investigating whether providing the seeds for cheap or free causes unfair competition can be very complex and, therefore, less appealing.

However, it seems like Mali needs help in the form of a complex project with potentially high overhead costs. Recent and older interviews namely indicate that improved seeds' total business infrastructure is far from perfect if even ready for functioning. For example, the certification of seeds is a slow and obscure process[1], and it has been mentioned that people perform fraud by mixing seeds[2]. Besides that, researchers at the VU have created an online seed database, including mobile and voice interface, for the AOPP and farmer organizations to increase insights into supply and demand. However, it recently turned out that this entire system is not being used at all, for yet unknown reasons[2]. This leaves the commercial seed market open for mismatched supply and demand, resulting from a lack of (digital) information and communication. Whether the ambition for improved seeds is driven by some form of evaluability bias, dominant western commercial ideals, governmental economic interest or envisaged results of improved seeds is not studied within this research. However, it appears that the actual processes within the value chains are overlooked, indicated by the still too unstable business infrastructure.

Another issue causing friction between the two models takes place at the level of human rights. Access to food is a general human right, and for ca. 80% of the Malian population, this right translates into farming seeds for own use within a community. However, this right is endangered by seed enclosures. Seed enclosures are intellectual property claims on a type of seed, turning common genetic heritage into private property (14). In more developed countries with full implementation of improved seeds, such enclosures seem realistic and logical. However, on the contrary, in a country where food security is an issue, where the majority eats from seeds considered a common good, access to food clashes with commercial intentions. Considering the combination of these seed enclosures and a government not officially recognizing the traditional seed model, it is understandable that many traditional

[1] W4RA Trip Mali AOPP, January 2020 Bamako

[2] Meeting with AOPP and partners from within the seed value chain, July 2021

farmers feel threatened. Moreover, these farmers often lack the financial means to bear the starting costs and risks of working with improved seeds (12), which means they are stuck to traditional farming.

This research has not solved how Mali should deal with the two seed value chains/systems. However, it has introduced new methods and opened doors to finding new pieces to the entire puzzle. Further quantifying and/or extending the models (especially the traditional seeds model) could lead to new valuable insights. Insights that could help Mali solve the puzzle of their seed value chains and improve the overall national food security. The question that remains is whether the right goal is to make all farmers become commercial seed traders. Is this sustainable in the long run and beneficial for the economy? Shouldn't there be more specialization in other industrial disciplines as well? Is it too much steered by western commercial ideals? However, independent of whether improved seeds should be implemented for all farmers, this research showed that Mali is not fully ready for large-scale commercial seed trade. The lack of communication, information, efficiency, technology, and financial means form a significant bottleneck. Therefore, two remaining topics should be studied in the future: First, to what extent is it desirable/efficient to turn every farmer into a commercial seed trader, and is the (inter)national push for commercial seeds coming too early? Second, the business processes of improved seeds should be studied and improved to ensure that Mali has the efficiency and resources necessary to use the improved seeds to their full benefit.

6.2 A reflection on using *e³value*

Several discussion elements can be drawn from using the *e³value* language to map a food value chain within a low-resource environment. First, it could be helpful to have a default simplified version build into the language. Especially in a low-resource environment, such a version could be more suitable to present to the research population. Second, the community element formed a valuable component of using the *e³value* language. However, if this element would be officially added, it would be beneficial to have an indication for single or multiple groups/communities. Third, even though the primary use of *e³value* is to show the value transfers within a network, it is interesting how *e³value* proved to be helpful in modeling and uncovering (non-digital) processes. Within this research, despite the exchange of valued objects still being the main activity in the models, it was valuable to concretize and formalize process-related knowledge. It showed where knowledge gaps still existed and therefore brought new questions to the table. These questions force

the researchers to uncover more detailed information, increasing the understanding of the studied value network and processes.

In terms of limitations, the physical barrier formed its difficulties since all the data gathering was dependent on existing reports, literature, or (sometimes chaotic) online Zoom meetings. These difficulties resulted in not fully quantifying the e^3value models and calculating the economic feasibility for all parties. Nevertheless, as mentioned above, future research could continue with this, trying to achieve more factual and numerical knowledge about both the traditional and commercial seed systems.

References

[1] Wieringa R Gordijn J. *E3value User Guide Designing Your Ecosystem in a Digital World*. The Value Engineers B.V., Soest, NL, 2020. ii, 26, 27, 28

[2] United Nations. **THE 17 GOALS**. https://sdgs.un.org/goals, 2015. [Online; accessed 3-May-2021]. 1

[3] FAO. *2019 Africa Regional Overview of Food Security and Nutrition*. FAO, 2020. 1

[4] Goedde, L., Ooko-Ombaka, A., 'I&' Pais, G. **Winning in Africa's agricultural market**. https://www.mckinsey.com/industries/agriculture/our-insights/winning-in-africas-agricultural-market, 2019. [Online; accessed 3-May-2021]. 1

[5] USAID. **Agriculture and food security**. https://www.usaid.gov/mali/agriculture-and-food-security, 2021. [Online; accessed 3-May-2021]. 1, 2, 10

[6] Statista. **Mali: Distribution of gross domestic product (GDP) across economic sectors from 2009 to 2019**. https://www.statista.com/statistics/457788/mali-gdp-distribution-across-economic-sectors/#:~:text=In%202019%2C%20agriculture%20contributed%20around,percent%20from%20the%20services%20sector, 2019. [Online; accessed 3-May-2021]. 2

[7] Steven Haggblade, Boubacar Diallo, Melinda Smale, Lamissa Diakité, and Bino Témé. **Revue du système semencier au Mali**. Technical report, 2015. 2, 3, 13, 14, 22, 35

[8] Harouna Coulibaly, Didier Bazile, and Amadou Sidibé. **Modelling seed system networks in Mali to improve farmers seed supply**. 2014. 2, 3, 12, 13, 36

[9] Bon. A. **Supporting the Seed Value Chain in rural Mali**. https://w4ra.org/2020/04/13/how-to-enhance-the-seed-value-chain-in-rural-mali/, 2020. [Online; accessed 3-May-2021]. 2, 3

[10] Melinda Smale, Lamissa Diakité, Mikkel Grum, et al. **When grain markets supply seed: Village markets for millet and sorghum in the Malian Sahel**. *Seed trade in rural markets: Implications for crop diversity and agricultural development*, pages 53–74, 2010. 2

[11] Paul Van Mele and Robert G Guéi. *African seed enterprises: sowing the seeds of food security*. CABI, 2011. 3

[12] Sophie Vos, Hella Schaefers, Anna Bon, and Patricia Lago. **Sustainability and Ethics by Design: In the development of digital platforms in low-resource environments**. 3, 10, 12, 14, 33, 41

[13] A. Baart W. Tuyp V. de Boer M. ouedraogo C. van Aart H. Akkermans, A. Bon. **Seed value chain in Mali: Workshop report**, 2020. Amsterdam, The Netherlands: VUA Centre for international cooperation. 3, 13

[14] Mohamed Coulibaly, Priscilla Claeys, and Anne Berson. **The Right to Seeds and Legal Mobilization for the Protection of Peasant Seed Systems in Mali**. *Journal of Human Rights Practice*, **12**(3):479–500, 2020. 3, 4, 36, 40

[15] S. Dagnoko S. Dembele M. Mugoya Waithaka, M. and K. Tihanyi. **Mali Rapport 2018: TASAI (The African Seed Access Index**, 2019. 3

[16] Alexander Osterwalder and Yves Pigneur. **Business model canvas**. *Self published. Last*, 2010. 4

[17] Jaap Gordijn, Cheah Waishiang, Anna Bon, and Hans Akkermans. **Understanding financial sustainability of ICT services for social and economic development using e3 value**. 06 2019. 4, 26, 27

[18] Anna Bon, Jaap Gordijn, and Cheah Wai Shiang. **Digital inclusion requires a business model too: Sustainability analysis of value webs in rural Sarawak**. In *12th ACM Conference on Web Science Companion*, pages 64–69, 2020. 4

[19] Anna Bon, Jaap Gordijn, and Hans Akkermans. **E-service innovation in rural africa through value co-creation**. In *Disruptive Technology: Concepts, Methodologies, Tools, and Applications*, pages 859–877. IGI Global, 2020. 4

[20] Reshmi Sarkar and Jaap Gordijn. **Modeling Communities in e3value.** In *VMBO*, pages 20–28, 2018. 5, 22, 34

[21] W4Ra. **About W4RA**. `https://w4ra.org/w4ra/`, 2021. [Online; accessed 4-May-2021]. 5

[22] Roel J Wieringa. *Design science methodology for information systems and software engineering*. Springer, 2014. 5

[23] Chrisanthi Avgerou. **Theoretical framing of ICT4D research**. In *International Conference on Social Implications of Computers in Developing Countries*, pages 10–23. Springer, 2017. 8, 9

[24] Subhash C Bhatnagar. *Information technology in developing countries*. 1990. 8

[25] Mayuri Odedra, M Bennett, Sy Goodman, and M Lawrie. **Sub-Saharan Africa: a technological desert**. *Communications of the ACM*, **36**(2), 1993. 8

[26] Mayuri Odedra. *Global information technology and socio-economic development*. Ivy League Pub, 1996. 8

[27] Geoffrey Kirkman, Peter Cornelius, Jeffrey Sachs, and Klaus Schwab. **The global information technology report 2001-2002**. *New York: Oxford*, **4**, 2002. 8

[28] Michael Porter, Andrew Warner, and Jeffrey Sachs. *Global Competitiveness Report 2000*. McGraw-Hill, 2000. 8

[29] Carlos A Primo Braga, Charles J Kenny, Christine Zhen-Wei Qiang, Daniel Crisafulli, Domenico Di Martino, Riva Eskinazi, Robert Schware, and William Kerr-Smith. **The Networking Revolution. Opportunities and Challenges for Developing Countries**. 2000. 8

[30] World Bank. *World development report 2002: Building institutions for markets*. The World Bank, 2001. 8

REFERENCES

[31] Leila Hassanin. **Egyptian women artisans: ICTs are not the entry to modern markets**. In *IFIP International Conference on Human Choice and Computers*, pages 179–190. Springer, 2008. 9

[32] Shirin Madon, Nicolau Reinhard, Dewald Roode, and Geoff Walsham. **Digital inclusion projects in developing countries: Processes of institutionalization**. *Information technology for development*, **15**(2):95–107, 2009. 9

[33] Melissa R Ho, Thomas N Smyth, Matthew Kam, and Andy Dearden. **Human-computer interaction for development: The past, present, and future**. *Information Technologies & International Development*, **5**(4):pp–1, 2009. 9

[34] Nir Kshetri. **Artificial Intelligence in Developing Countries**. *IEEE Annals of the History of Computing*, **22**(04):63–68, 2020. 9

[35] Roger W Harris. **How ICT4D research fails the poor**. *Information Technology for Development*, **22**(1):177–192, 2016. 9, 39

[36] Anna Bon, Hans Akkermans, and Jaap Gordijn. **Developing ICT services in a low-resource development context.** *CSIMQ*, **9**:84–109, 2016. 9, 20, 23, 24

[37] Richard Heeks. **Information systems and developing countries: Failure, success, and local improvisations**. *The information society*, **18**(2):101–112, 2002. 9

[38] Mario A Marais. **Analysis of the factors affecting the sustainability of ICT4D initiatives**. 2011. 9

[39] Maryam Ali. **THE CHALLENGE OF "SUSTAINABILITY" IN ICT4D–IS BRICOLAGE THE ANSWER?** 04 2007. 9

[40] Selima Jahana. *Human development report 2016 : human development for everyone.* United Nations Publications, New York, New York, 2016. 10

[41] **Population, total - Mali**. [Online; accessed 3-May-2021]. 10, 12

[42] Boubacar Ba and Morten BøÅs. **Mali: A political economy analysis**. 2017. 10, 11, 12

[43] Daniel N Dalohoun, Paul Van Mele, DIOUKAMADY DIALLO EVAWELTZIEN, HAMIDOU GUINDO, and KIRSTEN VOM BROCKE. **5 Mali: When Government Gives**. *African seed enterprises: Sowing the seeds of food security*, page 65, 2011. 10, 12

[44] Michael Bratton, Massa Coulibaly, and Fabiana Machado. **Popular views of the legitimacy of the state in Mali**. *Canadian Journal of African Studies/La Revue canadienne des études africaines*, **36**(2):197–238, 2002. 11

[45] Gerti Hesseling, Han van Dijk, P Chabal, U Engel, and AM Gentili. **Administrative decentralization and political conflict in Mali**. *Is violence inevitable in Africa*, pages 171–92, 2005. 11

[46] NOS Nieuws. **Is Mali weer terug bij af na arrestatie van president en premier?**, 2021. [Online; accessed 3-May-2021]. 11

[47] Morten BøÅs. *The Politics of Conflict Economies: miners, merchants and warriors in the African borderland*. Routledge, 2014. 11

[48] Yaya Dissa. **Impact of globalisation on the economy of Mali**. *International Journal of Business and Social Science*, **7**(8):80–90, 2012. 12

[49] Santandertrade. **MALI: FOREIGN INVESTMENT**, 2021. [Online; accessed 3-May-2021]. 12

[50] Santandertrade. **NETHERLANDS: FOREIGN INVESTMENT**, 2021. [Online; accessed 3-May-2021]. 12

[51] UNCTAD. **Investment flows in Africa set to drop 25% to 40% in 2020**, 2020. [Online; accessed 3-May-2021]. 12

[52] P.J. Malton. **Analyse critique des objectifs, méthodes et progrès accomplis à ce jour dans l'amélioration du sorgho et du mil : une étude de cas de l'ICRISAT/Burkina Faso.**, 1985. In H. W. Ohm J. G. Nagy (Eds.), Technologies appropriées pour les paysans des zones semi-arides d'Afrique de l'Ouest. (pp. 181-211). Purdue University, West Lafayette, Indiana (USA). 13

[53] Didier Bazile. **State-farmer partnerships for seed diversity in Mali**. 2006. 13

[54] Lamissa Diakité, Amadou Sidibé, Melinda Smale, and Mikkel Grum. **Seed value chains for sorghum and millet in Mali: a state-based system in transition**. 2008. 13, 35

[55] Anol Bhattacherjee. **Social science research: Principles, methods, and practices**. 2012. 16, 18

[56] Alan Bryman. *Social research methods*. Oxford university press, 2016. 16, 17, 18

[57] UNESCO. **Literacy rate among thepopulation aged 15 years and older.**, 2018. [Online; accessed 3-May-2021]. 18

[58] Don Tapscott, David Ticoll, and Alex Lowy. **Digital capital: Harnessing the power of business webs**. *Ubiquity*, **2000**(May):3–es, 2000. 18, 26

[59] Jaap Gordijn Cheah WaiShiang, Anna Bon, and Hans Akkermans. **Understanding financial sustainability of ICT services for social and economic development using e3value**. 20

[60] Matthew B Miles and A Michael Huberman. *Qualitative data analysis: An expanded sourcebook*. sage, 1994. 20

[61] Carlos Rodriguez Casal. **ICT for education and development**. *info*, 2007. 23

[62] Björn Sören Gigler. *Development as Freedom in a Digital Age: Experiences from the Rural Poor in Bolivia*. The World Bank, April 2015. 23

[63] Isaac Mbiti and David Weil. **Mobile Banking: The Impact of M-Pesa in Kenya**. Technical report, June 2011. 23

[64] Nana Baah Gyan, Victor De Boer, Anna Bon, Chris Van Aart, Hans Akkermans, Stephane Boyera, Max Froumentin, Aman Grewal, and Mary Allen. **Voice-based web access in rural Africa**. In *Proceedings of the 5th annual acm web science conference*, pages 122–131, 2013. 23

[65] IEG. **Capturing technology for development: An evaluation of world bank group activities in information and communication technologies**, 2011. [Online; accessed 3-May-2021]. 23

[66] Johannes Maria Gordijn J, Akkermans H. *Value webs: understanding e-Business Innovation*. 2018. 26

[67] Martin Owen and Jog Raj. **BPMN and business process management**. *Introduction to the new business process modeling standard*, 2003. 27

[68] B Visser. **The impact of national seed laws on the functioning of small-scale seed systems: A country-case study**. *Oxfam Novib*, 2017. 31

[69] AOPP. **Semences-Market**, 2021. [Online; accessed 3-May-2021]. 33

[70] Lucius Caviola, Nadira Faulmüller, Jim Everett, Julian Savulescu, and Guy Kahane. **The evaluability bias in charitable giving: Saving administration costs or saving lives?** *Judgment and decision making*, **9**:303–315, 07 2014. 40